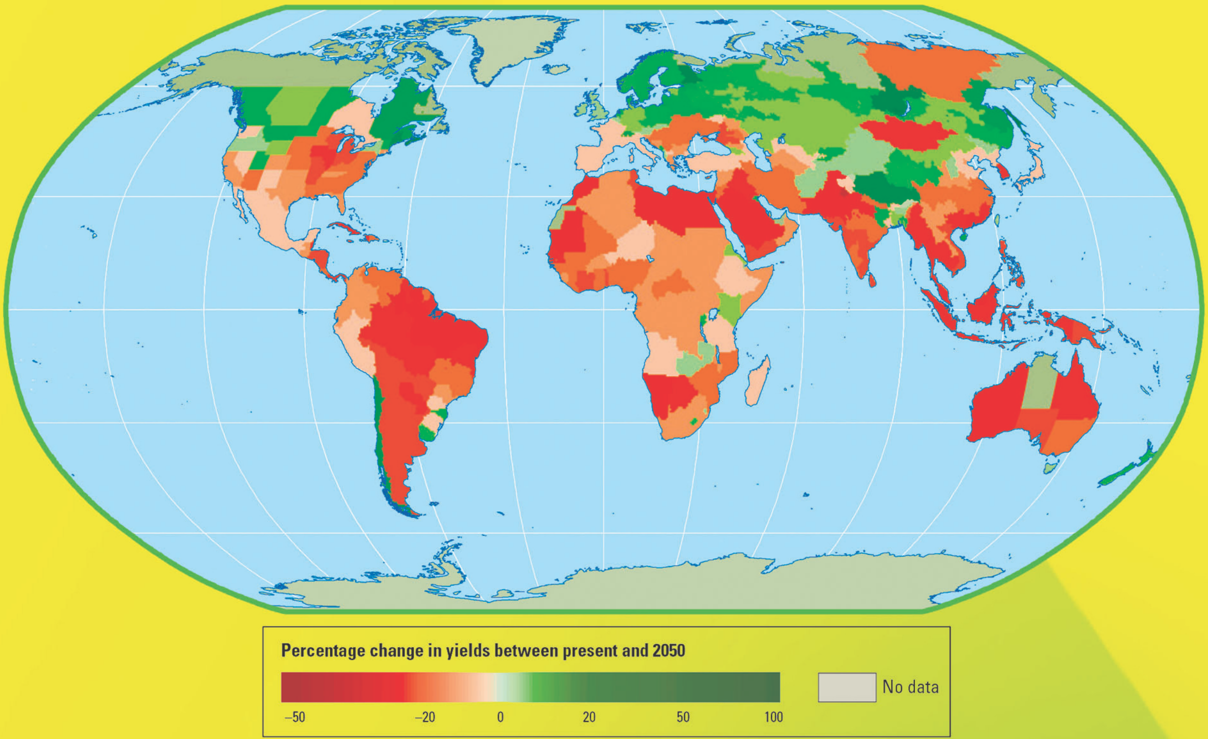
Twelfth International Dryland Development Conference

“Sustainable Development of Drylands in the Post 2015 World”

21-24 August 2016, Alexandria, Egypt

Projected impact of climate change on yield of major crops by 2050



Proceedings

BIBLIOTHECA ALEXANDRINA
مكتبة الإسكندرية

IDDC
INTERNATIONAL DRYLAND DEVELOPMENT COMMISSION

International Dryland Development Commission

August 2017

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Bibliotheca Alexandrina Cataloging-in-Publication Data

International Conference on the Development of Drylands (12th : 2016 : Alexandria, Egypt)
Sustainable development of drylands in the post 2015 World : Twelfth International Conference on the Development of Drylands August 2016, Alexandria, Egypt 21-24 : proceedings / editors, Adel El-Beltagy and Mohan C. Saxena. – Alexandria, Egypt : Bibliotheca Alexandrina, 2018.
pages ; \c cm
ISBN 978-977-452-463-3
1. Arid regions -- Congresses. 2. Arid regions agriculture -- Congresses. 3. Arid soils -- Congresses. 4. Desert resources development -- Congresses. 5. Sustainable agriculture -- Congresses. I. El-Beltagy, A. S. II. Saxena, Mohan C. III. Aliksāndrīnā (Library) IV. International Drylands Development Commission (IDDC) V. Title.
333.73--dc22 2018 494778803

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Cover Photograph

The figure shows the projected percentage change in yields of 11 major crops (wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed) from 2046-2055, compared with 1996-2005. The values are mean of three emission scenarios across five global climate change models, assuming no CO_2 fertilization (a possible boost – of uncertain magnitude – to plant growth and water-use efficiency from higher CO_2 concentrations). Large negative yield impacts are projected in many areas that are highly dependent on agriculture.

Sources: Mueller and others (2009); World Bank (2008).

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Citation: El-Beltagy, A. and Mohan C. Saxena (eds.). 2017. Proceedings. Sustainable Development of Drylands in the Post 2015 World. *Twelfth International Dryland Development Conference*, 21-24 August 2016, Alexandria, Egypt. Egypt: International Dryland Development Commission.

Twelfth International Dryland Development Conference

"Sustainable Development of Drylands in the Post 2015 World"

21-24 August 2016, Alexandria, Egypt

Organised by

International Dryland Development Commission

Hosted by

Bibliotheca Alexandrina, Alexandria, Egypt

Co-sponsored by

ALARI (Ain Shams University, Egypt), ALRC (Japan), ICARDA, CAREERI (CAS, China), JICA (JAPAN), JIRCAS (Japan)

Supported by

IFAD, FAO, COMSTECH, Shoura Foundation and ECOSF

Proceedings

Editors

Adel El-Beltagy and Mohan C. Saxena

International Dryland Development Commission

(www.drylanddevelop.org)

August 2017

International Dryland Development Commission

The International Dryland Development Commission (IDDC) is an autonomous nongovernmental nonprofit organization established in 1987 by the individuals and institutions interested in and concerned about the sustainable development of dry areas. It is promoting all aspects of dryland studies by fostering cooperation, collaboration and networking between various international, regional and national organizations. One of the important *modus operandi* of the networking of IDDC has been to hold a major scientific conference every two to three years to provide opportunity to participants from around the world to exchange research results and experiences in dryland development and combating desertification. In pursuance of this objective the IDDC has organized in the past following 11 international conferences in countries that have large dryland areas:

1. First International Conference on Desert Development: *Application of Science and Technology for Desert Development*, Cairo, Egypt, 1978.
2. Second International Conference on Desert Development: *Desert Development Systems – Technologies for Desert Agriculture*, *Energy and Communities*, Cairo, Egypt, 1987.
3. Third International Conference on Desert Development, Beijing, China, 1990
4. Fourth International Conference on Desert Development: *Sustainable Development for our Common Future*, Mexico City, Mexico, 1993.
5. Fifth International Conference on Desert Development: *Desert Development -The Endless Frontier*, Lubbock, Texas, 1996.
6. Sixth International Dryland Development Conference: *Desert Development: Challenges in the New Millennium*, Cairo, Egypt, 1999.
7. Seventh International Dryland Development Conference: *Sustainable Development and Management of Drylands in the 21th Century*, Tehran, Iran, 2003.
8. Eighth International Dryland Development Conference: *Human and Nature working together for Sustainable Development of Drylands*, Beijing, China, 2006.
9. Ninth International Conference on Dryland Development: *Sustainable Development in the Drylands – Meeting the Challenge of Global Climate Change*, Bibliotheca Alexandrina, Alexandria, Egypt, 2008.
10. Tenth International Conference on Development of Drylands - *Meeting the Challenge of Sustainable Development in Drylands under Changing Climate - Moving from Global to Local*, Cairo, Egypt, 2010
11. Eleventh International Dryland Development Conference - *Global Climate Change and its Impact on Food & Energy Security in the Drylands*, Beijing, China, 2013.

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Presentations in Special Sessions

Foreword

The Post-2015 Development Agenda is emphasizing Sustainable Development Goals (SDGs) for enhancing food security, increasing productivity of smallholder farmers, reducing poverty and hunger, and tackling the problems associated with increasing water scarcity, biodiversity loss and desertification. The two global agreements, "Paris Agreement regarding Climate Change", and "Sendai Framework for Disaster Risk Reduction", recently adopted, would greatly impact sustainable development globally. The sustainable development of dry areas is crucial for achieving the global objectives of these agreements, because dry areas are home to a large population and a major proportion of global poor, and they have a fragile natural resource base extremely vulnerable to climate change.

An approach of integrated natural resources management, customized to different dryland ecosystems, to meet the needs of communities that depend on them, would be crucial for this development. Such an approach would, however, require developing intensive knowledge and understanding of the coping mechanisms to deal with drought risk, managing and restoring ecological functions, sustainably using biodiversity, and diversifying production system and livelihoods. Supporting policies and institutional options would also be needed. This integrated approach only can enable us to realize the various components included in the SDGs.

The Twelfth International Conference on Dryland Development, with the theme "Sustainable Development of Drylands in the Post 2015 World", provided a forum for informed discussion on these issues. Most of the presentations made in six plenary sessions, three specialized group sessions, eleven concurrent sessions and a series of posters, covering nine themes of program of this Conference, constitute the body of this volume. Manuscripts of some presentations were unfortunately not available for inclusion in the proceedings of the Conference. These presentations however had valuable information. Hence, their abstracts have been included so that those interested in getting more information on those topics and/or interested in forging research collaboration might contact the concerned authors.

It is hoped that the information contained in this volume would help promote research and development activities targeted to dry areas and contribute to enhancing the resilience of the dryland communities to cope with the adverse effects of changing climates. It is further hoped that it would promote, in some measures, a rational use of the fragile natural resource base of the drylands and contribute to achieving sustainable development goals.

Adel El-Beltagy
Mohan C. Saxena
Editors

Inaugural Session Presentations

Chairman's welcome address and homage to late -Prof. Adli Bishay - Adel El-Beltagy, IDDC Chair, Cairo, Egypt

On behalf of the International Commission on Dryland Development it is my proud privilege to extend to you a hearty welcome to the 12th International Dryland Development Conference with the theme *"*Sustainable Development of Drylands in the Post 2015 World*"* in this historic city of Alexandria. We are extremely grateful to the Director of Bibliotheca Alexandrina Dr. Ismail Serageldin, our co-host, to provide us such a magnificent venue for holding this Conference. This is not the first time that we are holding the meeting here, which is a reflection of the commitment that Bibliotheca Alexandrina has for the Commission. Although we have a very tight schedule for next few days, I will strongly recommend to you to find some time from your busy schedule to explore the Bibliotheca Alexandrina and find the rich trove of information and artifacts it possesses.

As you know, The International Commission on Dryland Development was established in 1987, as an NGO, by individual and institutions that were interested in and concerned about the sustainable development of dry areas, particularly those in the developing world. In 2008, the International Commission on Dryland Development (IDDC) and the Bibliotheca Alexandrina (BA), motivated by the common objective of fostering scientific knowledge and its optimum exchange and dissemination, agreed that they shall cooperate in a program of activities, to promote science and technology for sustainable development of drylands. The activities may include the joint organization of conferences, group discussions and seminars, and BA shall assist the IDDC by receiving, holding and disbursing funds raised by the IDDC. The main founders of IDDC were: Dr. Adli Bishay (Egypt), Dr. Harold E. Dregne (USA), Dr. Mohamed El Kassas (Egypt), Dr. William G. McGinnes (USA), Dr. Adel El-Beltagy (Egypt), Dr. Idris R. Trayler Jr. (USA), and Dr. Iwao Kobori (Japan).

The vision of IDDC is: "Improved livelihood of the people in the dry areas through environmentally and economically sustainable development and halting and reversing the trends in desertification". The *modus operandi* of IDDC to attain its objectives are to: (a) encourage scientific dialogue and debate on issues constraining the development of dry areas, and (b) enhance information exchange among researchers engaged in developing environmentally, economically and socially acceptable solutions for improved livelihoods in dry areas.

The Commission encourages networking by holding a major scientific conference -- International Conference on Dryland Development -- every three years to provide opportunity to exchange recent research results and experiences in dryland development and combating desertification. So far, the Commission has organized eleven international conferences in different parts of the world with large areas under drylands. The most recent ones were held in Texas (1996), Cairo (1999), Tehran (2003), Beijing (2006), Alexandria (2008), Cairo (2010) and Beijing (2013). The proceedings of most of these conferences have been published. The proceedings of the ones held more recently have also been uploaded on the website (www.drylanddevelop.org) of the commission.

As I said before, one of the leaders amongst the founders of the International Dryland Development Commission was Prof. Adli Bishay. Having obtained a Ph.D. and D.Sc. from Sheffield University, UK, he joined the American University of Cairo (AUC) in 1962, establishing there the Department of Sciences. He served as the Chair of this prestigious department till 1973. Recognizing the need for initiating systematic studies and encouraging research on development of dryland communities and arresting or even reversing the desertification in the West Asia and North Africa region, he established the Desert Development Center in the AUC in 1979 and remained its Director till 1993. Having worked with like-minded research and development experts in a series of group discussions and symposia at the Desert Development Center he took initiative in establishing the IDDC in 1987 and chaired it till 1996. Because of his commitment for the dryland communities in Egypt he developed a project proposal outlining strategies for sustainable development using a holistic approach and sought funding from the UNDP. The proposal was accepted, and he established an NGO named FEDA (Friends of Environment and Development Association) in 1993 to implement this UNDP sponsored project "Strategies for Sustainable Development of Egypt". His wise council helped in formulating the theme and agenda of each International Conference and he made it a point to attend all of them including the latest held in Beijing in 2013 in spite of his fragile health. Unfortunately, he passed away on Nov. 8, 2015, in Cairo. With his demise the research and development community involved in dryland development has lost a great visionary and leader and he will be greatly missed. The best homage that we can pay to late Prof. Adli Bishay is to recommit ourselves to and double our efforts in working for the sustainable development of drylands and for the communities living there. As a mark of our respect let as rise and keep a minute of silence and pray for peace to the departed soul.

Thank you

Statements by Co-sponsors:

1. Food and Agriculture Organization of the United Nations - *Pasquale Steduto, Deputy Resident Representative, NENA Division, FAO, Cairo, Egypt*

On behalf of FAO Director-General, Dr José Graziano da Silva I would like to thank you for inviting FAO to speak at the Twelfth International Dryland Development Conference "Sustainable Development of Drylands in the Post 2015 World".

This Post 2015 World, is a world that requires a special attention, and I don't exaggerate if I say that it needs to be 'handled with care'. In fact, we are living today in what we feared to reach; with extreme weather conditions that are literally claiming lives in many places in the world; the climate change is affecting the crops, the soil and our water.

From this apocalyptic situation rises an opportunity; the world is ready to listen and we need to seize the moment and act as quickly as we can to get everyone on board, and let the governments assume their individual and collective responsibilities. FAO has been working with many partners, many of whom are present here among us, not only to mitigate impacts of the Climate Change but also to set the foundations for shock-proof sustainable solutions.

As we all know, the Near East and North Africa region is facing an unprecedented escalation in water scarcity. For this reason, among others, the governing council of FAO in the region chose to address Water Scarcity as a regional initiative, and led global efforts to mobilize resources in order to meet the ambitious goals of this initiative. We know that the average availability of fresh water per capita in our region stands at just 10 percent of the world average. We know that Water scarcity is rising, and is literally affecting food security and the rural economy. We know as well that climate change compounds the fragile natural resource situation in the region. It exacerbates existing vulnerabilities to natural hazards such as drought, heat and salinity.

On the way to implement the Water Scarcity initiative, FAO is supporting the implementation of the "Regional Collaborative Strategy on Sustainable Agricultural Water Management and Food Security". This strategy represents a framework to assist countries in identifying and streamlining policies, governance, investments and practices that can sustainably improve agricultural productivity and food security in the region and at the same time help attaining the 2030 Sustainable Developed Goals (SDGs).

As the 22nd session of the Conference of the Parties (COP22) to the United Nations Framework Convention on Climate Change (UNFCCC) will be held in November in Marrakech, I would like to invite you to think of the words of FAO Director-General Jose Graziano Da Silva during COP 21 in Paris where he said that "a solution for a better world must involve everyone. That is what the 2030 Agenda on Sustainable Development Goals is about: universality, solidarity and inclusiveness". He added that the 17 Sustainable Development Goals approved by the global community are intertwined. Climate change is probably the issue.

While noting SDG 13's call to take urgent action to combat climate change and its impacts, one cannot ignore that climate change is probably the single issue connecting the intertwined 17 Goals approved by the global community. Failing to heed this call puts the achievement of all the other SDGs at risk, in particular our fight against hunger. During COP 21, FAO succeeded with its partners in putting agriculture on the agenda, reiterating the role of agriculture as one of the main stakeholders of climate change, a role that had not yet been sufficiently factored in the global debate. Today, we look at Pre-COP 22 events as an opportunity to build on this success and leverage on the green climate fund (GCF). Indeed, in one week from now, FAO is holding the first meeting for the Maghreb countries in Rabat, followed by a similar meeting for the Mashreq countries in Cairo from 3 to 5 October.

FAO is pleased to see that its multi-dimensional plan of action to address water scarcity is in congruence with most of the themes of this conference, and is looking forward to hearing from the experts, their views over the solutions related to each of these important themes.

I wish you all the success, and hope that we will succeed in meeting the goals of this conference.

2. International Fund for Agricultural Development (IFAD) - *Abdelhaq Hanafi, IFAD Country Director, Cairo, Egypt*

It is my privilege to deliver these remarks on behalf of Dr Knayo F. Nwanza, President IFAD. We are proud to be a co-sponsor of this prestigious event. For the past several years, this conference has provided opportunities for key players to share the latest knowledge in dryland research. This year you have gathered once again in Alexandria, the ancient site of learning that has been reborn here in the Bibliotheca Alexandrina. This venue is the perfect symbol for the need to embrace the old and the new as we face the challenges of the post-2015 world.

We all know the challenges ahead are enormous. As we look for ways to achieve the Sustainable Development Goals, particularly as they relate to water, IFAD believes that solutions need to blend the expertise of researchers with the traditional knowledge and ingenuity of smallholder farmers. IFAD has seen how smart phones and tablets help smallholder farmers make better decisions. But we have also seen how farmers have recycled plastic sandals to support micro irrigation.

Whether we are considering high tech or low-tech solutions, what's important is that researchers engage local people right from the start. Smallholder farmers may not have University degrees, but they know their land better than anyone else. Their experience and insights can help ensure that research achieves its primary goal: to improve the lives of people. But success will depend on more than how we pursue research. It will also depend on what we research.

IFAD believes that our efforts to conserve water in Egypt and the Middle East must go hand-in-hand with the drive to ensure food security. This is the approach that guides our investment in the region. In Egypt, for example, IFAD has worked with the government to help reclaim over 200,000 hectares of productive land. At the same time, we have helped establish more than 1000 water users' groups. This has led to dramatic improvements in water savings.

Since 1980, IFAD through its investment projects in partnership with the Ministry of Agriculture and Land Reclamation, has helped several thousands of Egyptian families to diversify their crops, plant adapted cultivars and improve productivity. At the same time, we are linking smallholder farmers to markets so that agriculture in the dry areas can be profitable. By improving their livelihoods, these families are also improving their quality of life.

15. We also work with other partners such as ICARDA (International Centre for Agricultural Research in the Dry Areas) and ICBA (International Centre for Biosaline Agriculture), on research that benefits the poor in the drylands. The research programs funded by IFAD helped resource poor farmers in dry areas, cultivate crops and animal feed adapted to their environmental conditions, increasing their yields using salinity and drought tolerant cultivars and at the same time preventing environmental degradation. The research helped raise the incomes of poor people, but it has also helped farmers in wealthier arid and semi-arid nations.

Time and time again, IFAD has seen that transformation occurs when development takes a holistic approach. To be environmentally, economically and socially sustainable, for example, research must make the links between water use, food security and livelihoods, and involve local people right from the start.

Today, IFAD is looking at ways to sustain and scale- up solutions to water use for agriculture in dry lands. That is why we are proud to co-sponsor the 12th International Dryland Development Conference. Over the next four days, you will exchange knowledge about research into drylands. And you will reflect on how results in one part of the world can be adapted in another. No doubt you will encounter many new ideas, as well as old ideas with an innovative new twist. IFAD is confident that the conference will advance our collective knowledge about drylands, and move us closer towards achieving the Sustainable Development Goals.

We wish you all the best of success. Thank you.

3. Arid Land Research Center (ALRC), Japan International Cooperation Agency (JICA), Japan International Research Center for Agricultural Sciences (JIRCAS) - *Atsushi Tsunekawa, Professor, ALRC, Tottori University, Tottori, Japan*

On behalf of ALRC, JIRCAS and JICA, the cosponsors from Japan, I will like to extend my sincere thank and appreciation to Prof. Adel El-Beltagy, Chair of International Dryland Development Commission for leading this Conference. Since the first Conference – International Conference on Application of Science and Technology for Desert Development – held in 1978, the Conference has been serving the dryland research community as an important platform for discussing development of dry areas for almost four decades now. The excellent foresight and strong leadership of Prof. El-Beltagy should be admired.

Now let me introduce our Arid Land Research Center of Tottori University. ALRC has been serving as a Joint Usage Research Center to provide a place for Japanese dryland scientists to organize joint researches from 1990. In January 2015, Tottori University established the International Platform for Dryland Research and Education (IPDRE), aiming to create a platform for interdisciplinary research on drylands. I am serving as the Head of the Strategic Management Office of the Platform. With IPDRE, ALRC attempts to contribute to sustainable development of drylands through achieving practical use of technical findings developed by our researchers. It would be impossible for us to maintain our technical excellence in dryland research without our partner institutions. I would therefore like to take this opportunity to express my gratitude to our partners.

Now let me briefly introduce Japan International Cooperation Agency (JICA). It is a part of Japan's official development assistance efforts, with a role in providing technical cooperation, capital grants, and yen loans. Its activities are closely related to this Conference through its thematic issues such as agriculture and rural development, poverty reduction, water resources, disaster management, natural resource conservation and so on.

Another partner, JIRCAS (Japanese International Research Center for Agricultural Sciences) was established in 1993. JIRCAS is the sole national institute that undertakes comprehensive research on agriculture, forestry and fisheries technologies in developing areas in tropical and subtropical regions, aimed at providing solutions to the international food supply and environmental problems through technology development.

Finally, the theme of this Conference is focusing on the Post 2015 World in dry areas. As you are aware, last year, 2015, was historical year for us. In September, in the United Nations Sustainable Development Summit, the new 2030 Agenda for Sustainable Development, including Sustainable Development Goals (SDGs) was adopted. In December, the Paris Agreement was adopted at COP21 of the UNFCCC.

In closing, I would like to take this opportunity to extend my invitation to all present here to attend the Special Session: Restoration of Degraded Dryland Ecosystems – beyond conventional approaches, hosted by ICARDA and IPDRE, which is going to take place tomorrow evening.

I wish you a successful Conference.

4. International Center for Agricultural Research in the Dry Areas (ICARDA) - *Mahmoud El Solh, Director General, ICARDA, Beirut, Lebanon*

On behalf of ICARDA, I would like to welcome you to the 12th ICDD focusing on achieving the SDGs in drylands. The impressive gathering of distinguished experts and specialists we have today in this Congress is a reflection of the importance of drylands development at this critical time of the global food crisis and the serious threat of climate change implications to global food security, particularly in dry areas. ICARDA, as one of the organizers of this Conference, I would like to thank HE Prof. Adel El-Beltagy and Dr. Mohan Saxena for their leadership in organizing this important event and for their service to promote science and technology in dry areas, much of their life time working at or with ICARDA. We also would like to thank ARC/Egypt and the Alexandria Library for hosting this important event and the presence of Dr. Ismail Serageldin who is a distinguished visionary and global intellectual leader servicing this part of the world is a true reflection of the importance of this Congress.

We would like to express a special appreciation to our national, regional and international colleagues who are contributing to the rich Program of the Congress and we would also like to express appreciation to the highly-valued support of the long list of sponsors and donors.

This vast area of non-tropical dry lands is home to ICARDA. The Center has worked for over 39 years to improve livelihoods of farming communities in drylands through agricultural research and capacity development and we have accomplished a great deal to address issues related to achieving the SDGs in dry areas in close collaboration with the National Agricultural Research Systems (NARS). Trust, generated over decades, allows us to play the role of honest broker across the most of the non-tropical dry areas, particularly in Central and West Asia and North Africa, with strong involvement in both Eastern Africa and South Asia.

In addition to the negative implications of climate change, the current food insecurity and high level of unemployment in many dryland countries are key challenges facing communities as well as governments in dry areas. Thus, more investment is very much required in to achieve the SDGs to solve major challenges, particularly in drylands. Science and advanced technologies are essential to ensure sustainable agricultural and economic development to achieve the SDGs in drylands. Thus, impact of agricultural research for development is critical for sustainable development particular in rural areas where poverty prevails.

For the past four decades ICARDA has worked with its national and regional partners and other advanced research institutions following an integrated approach for sustainable agricultural development to achieve the SDGs in non-tropical dry areas.

In contributing to the SDGs in dry areas, ICARDA's collaborative research for development has taken an integrated pragmatic approach in providing solutions to the challenges facing sustainable agricultural development in production systems in three major agro-ecologies: rainfed production systems, irrigated agriculture and the agro-pastoral systems in marginal lands or low rainfall areas. This has been through technological improvements to ensure that (a) the natural resources are well managed and used sustainably within the context of agri-food production systems; and (b) the conservation and utilization of genetic resources of key staple commodities is enhanced and the introduction of desirable traits that improve the quantity, quality and efficiency of food production systems is accelerated. This has contributed to the development of sustainable livelihood systems for rural communities. Through its collaborative research and technology transfer with national partners, examples on the ground are presented in the paper to be presented later, demonstrating as to how they contribute to the eight SDGs below. Different strategies are used to achieve these goals in different agro-ecologies. These include sustainable intensification in high potential areas and to achieve resilient production systems in marginal lands of the non-tropical dry areas. ICARDA's collaborative research with national partners contributes mainly to the following SDGs:

- SDG 1, No Poverty: Ending poverty in all its forms everywhere
- SDG 2, Zero Hunger: Ending hunger, achieve food security and improved nutrition and promote sustainable agriculture
- SDG 4, Promoting Quality Education: Ensure inclusive and quality education and promote lifelong learning
- SDG 5, Gender Equality: Achieve gender equality and empower all women and girls
- SDG 8, Decent Work and Economic Growth: Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- SDG 13, Climate Action: Take urgent action to combat climate change and its impacts through adaptation, mitigation and resilient production systems
- SDG 15, Use on land: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss
- SDG 17, Partnerships for the Goals: Revitalize the global partnership for sustainable development and developing networking.

The Opening Session does not allow to talk in details on what the collaborative agricultural research work with various partners has achieved on the ground in several development goals. But my presentation later today will give concrete examples on that subject. Experience and efficiency of systems will go a long way to upscale and replicate our successes for large scale impact on SDGs.

We have many new scientific tools available now that we never had in the past: fast computers, satellite sensors, GPS, GIS, biotechnological tools, video tele-conferencing and decision-support models to name a few. These should be used along with new training and education programs to tackle the new challenges to achieve the SDGs. In particular, we need to encourage young scientist to devote their energies and intelligence to innovative agricultural research.

On behalf of ICARDA management and scientists, I wish the participants of this important congress fruitful deliberations and congratulations for your presence, which brings all of these bright minds together to see how best we should take action on ground to address the SDGs in dry areas.

5. Chinese Academy of Sciences (CAS) - *Wang Tao*

On behalf of the Chinese Academy of Sciences (CAS), it is my pleasure to extend a warm welcome to all the participants to this magnificent venue in Alexandria. We are indebted to Prof. Adel El-Beltagy, Chair of International Dryland Development Commission (IDDC) to continue promoting the cause of the drylands by convening the International Conference on Dryland Development (ICDD) at regular intervals and thus giving fillip to research and promoting research networking for development of dry areas. The CAS has had the privilege of hosting three of these conferences in China in the past and it continues to strongly support the efforts of IDDC by ensuring full participation of its researchers in the Conference. China has a long history of research, ranging from basic to applied, on land degradation and desertification and has put the results of these researches in preventing desertification, and even reversing it at some places. The ICDD provides us the opportunity to share these results with the international community and permits us to forge research and development partnership with scientists engaged in similar work in other parts of the dryland areas. The sustainable development of dry areas continues to receive very high priority in the research and development efforts of CAS and therefore we are fully committed to the objectives of IDDC and continue to provide it our full support. The theme of this Conference is highly topical and I look forward to very fruitful deliberations. On behalf of CAS and on my personal behalf, I once again extend very hearty welcome to all of you and wish you a very successful Conference.

6. Arid Lands Agricultural Studies and Research Institute (ALARI) - *Ayman F. Abou-Hadid, Professor, Arid Lands Agricultural Studies and Research Institute, Ain Shams University, Cairo, Egypt*

On behalf of the Arid Lands Agricultural Studies and Research Institute, a cosponsor of the 12th International Dryland Development Conference, I will like to extend a warm welcome to all the participants. Some of you might not be familiar with this Institute. So, let me give you its history and activities.

The idea of ALARI started as early as 1979 from the activities of Egyptian-Norwegian Tomato Project (EGNO) in the Faculty of Agriculture, Ain Shams University. The project introduced protected cultivation and monitoring agriculture microclimate to eliminate seasonality of tomato production. The first computer aided management system was introduced to Egypt as well as agro-climate monitoring by data-logger and use of sensory for crop management. At this point, the Arid Lands Laboratory was established in the Department of Horticulture, Faculty of Agriculture, supported by the "Cooperative Arid Land Research Program" CALAR1 (US-AID), Salinity Activity from 1981 to 1989, and IFS grants No C/0913 on "Vegetable Production under Modified Climate in Arid Zones" from 1985 to 1987. The Laboratory grew through several successive projects including: The Desert Greenhouse Research Project, Cooperative Arid Land Research Program CALAR2 financed by US-AID, 1989 to 1995, UNDP-FAO-EGY/86/014 Protected Cultivation Project, 1987 to 1995, UNDP-FAO-EGY/95/002 "Protected Cultivation "Phase II"

1995-2002, and several other projects. In 2005 the Arid Land Laboratory staff established the Arid Lands Agricultural Research Unit that was further developed to become a Research Center in 2006. In April 2007, the Center further developed to become the Arid Lands Agricultural Studies and Research Institute (ALARI) of the Ain Shams University, independent of its Faculty of Agriculture. ALARI deals with a wide range of subjects including agricultural and rural development, agro-climatology, environmental stress, remote sensing, water/plant/environment relations, crop water requirements, irrigation of horticultural crops, protected cultivation, soilless culture, vegetable production, and climate change issues. ALARI has a certified Laboratory that offers its services to the agricultural investors and growers in Egypt. The institute also cooperates on the regional scale and international levels in several research programs.

The staff of ALARI has contributed to the initiation and establishment of several institutions in the Agricultural Research Center of the Ministry of Agriculture and Land Reclamation, namely, Agricultural Genetic Engineering Research Institute (AGERI), Central Laboratory of Agricultural Expert Systems (CLAES), Central Laboratory for Agricultural Climate (CLAC), and the Climate Change Information Center and Renewable Energy (CCICRE). ALARI is keen to expand the international cooperation in the field of agricultural higher education and post graduate studies for students from the CWANA region and the African continent.

7. Economic Cooperation Organization Science Foundation (ECOSF) - *Manzoor H. Soomro, President, ECO Science Foundation, Islamabad, Pakistan*

It is indeed a great honor and a pleasure for me and my organization, to be joining this highly important forum and I thank Professor Adel El-Beltagy and his team for this opportunity.

Economic Cooperation Organization (ECO) is the successor organization of the Regional Cooperation for Development or RCD, which was originally established in 1964 by three member countries; Iran, Pakistan and Turkey. However, in 1985 it was renamed as "Economic Cooperation Organization- ECO" and after the collapse of Soviet Union in 1991, seven other members also joined in 1992; and they are; Afghanistan, Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan; 6 of these are actually former Soviet States. Purpose of the organization is economic development and cultural integration in the region.

ECO has a number of specialized agencies like the UN Agencies, and three major institutions are; ECO Cultural Institute in Tehran, ECO Educational Institute in Ankara and ECO Science Foundation in Islamabad, that I am the founder President of.

The mandate of ECO Science Foundation is to promote Science, Technology and Innovation in the region using all possible ways and means including promoting partnership with other international Science, Technology and Innovation (STI) organizations and UN Agencies. Our main partners include; UNESCO, ISTIC, IAP SEP, IPBES, EvK2-CNR, LAMAP France and TWESCO. The main activities of ECO Science Foundation include; Funding of Scientific and Technological Research; Coordination & Funding of University-R&D-Industry Linkage Programs; Funding of Capacity Building Workshops; Holding and funding of Science Conferences; Providing Travel Grants to researchers; Funding of key Science Popularization Activities and to strengthen the science base, Promotion of Inquiry Based Science Education (IBSE) at school level in ECO Region.

Science Technology & Innovation (STI) have been recognized as main driver of Productivity, Economic Growth and Prosperity, and are fundamental to achieving Sustainable Development. Whereas, the three main pillars of sustainable development; Economic growth, Social equity and Environmental protection, are directly linked to STI. Countries round the globe are using STI to improve production and productivity of agriculture and industries to meet needs as well as to overcome environmental challenges.

The innovations that transform societies towards sustainability, should base on sound STI, which in turn depend on high degree of expertise in different sciences and the know-how of their technological applications. The "inquiry" or critical thinking comes with science education and is vital in training the minds for understanding the world, through improving science literacy. It should be inculcated among children at primary and secondary school levels. Science literacy provides the basis for solutions to everyday problems that brings about transformative changes on the road towards sustainable development. Thus, ECOSF is promoting Inquiry Based Science Education (IBSE) at school level in the ECO Region. I would like to say that; all Great University Scholars and Scientists are actually nurtured at schools! And using IBSE is a step forward to ensure sustainable supply of young talent for linking advance research and industrial development to address the challenges and achieve UN Sustainable Development Goals.

The preservation and sustainable development of drylands are essential to conserve the biomass and biodiversity and achieve food security. At the same time, the protection of soil quality and crop and grazing land management, including restoration of degraded lands, have been identified as having the greatest agricultural potential to mitigate climate change, in addition to being cost-effective. Reducing the vulnerability of dryland communities to climate change requires measures that diversify livelihood options, reduce pressure on natural resources, and restore and protect dryland ecosystems.

The disaster and climate change response strategies contribute in a positive manner towards implementing sustainable development, including enhancement of social equity, sound environmental management and wise resource use. The practical IBSE modules developed by dryland experts and pedagogy specialists, can be incorporated in the syllabi of schools, particularly in the dryland areas of the globe; which in-turn can assure the sustainable development of the drylands.

ECO region has quite a few dryland areas and our problems are common. Thus, I assure you that ECO Science Foundation stands with you- the specialists and institutions engaged in noble work of dryland development, and would be very happy to cooperate and collaborate especially in research and awareness.

Opening Address

Achieving Sustainable Development Goals (SDG) in the dry areas - a myth or a real possibility

Adel El-Beltagy[1]

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Abstract

The World, in 2015, has witnessed three major agreements related to the global sustainable development: 'Sustainable Development Goals' (SDG's), the 'Paris Agreement' to coordinate efforts to tackle climate change, and the 'Sendai Framework for Disaster Risk Reduction'. They would greatly impact sustainable development globally in general and in the dry areas of developing countries in particular. The price of not implementing the three agreements or any complacency in developing action plans - globally, regionally and locally - would be catastrophic. Climate change, with an increase in temperature and the rise in sea water level, will have an adverse impact on the livelihood of seven billion people that inhabit our globe now, and the situation will worsen if the projected rise of the population to 9 billion in 2050 were to come true. This will greatly disturb the coping capacity of our planet, and lead to severe ecological disaster. The approach to integrated natural resources management has to be customized to different ecosystems to meet the needs of communities that depend on them. Such approach would require developing intensive knowledge and understanding of the coping mechanisms to deal with drought risk, managing and restoring ecological functions, sustainably harvesting of biodiversity, diversifying production system and livelihoods, and this technological understanding has to be shared globally, regionally and nationally. Supporting policies and institutional options would be needed. These are the building blocks for sustainable development. The landmark agreements of Paris and Sendai are only partially legally binding, and thus much will be left for voluntary action. A massive and dynamic campaign is, therefore, necessary to ensure that an internationally binding legal framework is put in place. Although there was a pledge made in Cancun in the past to establish a technology box and a fund to support the developing countries in improving their coping and adaptive capacities and minimizing their vulnerability to climate change, this has not been effectively fulfilled. The commitment of making hundred billion dollars available per year, up to 2020, to developing countries to adapt to climate change is yet to be met. Nationally Determined Contributions (NDC) that each country has to express voluntarily, reflect the pillars of implementation. These are: (a) Political will and effective governance, (b) Long term mitigation strategies, (c) Integrated adaptation planning and implementation programs, (d) Finance framework to cope with climate change, and (e) New institutions, credits, and legislation. Optimization and enhancing synergies between the international, regional, and national research systems is highly required. Knowledge gap related to the assessment of the impact of climate change on local and regional levels is yet to be assessed through global efforts and partnership. The developed countries have to realize that all their contributions (knowledge and finance) will

be an investment for secured livelihood of their peoples. The projected number of out migration because of possible climate change (environmental refugees) could reach two hundred million by 2050. This element, one of many negative implications of climate change, would justify the need for such a support. There is a need for a strong alliance for sustaining our planet and spreading peace and prosperity in the world. This will require a shift of consciousness on the part of both, those that 'have' and those that 'have not', and a new deep understanding of oneness of humanity.

Keywords: Climate change impacts, SDGs, Paris Agreement of UNFCC, Sendai Framework for Disaster Risk Reduction, Sustainable resource management, Bridging technological knowledge gap, Capacity building, Political will

Introduction

Drylands are facing unprecedented challenges to their sustainability because of climate change. The reports of the Intergovernmental Panel on Climate Change, one after the other, have reaffirmed that the changes are real and are being caused by anthropogenic activities that are contributing to increased greenhouse gas emissions. Using different models, the IPCC has predicted that if appropriate measures to curtail emissions are not taken and suitable adaptation and mitigation strategies not put in place the environmental consequences for the planet earth will be disastrous.

The drylands, with their fragile natural resource base, are particularly vulnerable to the climate change as this brings with it increasing weather aberrations with disastrous consequences (El-Beltagy and Madkour, 2012). Traversing between despair and hope in this scenario, the dryland communities need much attention to empower them to have a sustainable use of their natural resources so that their livelihoods are sustained in the face of changing climatic. Their coping capacity and resilience against the adverse effects of climate change has to be improved through a holistic approach involving application of science and technology, and socioeconomic, policy and institutional support.

Recent international efforts related to enhancing resilience to climate change

There have been fortunately several deliberations on global scale in the recent years to develop consensus on the adaptation and mitigation strategies for addressing the adverse effects of changing climate. The December 2009 Copenhagen Climate Change Summit failed to deliver the much hoped for commitment by the countries to cut greenhouse gas emission by 50% by 2050 to limit the rise of global temperatures to 2^{o} C above the temperature when the industrialization began. However, the move to combat global warming has continued to gather momentum since then; and the trend is likely to continue in the future.

In the 2010 UN Framework Convention on Climate Change (UNFCCC) in Cancun, Mexico, the Parties adopted the 'Cancun Adaptation Framework' (CAF), as a part of the 'Cancun Agreement', that affirmed that adaptation to climate change must be addressed with the same level of priority as mitigation (UNFCC, 2011). The CAF emphasized that the action on adaptation should be enhanced to reduce vulnerability and build resilience in the developing country parties including through international cooperation and coherent consideration of matter related to adaptation.

There was a suggestion at UNFCCC for mobilizing 'Fast-start Finance' amounting to nearly US$ 30 billion for the period 2010-2012 by the developed country Parties. It was proposed to have a balanced allocation between adaptation and mitigation; funding for adaptation was to be prioritized for the most vulnerable developing countries. Developed country Parties were to provide not only funds but also technology and capacity building to implement adaptation actions plans, programs, and projects at local, sub-regional and regional levels under the CAF.

As has now become evident, the promises mentioned above could not be fully realized. At the same time, the plant Earth is facing unprecedented deterioration in its health. Over 2000 million hectares of land has been degraded, there is serious loss of biodiversity, increasing water scarcity, and increasing frequency of climatic disasters. Increasing anthropogenic pressures, particularly in the developing countries because of population explosion, are taxing natural resources, which are being further destroyed by conflicts and war. Action is therefore needed to ensure sustained efforts to arrest the process and, where possible, reverse it.

Fortunately, a ray of hope decidedly emerged when the UN Member States adopted the 'Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR)' on 18th March 2015 at the Third United Nations World Conference on Disaster Risk Reduction in Sendai City, Miyagi, Japan (UNISDR, 2015). The Sendai Framework outlined its scope and purpose through one Global Outcome, one Goal, 13 Guiding Principles, four Priorities of Action at local, national, regional and global levels, and seven Global Targets. An important feature of the Framework was the element of monitoring outlined in great detail to avoid any ambiguity (Figure 1). If the commitments made by the Partners in the Framework are adhered to, there would be substantial progress towards enhanced residence of communities to climate change. The progress made at local, national and regional levels would be documented in reports and discussed at suitable intervals.

Figure 1. Monitoring of action on Disaster Risk Reduction at global, regional and national levels under the Sendai Framework.

The 'World Climate Summit' held in Paris, France in November 2015 also saw considerable political will for actions to save planet Earth from the disastrous consequences of climate change.

The collective efforts of Brazil, China, India and other countries with France contributed a great deal to the development of agreement on targeted reductions in the greenhouse gas emissions to mitigate future climate change. The susceptibility and vulnerability to climate change maps (Figure 2 and 3) of the world clearly show that the countries of the developing world are going to be the main victims of the adverse effects of climate change and their coping capacity (Figure 4) is highly constrained when compared to the industrialized countries. However, one should expect large internal differences at local and regional level within each country in susceptibility and vulnerability and their coping capacity because of differences in physical endowments and socioeconomic conditions. These need to be quantified to develop effective coping mechanisms.

Studies are needed in the developing countries using the 'Climate Change Integrated Assessment Methodology' that has been developed for assessing cross-sectorial adaptation and vulnerability hotspots in Europe using 'Integrated Assessment Program'. The European Commission Seventh Framework Program funded the development of the 'Climate Change Integrated Assessment Methodology for Cross-Sectorial Adaptation and Vulnerability in Europe'.

The assessment methodology exercise arrived at the conclusion that this approach to vulnerability assessment was replicable and transferable; it allowed integration of concepts of capitals and coping capacity with stakeholder-derived scenarios and produced patterns of coping capacity that might be expected for different socioeconomic scenarios. The hotspot maps developed using this methodology for different parts of Europe suggest that human wellbeing is most at risk from water stress and biodiversity loss in southern Europe, and from lack of food production and land use diversity in northern Europe. However, such integrated assessment at local, sub-regional and regional levels in the developing countries would need infrastructural development and trained human resources, for which support from the industrialized countries would be needed.

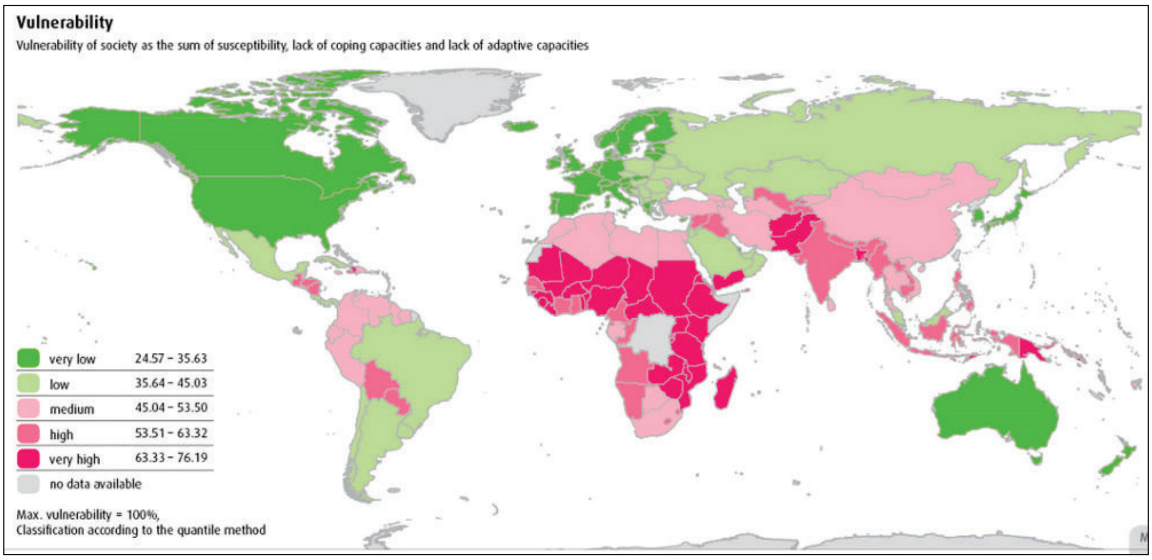

Figure 2. World map of vulnerability to climate change.

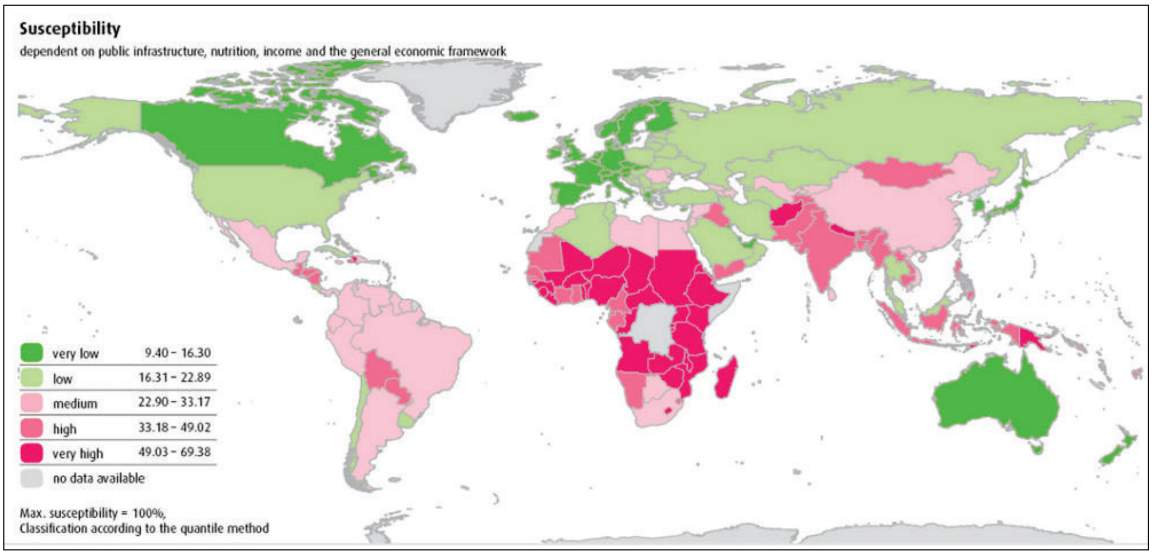

Figure 3. World map of susceptibility to climate change.

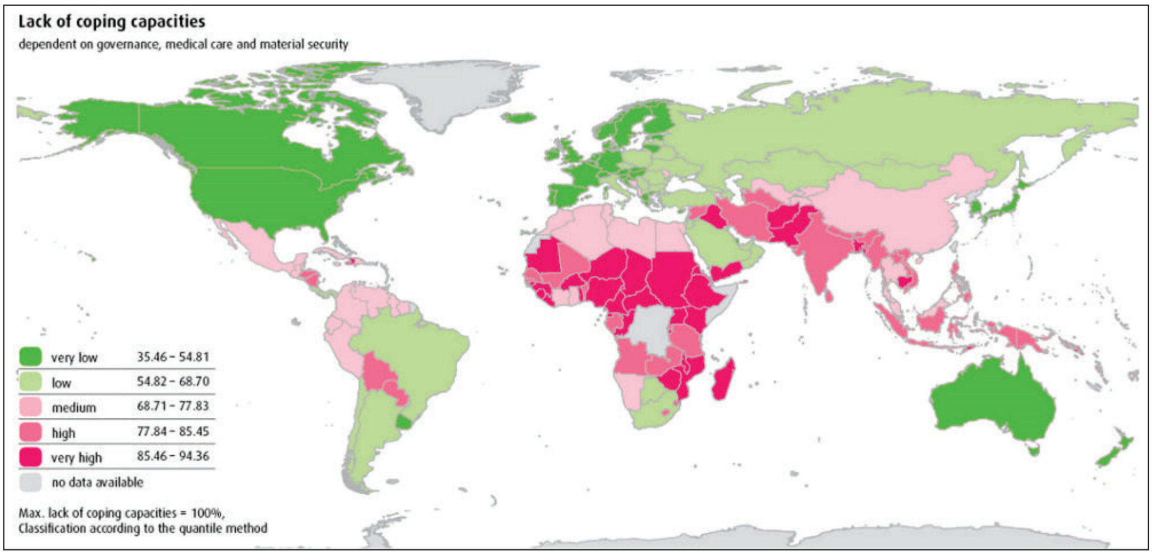

Figure 4. World map of coping capacity to climate change.

Studies are needed in the developing countries using the 'Climate Change Integrated Assessment Methodology' that has been developed for assessing cross-sectorial adaptation and vulnerability hotspots in Europe using 'Integrated Assessment Program'. The European Commission Seventh Framework Program funded the development of the 'Climate Change Integrated Assessment Methodology for Cross-Sectorial Adaptation and Vulnerability in Europe'. The assessment methodology exercise arrived at the conclusion that this approach to vulnerability assessment was replicable and transferable; it allowed integration of concepts of capitals and coping capacity with stakeholder-derived scenarios and produced patterns of coping capacity that might be expected for different socioeconomic scenarios. The hotspot maps developed using this methodology for different parts of Europe suggest that human wellbeing is most at risk from water stress and biodiversity loss in southern Europe, and from lack of food production and land use diversity in northern Europe. However, such integrated assessment at local, sub-regional and regional levels in the developing countries would need infrastructural development and trained human resources, for which support from the industrialized countries would be needed.

The 'Sendai Framework Agreement' and 'Paris Accord' have catalyzed the cooperative efforts to reduce the adverse effects of global climate change. In Paris, the Parties agreed to hold the increase in the global average temperature to well below 2^{o}C above the preindustrial levels and to pursue efforts to limit the increase to 1.5^{o}C, recognizing that this would significantly reduce the risks and impacts of climate change. The deliberations in Paris also resulted in the first ever-agreed global goal for adaptation. The goal considers enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, building on the 2010 Cancun Adaptation Framework, which is anchored in the Disaster Risk Reduction Framework. The Parties further agreed to enhance understanding, action and support with respect to loss and damage associated with the adverse effects of climate change with focus on early warning systems and emergency preparedness, comprehensive risk assessment and management, and risk insurance facilities, climate risk pooling and other insurance solutions.

The Paris Agreement also clearly identified the elements associated with the Nationally Determined Contributions (NDCs). These include: (a) building national awareness on NDCs among all stakeholders (ministries, local governments, private sector, general public, etc.; (b) strengthening institutional arrangements and technical capacities to manage NDC implementation; (c) identifying information gaps and undertaking technical analysis; (d) developing NDC implementation plans that prioritize concrete mitigation and adaptation measures to achieve NDC goals; (e) developing funding arrangements to mobilize public resources, private investment and international support based on the implementation plans; (f) implementing mitigation and adaptation measures in sectors, including enabling conditions to remove barriers to implementation; (g) developing monitoring systems, collecting data and transparently reporting progress towards NDC goals; and (h) planning for further NDC rounds, including institutionalizing progress and updating long-term strategies.

The third global agreement that also addresses concerns associated with climate change relates to the 'Sustainable Development Goals (SDGs)' adopted at the UN Sustainable Development Summit September 25–27, 2015 in New York, USA (UN, 2015). The **Sustainable Development Goals** (**SDGs**), officially known as **Transforming our world: the 2030 Agenda for Sustainable Development** is a set of 17 "Global Goals" with 169 targets between them. The goals were spearheaded by the United Nations through a deliberative process involving its 193 Member States, as well as global civil society. Of the 17 SDGs, 10 SDGs have 25 targets that are directly or indirectly related to disaster risk reduction (DRR), firmly establishing the role of DRR as a core development strategy.

Strategies for sustainable development in dry areas in the face of climate change

Sustainable development of dry areas will be a key to the global sustainable development because these areas are home to nearly 2.5 billion people constituting a majority of world's poor and have fragile natural resource base and thus are most vulnerable to adverse effects of climate change. If not given due attention now, they would get further degraded to the level that recovery would become nearly impossible. The 'water-food-energy' nexus is going to be seriously stressed because of climate change.

Rise in temperature and increased weather aberrations associated with climate change are going to affect adversely the food production in dry areas by directly reducing the productivity of agriculture and reducing the area suitable for agriculture. Increased shortage of water, unfavorable temperatures during the critical stages of crop growth, and development of new pests and diseases will lead to loss of crop yield. Crop yields might go down up to 50% if the temperature were to rise by 4^{o}C. Rise in temperature will lead to development of new animal diseases and shortage of feed adversely affecting livestock sector. Poor water quality, development of new predators and pests, change in abundance of food available, worsening dry season mortality, etc. will adversely affect aquaculture.

All these developments and increased frequency of such climatic events as prolonged drought, high density precipitation and cyclones causing flash floods, hot winds during critical plant development stages, hail storms at harvest time, etc. will make agriculture even riskier than now. Rise in the level of seawater would rob farmers in the coastal areas of their productive lands. Hunger will thus be triggered by poor harvest, high food prices, loss of employment and lowered incomes. Thus, climate change is also going to create the problem of human migration and creation of environmental refugees. Some estimates suggest that climate change might create some 200 million environmental refugees with serious socioeconomic consequences. The immigration could trigger serious problem of disrupting socioeconomic situation in countries where the environmental refugees might arrive. Unfortunately, there are no international laws that might come to the relief of environmental refugees in contrast to the political refugees. There should be a global ethical responsibility for the environmental refugees and a binding international agreement should be formulated in this regard.

The importance of formulation and implementation of adaptation and mitigation strategies that have been the subject of deliberations in the recent COPs and other global forums is increasing every day, as the cost of doing nothing would be immense. The commitments made in the above mentioned international meetings for the industrialized countries to provide support to developing countries for capacity building, transfer of technology and financial resources to assess the impact of climate change at local levels and to develop and implement adaptation and mitigation measures to enhance the resilience of the vulnerable communities become extremely important.

New tools of science and technology are opening new avenues for precisely identifying the problems associated with climate change and developing appropriate solutions and implementing them. These include: remote sensing, GIS and GPS techniques; biotechnology and genetic engineering; genomics and proteomics for gene mining; nanotechnology; information technology, expert systems, artificial intelligence; new energy saving techniques for desalination, water transportation, on farm agro-management techniques; and harnessing renewable energy (solar, wind, biofuels, etc.). Access to these technologies is very uneven and most of the developing countries may not be in a position to derive full benefits from them unless they are supported through capacity building and other supports.

In their efforts to enhance their resilience to adverse impacts of climate change, the developing countries see it prudent to give priority to adaptation rather than mitigation. Knowledge based interventions will be needed for achieving sustainable development in agriculture for drier areas of the developing world, as agriculture continues to be the key to sustaining the livelihoods of majority of the population there. Sustained development of dryland agriculture will require: (a) New genetic makeup of crops and crop cultivars to have heat and drought tolerance and tolerance to other common abiotic and newly emerging biotic stresses. (b) New agro-management techniques that build soil fertility and land productivity, improve water use efficiency under both rainfed and irrigated conditions, and improve nutrient use efficiency.

Harnessing the biodiversity and conserving it for future use are important for altering the genetic makeup of the crops and varieties needed to adapt to changing climates. The commitment of the international community to conserve genetic resources, and making them available to all those who need them as and when necessary, is evident from the efforts for storing world genetic resources conserved in leading gene banks in the world in permafrost in Svalbard, Norway. Bioinformatics and biotechnological tools would enable scientists to look for and use novel genes in the conserved genetic resources. In developing new and better adapted crops and varieties to changing climates and societal needs, biotechnological perspectives will have to come in consideration for improving: (a) crop yield and nutritional quality; (b) resistance to various insect pests and diseases; (d) ability to grow under harsh environmental conditions; (e) resistance to herbicides; (f) resistance to salinity and abnormal soil pH; (g) water and nutrient use efficiency; and ability to yield value added biopharmaceuticals. That many of these applications are already coming into play is evident from the work on the development of heat-tolerant wheat cultivars in Egypt for use in the Nile Valley. Drought tolerant maize cultivars/hybrids are now available through collaborative efforts of public private sector cooperation in several developing countries. For getting durable resistance/tolerance to the harsh environmental conditions novel genes from wild relatives and other species will have to be deployed using cutting edge science.

Water scarcity, which could become particularly acute in the West Asia and North Africa region and Sub Sahara Africa, would necessitate drastic changes in the way irrigation is practiced in the region. Use of alternate furrow/ permanent bed system for irrigation, use of gated pipes, sprinklers, drips and other micro-irrigation devices; laser leveling and use of smart irrigation scheduling techniques will have to be promoted. In situ and ex situ water harvesting and conservation and the strategic use of harvested water at critical stages of crop growth would be needed. Use of hydroponics to improve water, land and nutrient use efficiency will become increasing important not only for high value crops but also for raising other food and feed crops to cope with land and water scarcity. Other agro-management techniques such as conservation agriculture, nutrient recycling and soil organic carbon management would be necessary for sustainable increases in crop productivity. Agro-aquaculture-livestock production systems and agroforestry would be needed to make most efficient use of available natural resources while protecting environment.

Expert systems will be needed for different new agro-management techniques needed because of climate change.

In the field of renewable energy, the World is witnessing a revolution. Development of high-output wind turbines, new photovoltaic technology and other techniques to harness solar energy, biofuels from non-food sources, and modern biogas generation technology are opening avenues for producing cheap and environment friendly energy. Techniques are being developed for smallholder farmers for harnessing solar energy for various field operations and post-harvest processing activities. All these efforts will greatly contribute to reducing carbon footprint of agriculture and contribute to mitigation of climate change.

Many of the issues raised above are going to be covered in the presentations scheduled later in this Conference.

The multiple challenges the world is facing in terms of climate change, degradation of ecosystems, and food and nutritional insecurity require an integrated approach. Food security requires agricultural production system to change in the direction of higher productivity and production. Agriculture and water are closely linked as nearly 70 % of all fresh water withdrawals in the world are used for agriculture. The agriculture sector has the capacity to offer sound solutions to cope with these challenges.

National strategy for adaptation to climate change

Adaptation depends up on the cooperation between line ministries, as well as specialized agencies like geological and meteorological services and institutions for disaster prevention. Broad stakeholder involvement is key to success. A national strategy can help to: (a) provide a framework for coordination of adaptation strategies; (b) create a vision for mid- to long-term perspective for adaptation; (c) enable informed decision making based on information about vulnerabilities, impacts and adaptation options; (d) raise awareness in all sectors affected; (e) mobilize support in the country as well as from the international community; and (f) prepare the ground for appropriate institutional structures for adaptation.

Coping mechanisms need to be developed in the developing countries which are most vulnerable to climate change. There will be need for modeling using modern computing science so that effects at local levels are realistically assessed. The way forward should involve assessment of climate change scenarios on regional and local level, navigating across the scales. Rapid transition to inter-sectorial thinking, institution building, planning and policy making will be needed for responsible sustainable agriculture covering crop production, horticulture, agroforestry, livestock production, aquaculture, fisheries, etc. Coping with uncertainty would call for increased investment in research and information systems. Sustainable agricultural development would require technical trained human resources supported by legislations, policies and needed funding.

Moving ahead

We need to work together as international body to enhance coping and adaptation capabilities. Such a global research system will optimize efforts and enhance synergies between the international and regional research systems and the national systems in the south. Resilience knowledge has to be the property of all humanity. The 'Haves' and 'Haves not' gulf has to be bridged to get peace, stability and prosperity. A shift of conscience on the part of the 'haves' and 'haves not', and a new understanding of oneness of humanity is the need of the day if the sustainable development goals have to be achieved in a time bound manner.

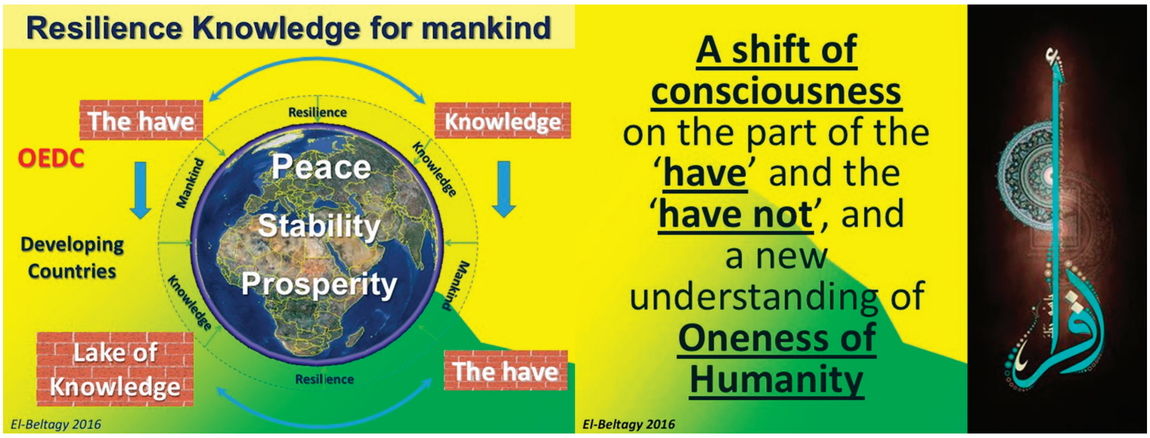

Figure 5. The way foreword new understanding of the oneness of humanity.

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Plenary Presentations

Plenary Session 1

1. Strengthening resilience and adaptive capacity of NENA dryland agricultural systems to climate change and related shocks: FAO contribution

Abdessalam Ould Ahmed, Pasquale Steduto and Fawzi Karajeh

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Abstract

Drylands ecosystems, typically characterized by conditions where mean annual precipitation is less than two thirds of potential evapotranspiration, have significant gaps in agricultural productivity and environmental services. With the expected rise in temperatures largely above 3°C by century's end, runoff decrease up to 40%, and the alarming trend of more frequent, intense and prolonged droughts during recent decades, NENA drylands will be among the world's most vulnerable ecosystems to climate change, uncertain variations, and related shocks.

There are various adaptation measures that can increase the resilience of these dryland ecosystems and associated livelihoods towards the anticipated negative impacts of climate change, drought and land degradation. Some of these can be based on improved natural resources management, combining land conservation and productivity enhancement practices, including conservation agriculture, rainwater harvesting, and sustainable agriculture intensification. Other measures are more market oriented, aiming at improving access to financial and non-financial services such as micro-credit, and business development services for small farmers and vulnerable communities. Given the wide variability and diversity of agro-ecological zones throughout the NENA Region, these measures need to be adequately designed, tailored, and applied according to specific local contexts and socio-economic realities. This paper therefore presents some of the major results achieved by FAO given its experience in strengthening resilience of dryland systems to climate change and related shocks in the NENA Region.

Keywords: Adaptation, Climate change, Resilience of agro-ecosystems, Conservation agriculture

Introduction

The Near East and North Africa (NENA) region (Figure 1) is categorized as drylands ecosystem, whereby annual precipitation is about 30% of potential evapotranspiration, thus characterized as the most water-scarce region in the world. Accordingly, in light of its shrinking finite natural resources, demographic pressure, urbanization expansion, vulnerable livelihoods, growing energy demand, and climate change impacts, these challenges necessitate the countries of the region to revisit their policies to ensure overall sustainable socio-economic development. Given these uncertainties, there is no doubt that, the path for sustainable development requires well-designed and more comprehensive technical, social, economic, and environment measures.

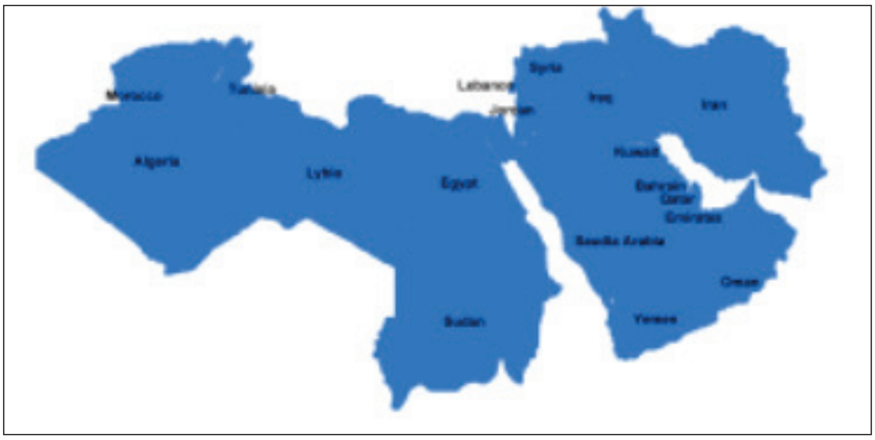


Figure 1. The Near East and North Africa (NENA) region map.

NENA is the only region where the overall hunger situation has deteriorated. The number of chronically undernourished in the region has doubled from 16.5 million people in 1990–1992 to 33 million people in 2014–2016. Cereals and other carbohydrate-rich foods account for the region's main source of dietary energy. Despite its high import dependency, the region has made considerable progress in stepping up its own supplies. Cereal production, for instance, gained 4.3 percent annual growth over the period 1994–2014. Yet, total food production consistently lagged behind total demand resulting in widening the supply-demand balance which resulted in growing imports at accelerating rates (Figure 2). As a result, this trend has positioned the NENA region as the largest net importer of cereals in the world, with over half of its cereal consumption originating from other regions (Figure 3). Notwithstanding the fact that the food import bill has been partially covered by a steady increase of exports of fruits and vegetables, the region's food import dependence is likely to increase further, as larger, more urban and more affluent populations drive up food consumption in general and high-end food items in particular.

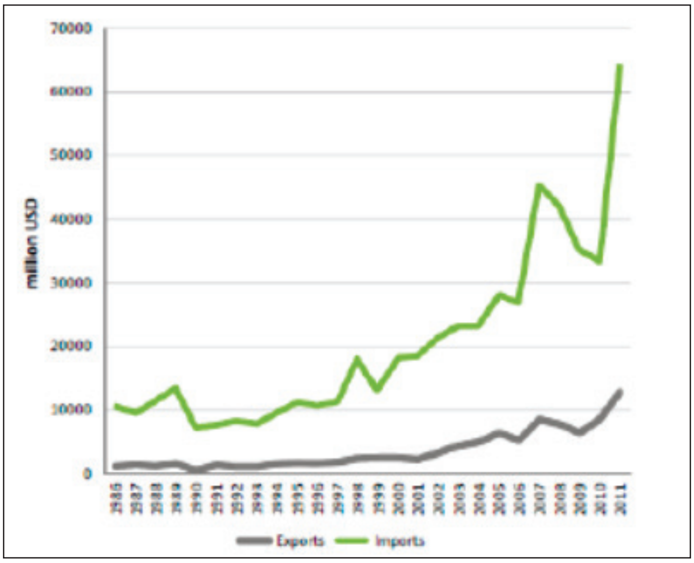


Figure 2. NENA's rising trade deficit for food and agricultural products.

Given the limits of growth towards further sustainable agricultural development in the NENA region imposed by natural resources capacity constraints, the region is expected to continue to be a major food importer. Accordingly, the primary question for the region is not to eliminate the food imports- which is not attainable as a strategic objective- but rather how can the region reduce or stabilize food imports by optimizing economic production from the limited available natural resources, while conserving healthy, productive communities, and ensuring environmental sustainability of the existing natural capital. In turn, strengthening resilience and adaptive capacity of NENA dryland agricultural systems towards climate variations and related shocks needs to be enhanced and prioritized to start immediately.

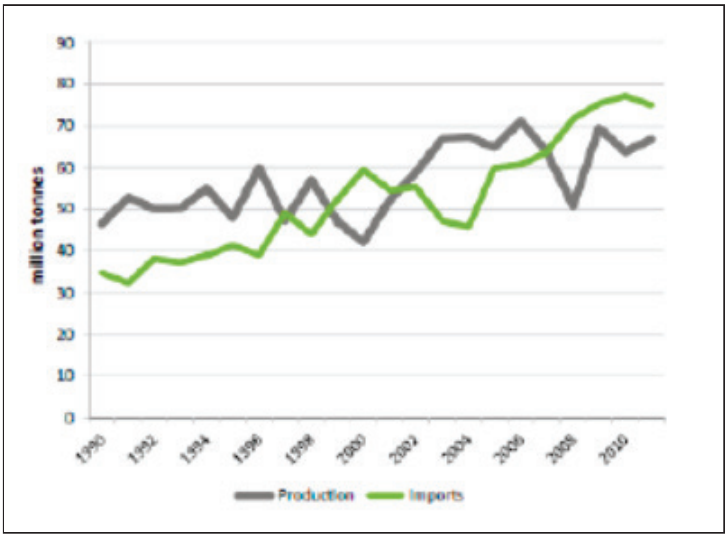


Figure 3. Evaluation of cereal production and imports in the NENA region.

Water and agriculture

In the NENA region, it is well known that per capita renewable water availability has decreased annually by over 1.3% over the last 50 years, currently reaching a level as low as 10 percent of the world average (609 m^3 compared to the world average of 6,080 m^3 per person per year, based on 2012 data). Per capita arable land availability is also the lowest in the world, representing only 20 percent of the world's average in 2013 (Figure 4). Furthermore, agriculture remains important in almost all countries of the region, and much of that agriculture has become market-oriented. However, rainfed farming systems still predominate in many countries and rainfed farmers face particular challenges of low productivity and unpredictable rainfall as a result of climate variations.

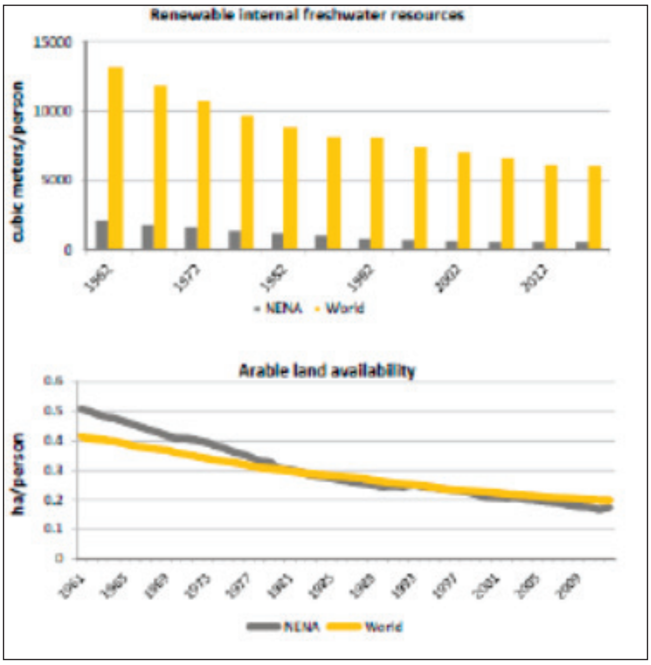
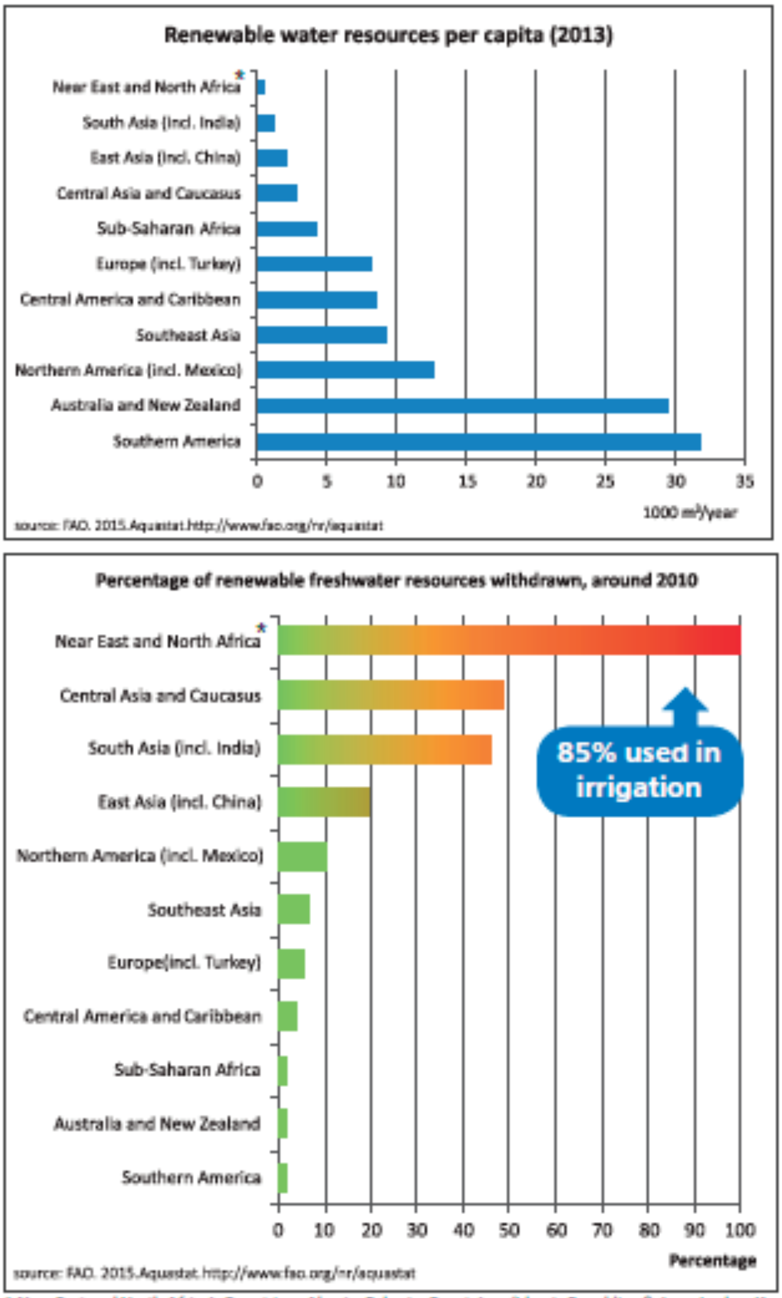


Figure 4. Land and water availability in NENA and the world.

Despite these factors, the region has heavily invested in irrigation over the last years, and has used a higher proportion of the available water resources compared to other region of the world. As a result, over 80 percent of the available fresh water resources on average are used by agriculture in the NENA region. Given the existing pressure on surface water resources, groundwater resources have become a significant source of irrigation across the region. As such, groundwater resources provide the basis for the rapid growth of new agricultural economies in the Arabian Peninsula, especially for the GCC countries totally dependent on underground water for irrigation. In the Mashreq countries, the proportion of irrigated land represents 43 percent of the total cropland, while the Maghreb countries are much less dependent on irrigation (7 to 18 percent), whereas Egypt is nearly 100 percent irrigated (Karajeh et al., 2013).

Several venues can be used in harmony to enhance the resilience of the agriculture production systems and livelihood to face the negative impact of climate change, drought and land degradation. These include technical options such as land and water conservation in the form of conservation agriculture, rainwater harvesting and use, improved irrigation interventions, and sustainable agriculture diversification and intensification; economic options to include market driven (micro-credit access), comparative advantages and demand- based agriculture production systems; social options (locality consumption, preference, and capacity); and environmental options to include land suitability, water quantity and quality, agroecological capacity.

With limited internal surface and underground water resources and the distressing level of water withdrawals (Figure 5), it is of paramount relevance that the countries of the NENA region strategically plan their water resources allocations and review their water, food-security and energy policies. A review accounting for the impact of climate change (particularly its extreme events) and ensuring policy alignment with the imperative of making the best use of each single drop of water is required. Moreover, risk reduction of drought and other climate-related hazards needs to be addressed and 'Drought Planning and Management' measures need to be incorporated at policy and institutional levels.



* Near East and North Africa's Countries : Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, West Bank and Gaza, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, Yemen.

Figure 5. NENA's renewable water resources per capita and total water withdrawals in relation to the other regions of the World.

To address these challenges, FAO has launched in 2013 the "*Regional Initiative on Water Scarcity" (WSI)*, providing as a first output the Regional Collaborative Strategy on Sustainable Agricultural Water Management in the Near East and North Africa Region. The Regional Collaborative Strategy represents a framework to assist countries in identifying and streamlining policies, governance, investments and practices that can sustainably improve agricultural productivity and food security in the region while at the same time helping in the achievement of the 2030 Sustainable Developed Goals SDGs.

Potential impacts of climate change

The potential impacts of climate change are already being observed to negatively influence agricultural productivity and production in some areas of the region. Some production areas will likely become warmer and drier, while others will receive more annual rainfall, although the timing of the additional precipitation might not be optimal from a seasonal crop production perspective (Roudier et al., 2011). Thus, regions such as NENA, where water supplies already are limited, will experience reductions in agricultural output in the coming seasons. A summary of the projected climate change impacts in NENA region are presented below:

- Climate models predict warmer temperatures and more variable rainfall for the region under global warming. Desertification and loss of productive land is expected to accelerate, while increasing extreme events (worldwide) - such as droughts and floods - could lead to food shortages and famines in several regions, which will affect food prices and the availability of some solutions such as virtual water.
- By the end of this century, the region is projected to experience an increase of 3°C to 5°C in mean temperatures and a 20% decline in precipitation (IPCC, 2007). Due to lower precipitation, water run-off is projected to drop by 20% to 30% in most of NENA by 2050.
- Reduced stream flow and groundwater recharge might lead to a reduction in water supply of 10% or greater by 2050.
- Underground water salinity will increase, more land degradation will occur in the region, and all aspects of biodiversity will be negatively affected
- Greater seasonal temperature variability.
- Significant sea level rise: the Mediterranean is predicted to rise between 30 cm and 1 meter by the end of the century—causing flooding to coastal areas along the Nile Delta (IPCC, 2007).
- Mediterranean biomes are expected to shift 300-500 km northward if a 1.5°C warming were to occur, which could mean that Mediterranean ecosystems (e.g. in Jordan) would become more desert-like.
- If temperature rise is not stopped, and particularly if it exceeds 2°C to 3°C, the IPCC warns that the world could face massive species extinctions, widespread starvation, declining production of crops.
- An increase in vector-borne diseases and pests, as well as mortality.
- Climate change, compounded by rapid population growth, threatens an increase in competition for water in the region.

- A study by Strzepek et al. (2001) found a propensity for lower Nile flows in 8 out of 8 climate scenarios, with impacts ranging from no change to a roughly 40% reduction in flows by 2025 to over 60% by 2050 in 3 of the flow scenarios used.

Despite the constant improvements in Global Climate Models (GCM), uncertainty remains associated with climate variability and social welfare. The scale of future GHG emissions, as well as the limited available scientific knowledge concerning the interactions of different components of the global climate system - will continue to limit the confidence with which predictions of future climate conditions can be made. However, uncertainty is no reason for inaction or delaying adaptation and mitigation measures. This is particularly relevant to the NENA region, where uncertainty of projected precipitation trends (decrease) are considerably lower than in other regions of the world, in addition to the widely recognized global warming trend.

Transformation change

Managing the limited and shrinking water, supply side has come to its critical suitability limit and from a technical rational dimension, the question is not about the desired level of agriculture production by the region, rather, it is about what level of agriculture production the region can sustainably afford. Regretfully the current levels of water availability and supply side of food production do not sufficiently reflect the complexities of this region in terms of its challenges of meeting the food demands. Governance, policies, and enforcement of such policies and regulations represent some of the critical constraints to manage water scarcity and ensure food security. Understanding which policies are needed requires better inter-ministerial efforts, deliberation, and coordination, particularly as it relates to adaptation, capacity building, and enhancement measures to absorb climate change impacts and resultant shocks. Therefore, the need is pressing to integrate climate change adaptation measures and shocks resistor into the government agencies in order to better align the decision-making processes to minimize risks in the path towards sustainable national development.

A prerequisite to identify the 'sustainable operational boundaries of water use' is to have a reliable 'water accounting' system that can (i) monitor supply, demand to include water recycling, safe use, and quality of water, (ii) provide present status and projected scenarios of these water variables and (iii) assess the institutional effectiveness to govern water resources. A sound application of the water accounting approach is the only way to demonstrate whether measures to increase water productivity remain or not within the sustainability boundaries, which represent the operational threshold.

Focusing on increasing agricultural water productivity, a few dimensions need to be considered including water delivery services in irrigated agriculture, on-farm agricultural practices, harvest and post-harvest handling and value chain, evolving innovative technologies, decentralized governance, gender, incentive frameworks for farmers to uptake improved technologies and practices, and plans for responsible investments.

A relevant module for the various projects components is represented by 'capacity development' for governmental staff, practitioners and engineers, extension-services professionals and farmers (through Farmers Field Schools, Farmers-to-Farmers visits, and travelling workshops to other agriculture areas within a county or to other countries within the region and elsewhere with similar agroecologies).

Adaptation measures

FAO has been working closely over the past years with the national agriculture systems and its member countries, as well as the different regional, and international interested entities to develop, evaluate, and scale up appropriate technical, socioeconomic, and policy adaptation measures to enhance the resilience and adaptive capacity of NENA dryland agricultural systems to climate change and related shocks. Promoted technical measures include land conservation such as conservation agriculture, land and water productivity enhancement practices including rainwater harvesting, improved irrigation performance, sustainable agriculture diversification and intensification, taking into consideration the best growing system calendar.

It should be noted, however, that crop varieties grown today might not produce sufficient yields given the anticipated future climate variations. Therefore, better adapted, more stress-tolerant and efficient water use varieties, and new crops and cropping patterns are critically needed to drive stronger agriculture growth. In this respect, rainwater harvesting is a technique to improve water productivity by the collection of rainwater runoff for on-site (micro catchments) or off site in a pond or reservoir to serve one or community of farmers (macro catchment). The system is more than engineering design and construction; it involves management and management of the collection and distributing systems. Water harvesting is an old practice and can improve agriculture productivity, if well managed, by more than 300% compared to traditional rainfed agriculture. Reports indicate that reduction of 50% in the seasonal rainfall, for example, may result in a total crop failure. If, water harvesting is practiced, reasonable yields will still be received. One common technique is to use harvested water as a supplemental irrigation, where one or two irrigation events at critical crop growing period are applied to boost the crop yield substantially.

Achieving these objectives requires developing a comprehensive reform agenda. Accumulated experience and established best practices suggest that such an agenda requires several policy measures including the following elements: an inclusive analytical process to study and debate accurate information on water availability and use to reach a national consensus on water allocation and policy; a solid governance framework with well-designed and progressive institutions that have clear authority, as well as accountability mechanisms and adequate capacities and resources. These policy priorities, therefore define the scope for regional collaboration to address the water and climate change challenges in the NENA region especially through knowledge exchange, South-South Cooperation, dissemination of best practices and joint research and development programs. Areas for regional collaboration include agriculture water productivity, governance and institutions including water users association, integrated water resource management, groundwater governance, use of unconventional water resources, climate change and droughts management.

On the socioeconomic front, improvements in market access and crop insurance programs have enabled and encouraged farmers to make better use of land and water resources (Kassie et al., 2015). Outreach efforts, such as farm extension or farm advisor programs, farmers' organizations and farmer training programs have enhanced the capacity of many small-scale farms to implement advances in production technology and to enhance their participation in input and output markets (Dethier and Effenberger, 2012); a good example in this respect is contract farming schemes. Flexibility in water delivery system, even at a well calculated incentive-based water valuation system, is helpful in communicating water scarcity conditions and motivating water users to generate substantial value with their allocations of the limited resource. Public support for investments in land leveling and irrigation method/system improvement can be helpful in achieving improved land and water productivity.

On the policy front, conventional policy-making using a sectorial approach has proven not to work; enabling policy formulation to support sustainable and profitable farming production system should be coordinated within the framework of the 17 Sustainable Development Goals by 2030. Most of the countries in the region have had a long history of subsidizing energy, water, and food prices for different reasons; an approach that is no longer sustainable and that urgently needs to change. The region should therefore start building an active partnership among the countries in the region and beyond in which abundant sustainable natural resources outside the region can provide a strategic base for agriculture production systems reservoirs for the benefit the people of the region to get what they need at cheaper economic and environmental costs with better socioeconomic and environmental services return.

As such, FAO is working with member of countries to improve strategic plans, water and food-security and energy policies to account for the impact of climate change (particularly its extreme events). Furthermore, Climate Smart Agriculture, a FAO program, is established to promote production systems that sustainably increase productivity, promote resilience or adaptation, mitigate the effect of greenhouse gases, and enhance achievement of national food security and development goals within the NENA region and beyond.

The new global context: SDGs and their relation with water and food

The recently established 17 Sustainable Development Goals offer a vision towards a fairer, more prosperous, peaceful and sustainable world in which no one is left behind. As it relates to food - the way it is grown, produced, consumed, traded, transported, stored and marketed - the fundamental connection is established between people and the planet, and the path to inclusive and sustainable economic growth is mandatory. Accordingly, without rapid progress in reducing and eliminating hunger and malnutrition by 2030, the full range of Sustainable Development Goals cannot be achieved. At the same time, reaching the other SDGs will pave the way for ending hunger and extreme poverty.

Given that by 2025, 1.8 billion people are projected to be living in countries or regions with absolute water scarcity, two out of the 17 proposed Sustainable Development Goals are directly linked to food and water security. In particular, SDG 2 calls for ending hunger, achieving food security, and improving nutrition, while promoting sustainable agriculture. SDG 6 calls for ensuring availability and sustainable management of water and sanitation for all.

In this respect, the region will advance faster if stakeholders work together and effective partnerships are formulated. The battle to end hunger and poverty must be principally fought in rural areas, where almost 80 percent of the world's hungry and poor live. To achieve this objective, there is a need to demonstrate a strong political will while also investing in the critical agents of change – smallholders, family farmers, rural women, fisher folk, indigenous communities, youth and other vulnerable or marginalized people. It is possible to eradicate hunger by 2030. This requires a combination of pro-poor investments in sustainable agriculture and rural development and social protection measures to immediately lift people out of chronic undernourishment and poverty. There are more people to feed with less water, farmland and biodiversity. But the world produces enough food for all. We need to transform the current input-heavy food systems to make them more sustainable – including reducing food waste and loss – through better management and improved techniques in agriculture, livestock, fisheries and forestry. Agriculture also has a major role to play in combating desertification and other negative impacts of climate change. With its expertise and resources, FAO is striving to support countries in achieving the Sustainable Development Goals.

To this end, it is essential that the regional and international research communities continue to generate global public goods to enhance resilience to climate vulnerability for better food and security and healthy agroecosystems.

Conclusion

The NENA dryland ecosystem is situated in one of the most water-scarce regions of the world. Yet, despite these natural limitations, the region will continue to have agriculture as an important sector while being simultaneously a major food importer globally. This is primarily due to several factors such as the limited and shrinking natural resource base, climate variations and uncertainties including the anticipated climate change negative impacts, growing food demand, high demographic pressure, urbanization expansion, improved livelihood, energy demand, and overall socio-economic development.

To enhance the resilience and adaptive capacity of NENA dryland agricultural systems to climate change and related shocks, FAO has launched in 2013 the "*Regional Initiative on Water Scarcity" (WSI)*, providing as a first output the Regional Collaborative Strategy on Sustainable Agricultural Water Management in the Near East and North Africa Region. The Regional Collaborative Strategy represents a framework to assist countries in identifying and streamlining policies, governance, investments and practices that can sustainably improve agricultural productivity and food security in the region and at the same time helping the achievement of the 2030 Sustainable Developed Goals (SDGs). Moreover, FAO is working closely with the national agriculture systems of its member countries, and regional, and international interested entities to develop, evaluate, and scaling out appropriate technical, socioeconomic, and policy adaptation measures. The region strategically has to plan its water resources allocations and review its water, food-security and energy policies.

To this end, inter-institutional policy coordination and harmonization need to be improved whereby regional strategies must be translated into realistic, concrete, and achievable actions plans. Partnerships and linkages between stakeholders (farmers, extension services, ministries, researchers and private sector) at national and local levels are to be stimulated in order to ensure that technical, financial and human resources are directed to strengthening resilience and adaptive capacity of NENA dryland agricultural systems to climate change and related shocks. These are the pre-requisites for strengthening resilience and adaptive capacity of NENA dryland agricultural systems to climate change and related shocks based on FAO's experience.

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2. Innovating sustainable land management for dryland development toward the Post 2015 World

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Abstract

At the United Nations Sustainable Development Summit on 25 September 2015, more than 150 world leaders adopted the new 2030 Agenda for Sustainable Development, including the Sustainable Development Goals (SDGs). With respect to dryland development, the SDG target #15.3 states: "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world". Sustainable Land Management (SLM) plays an essential role in achieving a land degradation-neutral world. SLM is defined as a knowledge-based combination of technologies, policies and practices that integrate land, water, biodiversity, and environmental concerns to meet rising food and fiber demands while sustaining ecosystem services and livelihoods. By exploring traditional knowledge and reevaluating indigenous technologies which have been refined over many generations in the region, or developing new appropriate technologies, a variety of SLM technologies are now available. However, we have noticed that there are still challenges in the current SLM to be solved. First, to prevent land degradation and restore degraded land, the soil and water conservation measures should be improved further. Second, effective and efficient SLM approaches, which are defined as the ways and means used to promote and implement SLM technologies and to support them in achieving widespread SLM, should be established. Third, SLM projects should be linked with socio-economic empowerment of local people, to improve their livelihood and assist the socially vulnerable. By innovating SLM through development of eco-friendly and profitable technologies, we must achieve a land degradation-neutral world.

Keywords: Sustainable Development Goals, Sustainable Land Management, Traditional knowledge, Land degradation, Socio-economic empowerment

1. Introduction

At the United Nations Sustainable Development Summit on 25 September 2015, more than 150 world leaders adopted the new 2030 Agenda for Sustainable Development, including the Sustainable Development Goals (SDGs). SDGs are the successor of Millennium Development Goals, which had targeted 2015. There are 17 Goals and 169 targets under these goals. With respect to dryland development, the SDG target #15.3 states: "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world". The definition of land degradation neutrality was decided in the UNCCD/COP12, held in Ankara, Turkey, from Oct 12 to 23, 2015. Land Degradation Neutrality is "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems".

2. Sustainable Land Management (SLM)

Sustainable Land Management (SLM) plays an essential role in achieving a land degradation-neutral world. SLM is defined as a knowledge-based combination of technologies, policies and practices that integrate land, water, biodiversity, and environmental concerns to meet rising food and fiber demands while sustaining ecosystem services and livelihoods (Liniger *et al.,* 2011). Thus, SLM covers not only physical land issues, but also includes other issues such as biodiversity, environment, and people's livelihood and welfare.

SLM has two components, one is technology, and another is approach. Different SLM technologies are used depending on the land use. For cropland, residue retention, mulching, and application of manure and compost are used. For pastoral land, technologies such as reducing stocking rates and adopting controlled grazing can be used. For plantation crops and forestry, enhancing resilience against drought and supplemental irrigation can be used as SLM technologies. On the other hand, an SLM approach defines the ways and means used to promote and implement a SLM technology and to support it in achieving better and more widespread SLM. It is said that SLM approaches have been changing from top-down interventions to farmer-first approach, and from one purpose project to trans-disciplinary approach.

3. SLM in Ethiopia

We are now conducting a research project in Ethiopia supported by the Science and Technology Research Partnership for Sustainable Development (SATREPS) program. The title is "Development of next-generation Sustainable Land Management (SLM) framework to combat desertification". In the SATREPS projects, international joint research on global issues, among research institutions in developing countries and Japan is promoted by Ministry of Foreign Affairs (MOFA) and JICA and Ministry of Education, Culture, Sports, Science and Technology (MEXT) in collaboration. Thus, the project is linking diplomacy and science and technology policy.

Our study area is located in the upper Blue Nile basin, Ethiopia. Figure 1 shows the soil erosion rate in Africa, and red color shows severe water erosion. As shown in Figure 1, the upper Blue Nile basin is one of the areas most severely affected of water erosion. Soil erosion is one of the most important socioeconomic and environmental issues in Ethiopia. Soil erosion there has two different effects. One is onsite effect, for example, land destruction by gully and decrease in soil fertility by sheet erosion. The other is offsite effect, for example, soil is eroded at farmlands, then the sediment comes through river polluting water and settling in the dam decreasing its function.

To tackle those problems, soil and water conservation (SWC) measures are being introduced in Ethiopia such as construction of stone bunds and trenches. These measures are being introduced by SLM projects (Haregeweyn *et al.,* 2015). There are a number of SLM projects being carried out in Ethiopia. However, there was no scientific evaluation of effect of the measures taken under these projects in the past. Thus, we started from basic research to provide scientific evaluation about the effects of those measures.

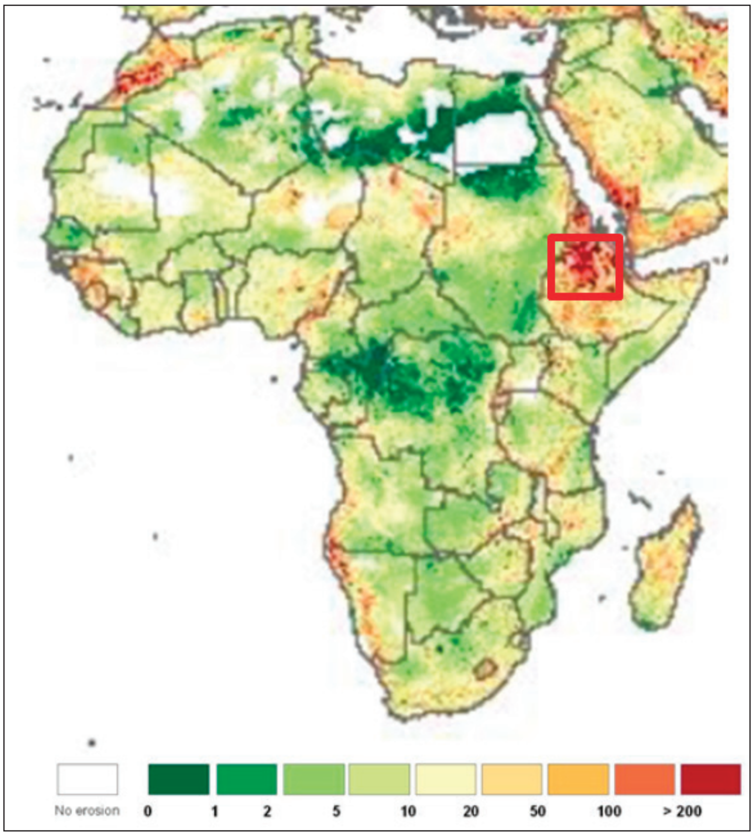

Figure 1. Soil erosion rate estimated using USLE model (Nachteragaele et al., 2011) and the location of the upper Blue Nile basin shown by red line.

We selected three sets of paired-watersheds; one watershed of the pair was treated with soil and water conservation (SWC) measures, while the other received no such measures. We also set experimental plots in these watershed for measuring runoff and sediment yield at both watershed and plot level. A total of 18 experimental runoff plots (30 m long × 6 m wide, bounded at the sides and top) were established in May 2014. Plots were characterized by land use, slope, and SWC treatment, which required them to be located in seven separated groups (land-use land classes; LULCs) within the watershed. The five land-use types comprised cultivated land (CL) planted with potatoes (*Solanum tuberosum)* and faba beans (*Vicia faba*), and four non-agricultural (uncultivated) land uses: grassland (GR), *Acacia decurrens* (AD), *Eucalyptus* spp. plantation (EP), and degraded bush land (DB) (Figure 2).

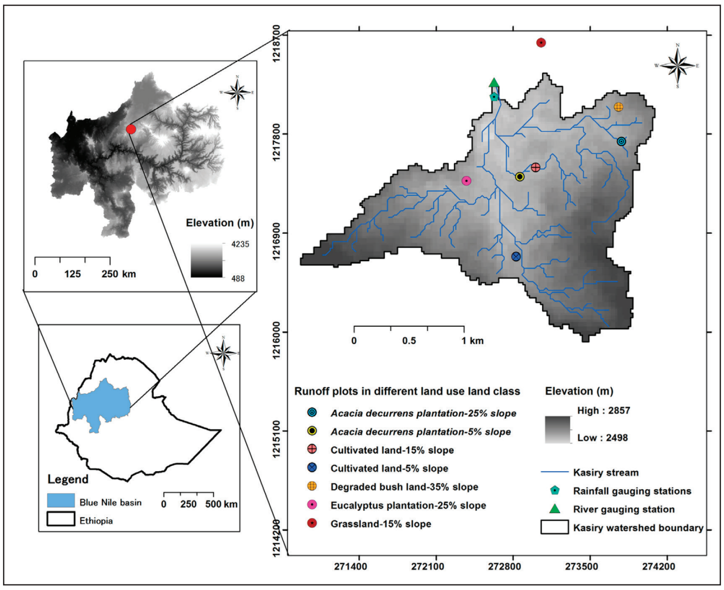

Figure 2. Location of Kasiry watershed in the upper Blue Nile basin, where 18 runoff plots representing different land-use/land-cover (LULC) classes and slopes were established (Map projection is UTM, WGS 1984 zone 37 N). Source: Sultan *et al*. (2017).

Incorporating the SWC technique of trenches aligned normal to the slope significantly contributed to the conservation effect of vegetation on the runoff process in the non-cultivated plots. Trenches reduced runoff and the runoff coefficient (RC) by 65 and 61%, respectively, as compared to untreated control (i.e. conventional practice) plots. For all the non-agricultural plots, RCs were clearly higher on control plots without SWC structures (0.11–0.33) than on the plots with trenches (0.05–0.1) (Figure 3). The effect of slope on RC in the AD plots was the reverse of what would be expected, with a lower RC on the plots with the steeper slope gradient (Figure 3).

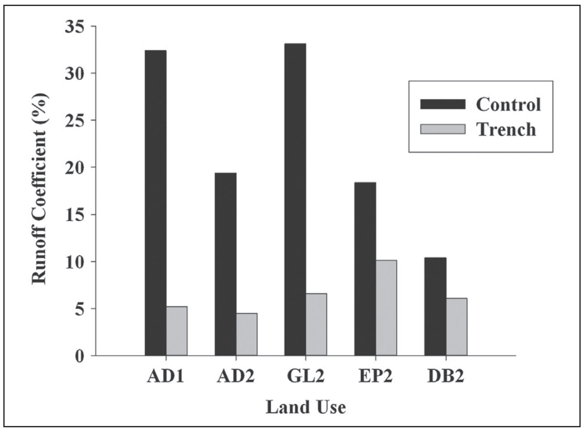

Figure 3. Runoff coefficients from plots of different land-use and slope class with and without trenches. AD is Acacia decurrens, EP is eucalyptus forest, GL is grassland, and DB is degraded bush land; 1 indicates gentle slope, 2 indicates steep slope. Source: Sultan *et al*. (2017).

The above results clearly show the effects of soil and water conservation measures. They can significantly reduce soil erosion for the target watershed. The question then arises as to how can farmers introduce SLM measures in their village? In the experimental sites, we made soil bunds and trenches. In SLM projects, farmers are forced to participate in the project, and they have to work without payment. This is leading to unsustainability of the project, because some farmers are not willing to get involved in SLM projects.

Table 1. Features of the next generation SLM

	Current SLM	**Next generation SLM**
Agricultural production system	Traditional cultivation linked system dependent on free grazing. Large amount of soil erosion and low productivity	For reducing soil erosion and improving productivity, implementation of a new cultivation linked with stall-feeding system
Form of farmers' participation	In most of the cases, legally forced participation and unpaid work	Voluntary participation of farmers through economic incentives
Main purpose	Reduction of soil erosion	In addition to reduction of soil erosion, improving land productivity, livelihood, and economic and social empowerment
Implementation method	Top down implementation of the project by the administration	Setup a committee where diverse stakeholders participate, and take participatory approach
Problems and issues	Insufficient soil erosion reduction benefits Lack of sustainability and autonomy	Developing elemental technology (SLM technology) and methods for upscaling it (SLM approach)

Based on our experiments and experience so far, we are now proposing the framework of next generation SLM in the SATREPS project (Table 1). In the current SLM, the main purpose is reduction of soil erosion, and in most of cases, the SLM projects are supported by legally forced participation and unpaid work. In the next generation SLM, we should think also of the benefit that farmers can directly get from adopting these measures. SLM projects should aim at voluntary participation by farmers. Thus, in addition to preventing soil erosion, the project aim should include improvement of livelihood and economic and social empowerment of the farmers. Therefore, we have to develop elemental technology (SLM technology) and methods for up-scaling it (SLM approach) together.

4. Conclusions

By exploring traditional knowledge and reevaluating indigenous technologies, which have been refined over many generations in the region, or developing new appropriate technologies, a variety of SLM technologies are now available. However, we have noticed that there are still challenges in the current SLM to be overcome. First, to prevent land degradation and restore degraded land, the soil and water conservation measures should be improved further. Second, effective and efficient SLM approaches, which are defined as the ways and means used to promote and implement SLM technologies and to support them in achieving widespread SLM, should be established. Third, SLM projects should be linked with socio-economic empowerment of local people, to improve their livelihood and assist the socially vulnerable. By innovating SLM through development of eco-friendly and profitable technologies, we must achieve a land degradation-neutral world.

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3. Oasis and oasification in China

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Abstract

Oasis is a kind of geographic landscape suitable for plant growth and sustaining human life, supported by stable water resources in desert regions; and it is obviously different from desert landscape. Oasification is the process of desert transforming toward oasis (usually named artificial oasis), including expansion of oasis size and optimization process of oasis ecosystem structure and function, due to the interventions of human beings and the natural factors. According to monitoring and evaluation data, the total area of oases in the arid region of northwest China in 2010 was about 210,000 km2. Among this, the area of oasified lands (or artificial oases) expanded to 110,000 km2 from 25,000 km2 of the late 1950s. Although oases and oasified lands, with their scattered distribution, only accounts for about 7% of the total area of the arid region, these are the core areas in the arid areas of China where 27 million people live and engage in production activities, and are also considered as the foundation of the development in the northwest region. Oasification is a process of natural ecosystem promoted to artificial ecosystem through human activities, but low-level and disorderly exploitation also can decline oasis stability and make oasis degradation. With the reduction or loss of the oasis productivity, unreasonable exploitation of oasis also brings about a series of ecological environment problems, such as rivers cutoff, lakes shrinking, vegetation degradation, soil erosion, etc. Therefore, it is necessary to fully understand the hydrological, soil, air and plant processes of oases and oasification and their interaction in the context of human activities and climate change, to reveal the oasification characteristics and their spatial-temporal pattern evolution, process and driving mechanism, in order to provide the scientific basis for establishing the regulation and management modes of oasification. Through systematic research, we reconstructed landscape pattern change of land use/cover in past 50 years in the arid areas of China, and developed the spatial-temporal evolution rules of oasification in the study area and its variation characteristics associated with key impact factors. We studied water, energy transfer and transformation, and their interaction mechanism in the process of radiation-water-soil-vegetation interaction about oasification, and established the feedback and response models among water, soil, air and plants. Especially in the middle and lower reaches of Heihe River Basin, hydrological process of oasification was studied, the interaction mechanism of water and vegetation in desert ecosystem, and the relationships between hydrological and ecological process at different scales were identified. The distributed watershed hydrological models suitable for arid regions of China were established, and the watershed hydrological variable threshold was determined aiming at oasification. The distinguishing methods of human activities and climate fluctuation affecting oasification were put forward and the quantitative analysis model was established. It was found out that the influence of human activities in the oasification process accounted for over 85%. The research framework and analysis methods of oasification trend were put forward and the prediction model was built, and the change trend of oasification in the next 20 to 30 years was analyzed. The decision support system to regulate the relationship between human and earth was established, and the ways of investment to regulate the human-earth system was recommended. The regional target balance method among ecology, economy and environment was established, and the optimization goal of the coordinated development between ecological environment and social economy, and evaluation indicators of objective compatibility degree and balance method was put forward. The final oasis stabilization and oasification regulation regionalization map was completed.

Keywords: Oasis stability, Feedback model, Hydrological processes, Ecological processes, Decision support system, Human-Earth relationship.

Plenary Session 2

1. The contribution of innovative agricultural research to the sustainable development goals (SDGs) in dry areas

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Abstract

In contributing to the Sustainable Develop Goals (SDGs) in dry areas, ICARDA over the last 39 years has taken an integrated pragmatic approach in providing solutions to the challenges facing sustainable agricultural development in production systems - rainfed and irrigated agriculture as well as the agro-pastoral systems. This has been through technological improvements to enhance in the way natural resources are managed within the context of agri-food production systems; the conservation and utilization of genetic resources of key staple commodities and the introduction of desirable traits that improve the quantity, quality and efficiency of food production systems This has contributed to the development sustainable livelihood systems for rural communities. Through its collaborative research and technology transfer with national partners, examples on the ground are presented in the paper to demonstrate how to contribute to the eight SDGs below. Different strategies are used to achieve these goals in different agro-ecologies. These include sustainable intensification in high potential areas and to achieve resilient production systems in marginal lands of the non-tropical dry areas. ICARDA's collaborative research with national partners contributes mainly to the following SDGs: SDG 1, No Poverty: End poverty in all its forms everywhere; SDG 2, Zero Hunger: End hunger, achieve food security and improved nutrition and promote sustainable agriculture; SDG 4, Quality Education: Ensure inclusive and quality education and promote lifelong learning; SDG 5, Gender Equality: Achieve gender equality and empower all women and girls; SDG 8 Decent Work and Economic Growth: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; SDG 13, Climate Action: Take urgent action to combat climate change and its impacts; SDG 15, Use on land: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss; SDG 17, Partnerships for the Goals: Revitalize the global partnership for sustainable development.

Keywords: Collaborative research, ICARDA, Sustainable intensification of agriculture, SDGs

Introduction

The vast areas of non-tropical dry lands have been the home of the International Center for Agricultural Research in Dry Areas (ICARDA) since 1977. ICARDA has been working for almost 40 years to contribute to enhancing food security and improve livelihoods of farming communities in the drylands through agricultural research and capacity development. The Center contributed greatly to achieving the Strategic Development Goals (SDGs) in dry areas in close partnership with the National Agricultural Research Systems (NARS) of collaborating countries. Trust generated over decades with these countries provided ICARDA with the opportunity to play the role of honest broker across most of the non-tropical dry areas particularly in Central and West Asia, North and Eastern Africa and South Asia.

In addition to the negative implications of climate change, the current food insecurity and high level of unemployment in many of these countries are key challenges facing communities and their governments. Thus, more investment is very much required to achieve the SDGs to solve major challenges, particularly in drylands.

Science and advanced technologies are essential to ensure sustainable agricultural and economic development to achieve the SDGs in drylands. Therefore, the impact of agricultural research for development is critical for sustainable development particularly in rural areas where poverty prevails.

For the past four decades, ICARDA has followed an integrated approach for sustainable agriculture development to achieve the SDG goals with its national, regional, and other advanced research institutions.

In contributing to the SDGs in dry areas, ICARDA's collaborative development research has taken an integrated pragmatic approach in providing solutions to the challenges facing sustainable agricultural development in production systems in three major agro-ecologies: rainfed production systems, irrigated agriculture and the agro-pastoral systems in marginal lands or low rainfall areas. This has been achieved through technological improvements to enhance the way natural resources are managed and ensure they are being used in a sustainable manner within the context of agri-food production systems. The conservation and utilization of genetic resources of key staple commodities and the introduction of desirable traits can improve the quantity, quality and efficiency of food production systems. Through its collaborative research and technology transfer with national partners examples on the ground are presented later to demonstrate how they contribute to the eight SDGs below.

Different strategies are used to achieve these goals in different agro-ecologies. These include sustainable intensification and diversification of production systems in high potential areas and the development of resilient production systems in marginal lands of the non-tropical dry areas. ICARDA's collaborative research with national partners contributes mainly to the following SDGs:

- SDG 1: No Poverty: Ending poverty in all its forms everywhere
- SDG 2: Zero Hunger: Ending hunger, achieve food security and improved nutrition and promote sustainable agriculture
- SDG 4: Promoting Quality Education: Ensure inclusive and quality education and promote lifelong learning
- SDG 5: Gender Equality: Achieve gender equality and empower all women and girls
- SDG 8: Decent Work and Economic Growth: Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

- SDG 13: Climate Action: Take urgent action to combat climate change and its impacts through adaptation, mitigation and resilient production systems;
- SDG 15: Use on land: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss
- SDG 17: Partnerships for the Goals: Revitalize the global partnership for sustainable development and developing networking.

The paper provides concrete examples on the contribution of collaborative agricultural research to achieving the SDG goals mentioned above in well targeted pilot areas. Experience and efficiency of systems will go a long way to upscale and replicate our successes for large scale impact on SDGs. We currently have many new scientific tools available such as fast computers, satellite sensors, geographic positioning system (GPS), geographic information system (GIS), and remote sensing to develop agro-ecologically similarity maps, expert systems to support technology dissemination and decision-support models to name a few. These should be used along with new training and education programs to tackle the new challenges to achieve the SDGs. In particular, we need to encourage young scientist to devote their energy and intelligence to innovative agricultural research.

ICARDA's mission and mandate

ICARDA is an international agricultural research center whose activities are coordinated by the CGIAR. The strategic goals of the CGIAR and ICARDA are 1) reducing rural poverty; 2) improving food security; 3) improving nutrition and health; and 4) sustainable management of natural resources. ICARDA's vision is improved livelihoods of the resource-poor in dry areas; and its mission is to achieve its vision by enhancing food security and reducing poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient, more equitable use, and conservation of natural resources.

Technically ICARDA's mandate focuses on the following thematic research areas: Conservation of Agricultural Biodiversity; Crop Improvement; Agronomy; Integrated Water & Land Management; Livestock Productivity & Rangelands Management; Land Degradation & Desertification; and Socio-economics, Policy, Markets and Institutions. ICARDA's focus on crosscutting areas includes adaptation to climate change; Capacity Development; and Gender equity. Geographically, ICARDA's mandate covers non-tropical dry areas around the world with focus on collaboration with developing countries in these areas. This includes the Middle East and North Africa (MENA) Region; Sub Saharan Africa with focus on Eastern Africa; Central and West Asia.

Contribution of innovative research to SDGs in dry areas

Figure 1 presents ICARDA's relevant goals along with thematic collaborative research areas and cross cutting activities that contribute directly towards the achievement of eight sustainable development goals (SDGs). The achievement of specific collaborative research activities to these SDGs will be presented in clear examples.

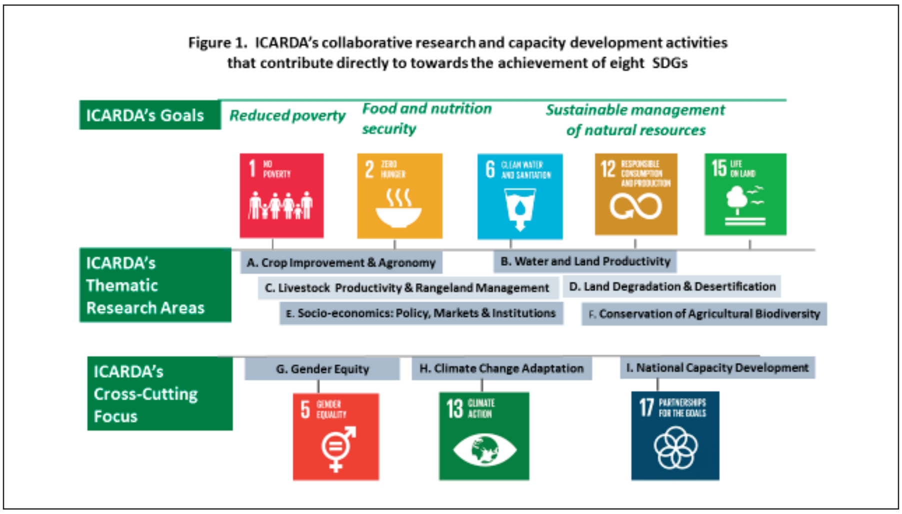

Figure 1. Contribution of ICARDA activities to SDGs.

Contribution of innovative research on crop improvement and agronomy to SDG 1 (Reduced Poverty) and SDG 2 (Food and Nutritional Security)

Agricultural productivity in most of the developing countries in the dry areas is below the global average because of technical, socio-economic and policy constraints. However, improving technology through technology transfer and appropriate input management would bridge the yield gap between the farmer's actual yield levels and potential yields. This has clearly shown great potential to enhance agricultural productivity in rural areas. Figure 2 shows the yield gap between actual farmers' yields and the potential in wheat production in several countries in the Middle East and North Africa.

A project on Enhancing Food Security in Arab Countries involving Egypt, Morocco, Jordan, Palestine, Sudan, Syria, Tunisia and Yemen, focused on whole wheat-producing provinces, has resulted in substantial increases in wheat productivity by using improved production package including improved wheat varieties resistant/tolerant to drought, heat, and virulent pests and diseases. Increasing wheat production was achieved not only by introducing improved wheat varieties but also with improved soil fertility, water and crop management packages to improve the sustainable use of resources and maximize yield gains. An average yield over six seasons (2010-2011 to 2015-2016) ranged from 12% under a supplemental irrigation in Syria to 59 % under irrigation in the Sudan with an overall mean average increase of 20% across all countries (Table 1). With respect to the maximum increase in wheat productivity, this ranged from 42%

under rainfed conditions in Palestine and 124% under irrigation in Sudan with an overall average of 70% across all countries. Financial gains were also notable: wheat supply increased in Egypt from 557,030 tons in 2009-2010 season to 880,941 tons in 2013-2014 (a 58% increase), the annual value of which is estimated to be 52.2 million US dollars. The outcome of wheat productivity in four years is presented in Table 1.

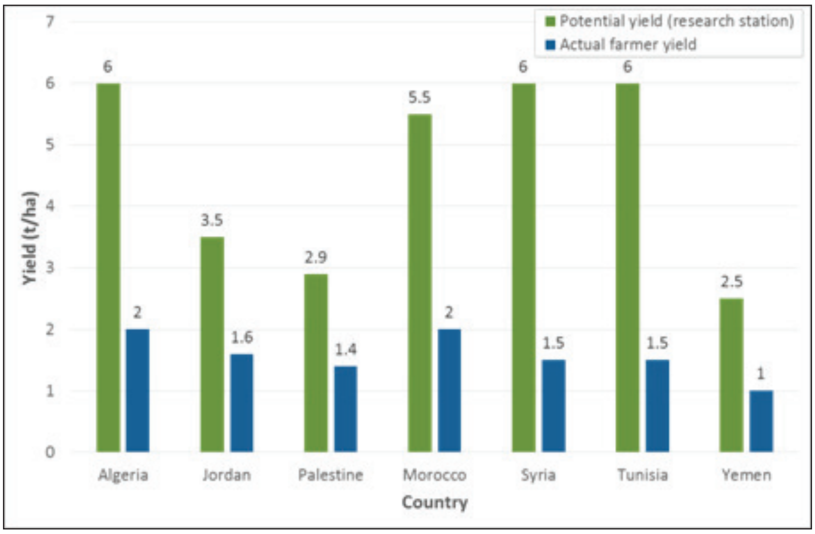

Figure 2. Yield gap in wheat in various Arab countries.

The increase in wheat productivity at the provincial level in the different participating countries was based on effective collaboration among researchers, extension agents and farmers. Farmers' keen interest in participating in farmers' field schools, farmers' field days and on-farm demonstrations was clearly reflected in a high adoption rate of various improved technologies to increase their productivity, reduce their production cost and, consequently, increase their income and improve livelihoods in rural areas. The outcome of the Project at provincial level contributed greatly to enhancing food security and improving livelihoods to reduce poverty in rural areas.

The other example of large-scale impact of innovative agricultural research on food security and improving livelihoods is the Support Agricultural Research for Development Project for Strategic Crops (SARD-SC) in Sub-Saharan African (SSA) countries in which the Wheat Component is implemented by ICARDA in collaboration with national programs. The Project involved 12 target countries: 3 hubs: Ethiopia, Nigeria, Sudan and 9 partner countries namely Eritrea, Kenya, Lesotho, Mali, Mauritania, Niger, Tanzania, Zambia, and Zimbabwe. It covers two major agro-ecologies: warm areas (lowlands) and cool areas (highlands). The three project hub countries are platforms for technology testing, validation dissemination and serve as spring board for transferring best-fitted technologies to "partner" countries. The Project has three components: 1. Technology Generation; 2. Technologies Dissemination through Innovative Platforms (IPs); and 3. Capacity Development.

Table 1. Grain wheat yield (t/ha) obtained in the demonstration fields versus farmers' fields (average of 2010-2011-2015-2016 seasons, courtesy of Dr. Habib Halila, ICARDA)

Country	Egypt	Iraq ****	Jordan *	Morocco		Palestine ***	Sudan	Syria		Tunisia		Yemen **	Overall mean
Production system *****	I	I	R	R	SI	R	I	R	SI	R	SI	SI	
Participating Farmers	8.51	5.50	2.52	3.63	6.56	2.48	3.89	2.33	5.40	3.14	5.35	3.36	4.39
Non-Participating Farmers	6.87	4.30	2.03	3.17	5.20	2.09	2.44	1.75	4.84	2.49	4.11	2.31	3.47
Average increase (%)	24	28	24	15	26	19	59	33	12	26	30	45	28
Maximum yield	10.29	6.20	3.64	5.15	7.98	2.97	5.48	3.23	7.39	4.40	7.39	4.53	5.72
Potential max increase %	50	44	79	63	53	42	124	84	53	76	80	96	70

* Av of 2012-2016 seasons; ** Av of 2013-2016 seasons; *** Av of 2014-2016 seasons; **** Av of 2016 season; *****Farming Systems: R- rainfed, SI-supplemental irrigation, I- irrigated

Achievements of the Project in last three years (up to 2015-2016) in the first Component, Technology Generation, include the release of 15 varieties with production packages in the three hub countries. The varieties were highly adapted to the hub countries, with heat tolerance, good seed quality, disease resistance and average yields of 5-7t/ha compared to about 2 t/ha general average (Figure 3). In Partner countries 15 varieties were released in 2014 and 2015 that were highly adapted to these countries, having good seed quality, disease resistance and stress tolerance with yields of 4-7t/ha.

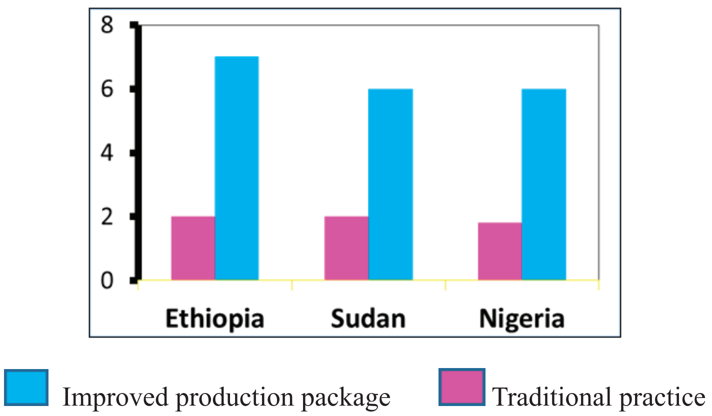

Figure 3. Wheat productivity (tons/ha) of farmers' traditional production package and improved production package averaged in two seasons in the three major hubs'in Ethiopia, Nigeria and Sudan (courtesy of Dr. Solomon Assefa, ICARDA - Tunisia).

In the second component, Technology Dissemination, results from technology demonstrations across the 26 IP sites in the three hub and partner countries revealed that farmers in the IP sites increased their wheat productivity from the current average yield of 1-2t/ha to more than 4-7t/ha (Figure 4). The following are the number of farmers participating in these platforms: Sudan: 6 IP sites, 3124 farmers; Nigeria: 6 IP sites, 5000 farmers; and Ethiopia: 6 IP sites, 3005 farmers. About 21% of the above IP participants were women.

Interventions through SARD-SC Wheat Component at the IP sites of hub countries indicated that the potential impact on household wheat income could be significantly raised, ranging from 204%-380%, thus improving livelihoods of wheat farmers.

In Ethiopia, investment in agricultural research for development and technology transfer in food legumes in collaboration between the Ethiopian Institute for Agricultural Research and ICARDA resulted in tripling lentil production, doubling chickpea production and increased faba bean production by 40% nation-wide between 2001 and 2015. This was a result of mostly vertical increase of food legumes productivity. Food legumes crops provide staple food and protein requirement to all strata of the Ethiopian population because of reliance on vegetarian diets for almost half of the year because of the fasting Coptic traditions. Besides the contribution of food legumes to achieving SDG 2 on food and nutritional security, the substantial improvement in food legumes production contributed to SDG 1 on poverty reduction in Ethiopia since food legumes are considered cash crops after they became major export crops. As a result of this, small farmers have increased their income and improved their livelihoods. Ethiopia exported in 2010 more pulses/food legumes than coffee which has been a strategic export crop over a number of years.

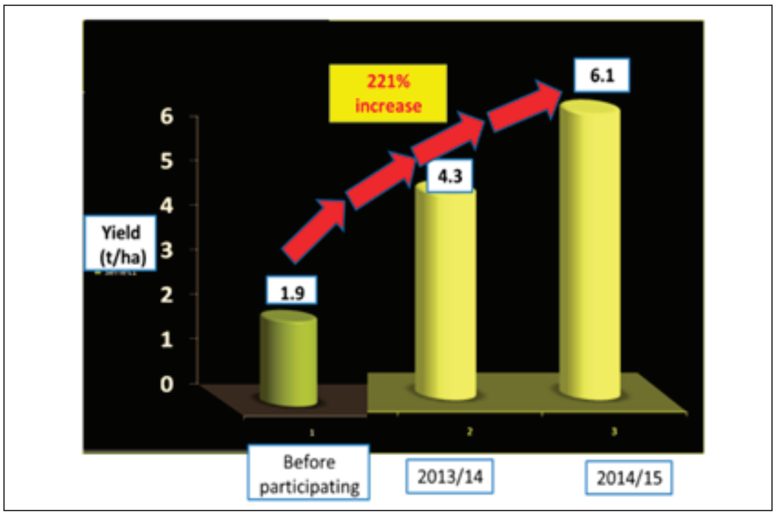

Figure 4. Trends of wheat productivity attained by model IP participating farmers in project hub countries over the years (courtesy of Dr. Solomon Assefa, ICARDA – Tunisia).

Another good example on contribution to SDG 2 on food and nutritional security is bio-fortified lentil cultivars with high content of iron (Fe levels 78 – 102 ppm) and zinc (Zn levels 59 – 68 ppm). These varieties have contributed towards the elimination of hidden hunger as a result of micro-nutrient deficiencies in several countries. They have been released in Ethiopia (‘Alemaya’), in Bangladesh (‘Barimasur-4’, ‘Barimasur-5’, ‘Barimasur-6’, ‘Barimasur-7’ and ‘Barimasur 8’), in India (‘Pusa Vaibhav’), in Nepal (‘ Sisir’, ‘Shital’, ‘Shekhar’, ‘Khajurah-1’ and ‘Khajurah-2’), in Syria (‘Idlib-2’, ‘Idlib-3’ and ‘Idlib-4’), in Turkey (‘Myveci-2001’) and in Portugal (‘Beleza’). In Bangladesh, bio-fortified lentil cultivars with high concentration of Fe and Zn have yielded an average of 1.3 t/ha; and they have produced 86,000 tons of micronutrient dense lentil worth $30 million annually. About 1 million farm families have directly benefited in house-hold nutritional security. Lentil diet has helped cure anemic Sri Lankan children after 60 days of feeding. This is another important example of the impact of research towards achieving SDG 1 and 2.

Figure 5. Alemaya lentil variety in Ethiopia (Fe-98, Zn-64 ppm) (photos courtesy late Dr. Geletu Bejiga, ICARDA - Ethiopia).

Figure 6. Pusa lentil variety (Fe 102 ppm) (photo courtesy Dr Ashutosh Sarker, ICARDA-India).

Replacement by food legumes (short season lentil, chickpea, mung bean and grass pea) of fallow component of ‘rice-follow’ rotation in India (11.6 million ha), Bangladesh (more than 1.2 million ha) and Nepal (0.55 million ha) is already contributing to enhancing food and nutritional security as well as increasing farmers income for better livelihoods in dry areas. In India, a farmer Mr. S H Khunou earned Rs. 80,000 ($ 1230) in 2 ha of rice-fallow land in Manipur state from lentil. Another farmer, Mr. P. Das earned Rs. 24,600 ($ 378) from lentil in 0.48 ha rice-fallow land.

Contribution of innovative research on livestock to SDG 1 (Reduced Poverty) and SDG 2 (Food and Nutritional Security)

Small ruminants (goats and sheep) are an important component of smallholder agrarian communities providing meat, dairy products, wool, fiber and are used as assets that can be easily sold and traded as a source of cash for making investments and for sustaining livelihoods in times of hardship. They contribute significantly to livelihoods and food security of many resource-poor households (SDG 1 and 2), especially in drylands and marginal areas. In the Collaborative Research Project(CRP) 'Livestock and Fish' (L&F), ICARDA is leading the small ruminant meat value chain development in Ethiopia by integrating technology and institutional innovations and establishing new partnerships. The approaches and concepts developed in Ethiopia are now being applied also in an USAID-funded Agricultural Innovation Program in Pakistan. In Central Asia, ICARDA has successfully developed goat and sheep fiber value chains.

ICARDA has worked extensively on improvement of small ruminant management in drylands through the following interventions:

1) **Smart feeding:** The development of compact programs of nutritional supplements that are precisely timed and specifically designed for individual events in the physiological process of animals, that include reproduction, growth, and fattening. The novelty is to demonstrate that strategically delivered nutrient inputs using locally available alternative feed resources (natural rangeland vegetation, agro-industrial by-products, shrubs, cactus, feed blocks etc.) in low input production systems could represent a sustainable home-grown solution to a global issue across the project areas.

2) **Fertility management:** This includes a combination of the following activities to increase reproductive performance of males and females: i) examination of male breeding soundness (fit males for fertility); ii) application of ultrasound technology; iii) synchronizing reproductive events to target the birth moment and environment; iv) focused feeding to enhance reproductive response; v) disease control strategies for major abortive diseases affecting herd productivity.

3) **Disease control/prevention:** Based on available information in the target countries, animal health control strategies for smallholders are designed with NARS partners. In some countries there may be a need for updating data on disease incidence and importance through rapid epidemiological studies to confirm and prioritize diseases limiting productivity and/or market access. Small ruminant health control interventions are then designed to address diseases of major economic importance; an example of successful disease prevention in marginal areas is the dairy goat project in Afghanistan.

To improve sheep and goat's productivity, production and added value products in marginal lands of the dry areas, ICARDA's collaborative research focused on the development of integrated livestock/rangelands/crops systems (Figure 7). This was done through an integrated approach involving natural resources (animal genetic resources, rangelands and crops), socio-economic consideration involving community approach and gender, the policy environment and markets. Improved technologies and efficient management of natural resources increased small ruminant meat and fiber production as well as added value dairy products namely milk, yoghurt, cheese and '*jameed*'. *Jameed* is dehydrated yoghurt that fetches high prices in Jordan for traditional dishes. All of these achievements contributed to food and nutritional security and more income to rural communities including women; thus, contributing to SDG 1 and 2.

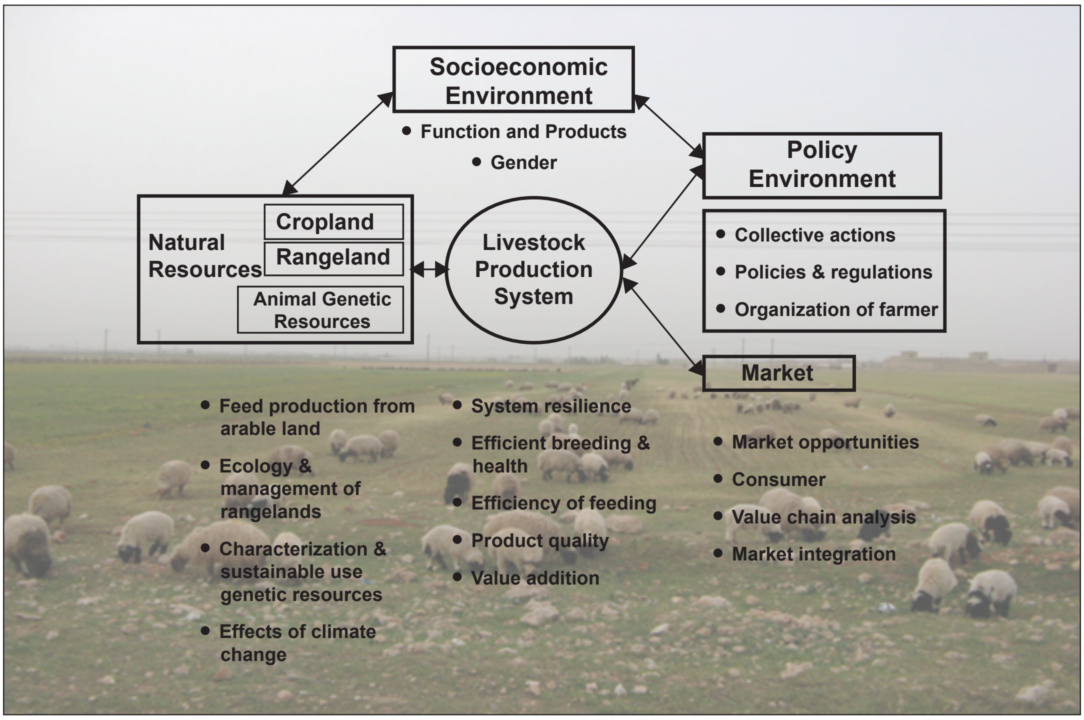

Figure 7. The integrated research approach for the development of Integrated Crop/Rangelands/ Livestock Production Systems at ICARDA (courtesy Dr. Barbara Rischkowsky, ICARDA -Ethiopia).

Contribution of innovative research on water management to SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production) and SDG 13 (Life on Land)

ICARDA has been working intensively with partners in national programs on water management and land productivity, land degradation and desertification and conservation of agro-biodiversity which has .contributed directly to achieving SDGs 6, 12 and 13

The collaborative water management research to enhance water productivity and water use efficiency has been carried out at the basin level in cooperation with IWMI. The research focused on competition among uses (agriculture and domestic use with environmental considerations). It also involves conflicts and equity issues among countries sharing the same basin. Water collaborative research is done also at the national level focusing on water management to enhancing food security, reduce food imports and tackle socio-political implication. The work is done at farm and field levels focusing on water allocation, maximizing water use efficiency (WUE) and water productivity and income. To accomplish this, ICARDA in collaboration with national programs established water bench mark sites for research on farmers' fields in three major agro-ecologies, specifically rainfed agriculture led by Morocco, irrigated agriculture led by Egypt, and marginal lands (low rainfed areas) led by Jordan. This was done through a project supported by the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Development (IFAD) to Enhance Water Management and WUE in Middle East and North Africa. Through this Project, the research done over several years developed the following innovative agricultural practices and technologies (El Solh, 2016):

- Deficit irrigation
- Supplemental irrigation
- Water harvesting for fruit trees & forage production
- *Vallerani* micro-catchments for rangeland rehabilitation
- Sustainable intensification of production systems
- Improving the WUE through raised-bed production
- Grey water reuse
- Hydroponics/Soilless Culture for high-value crops
- Enhancing WUE through drought tolerant crops and varieties.

Raised bed wheat farming is an ancient water-efficient farming practice in Egypt with many conservation benefits in enhancing WUE by substantially reducing irrigation water application to the field to minimize excessive water use and minimize water loss due to percolation. This practice results in good aeration of the roots in the soil, efficient use of fertilizer, and easier weed control. However, smallholder farmers have historically had difficulty benefiting from this technology because the machinery for bed planting is expensive and not suited for fragmented lands (El Solh 2016).

ICARDA scientists, in partnership with the Agricultural Research Center and the Extension Department of Egypt, have developed an innovative adaptation of the machinery required for raised-bed planting. This is changing the wheat production practices of the smallholder farmers first in the 'Al-Sharkia' Province in Egypt's Nile Delta region. Raised-bed cultivation of wheat led to 24 percent saving in irrigation water, 34 percent increase in wheat yield, and 78 percent improvement in water use efficiency for farmers in the 'Al-Sharkia' province (Figure 8). Given its low cost and impressive results, the technology is rapidly gaining momentum in other parts of Egypt and also being transferred to countries such as Sudan, Ethiopia, Eretria, Nigeria, Iraq and Morocco.

Figure 8. Broad-bed grain drill and broad-bed wheat planting in 'Al-Sharkia' Province in Egypt. (courtesy Dr. Atef Swelam, ICARDA – Egypt).

Contribution of innovative research on reversing land degradation and desertification to achieve SDG 13 (Life on Land)

A good example of such a contribution is the research and development on the rehabilitation of the 'Badia' of Jordan and Syria through water harvesting. The Badia is the marginal land typical of dry low rainfall areas where rainfall is only around 150 mm. Water harvesting technologies, through micro-catchment integrated through a mechanized laser-guided contouring direct planting in Badia, stored irrigation water in soils and aquifer for forage shrubs, mostly drought tolerant Atriplex and grasses (Figure 9). These forage shrubs and grasses provide important feed source for small ruminant (sheep and goats) in the *Badia*. Grazing management through the community's direct involvement from the beginning of technology development has been very important for the adoption and dissemination of this technology to combat desertification and land degradation. This technology has been expanding in the *Badia* of Jordan and Syria and other countries of the MENA region. This contributes to SDG 13 by restoring biodiversity in the marginal lands.

The other example of impact of innovative research on combating desertification and controlling land degradation is the management of saline-affected soils in Iraq. Following two approaches: 1) Managing salinity by preventing salinity build up in saline-affected soils; and 2) living with salinity were adopted. The two approaches were implemented at the Regional and Watershed Scale, Irrigation District Scale and Field Scale.

Figure 9. Laser-guided contour micro-catchment development by the Valarani cultivator and the planting of forage shrubs (*Atriplex*); grazing of vegetative growth by goats and sheep; and a google view of the large scale adoption of the micro-catchments water harvesting in the *Badia'* of Jordan (photos courtesy Dr. Theib Oweis, ICARDA – Jordan).

Managing salinity involves regional irrigation and drainage management at watershed scale while at the field scale it involves soil reclamation, drainage, salt extraction and thus salinity prevention. Living with salinity involves marginalized basin by focus on non-agricultural sectors at watershed scale while at the irrigation district and field scales it involves shifting agricultural systems by growing salinity tolerant forage crops for grazing by sheep and goats, bio-saline agriculture with salt-tolerant crops and varieties, and agro-forestry that tolerates salinity. As a result of the large scale adoption of the integrated approach for salinity management and to live with salinity in Dujaila province in Iraq, Figure 10 shows the impact on large scale in the Dujaila province of Iraq where salinity in the irrigated land is most serious. Managing and living with salinity clearly reversed land degradation and desertification as a result of salinity which recovered agriculture, vegetation and the green cover, a which direct contribution to SDG 13, Life on Land.

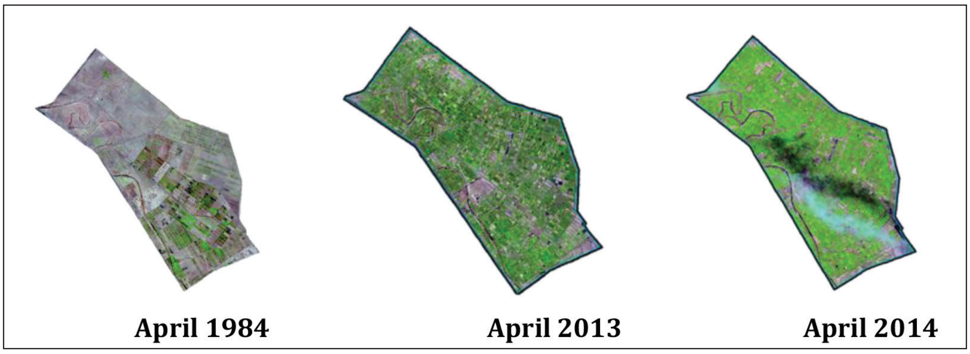

Figure 10. Google maps of Dujaila province of Iraq showing impact of scaling out salinity management research output to reclaim salt-affected soils to enhance food security. Project supported by ACIAR-Australia and USAID. (Photos courtesy Dr. Richard Scope and Dr. Saleh Badr, ICARDA - Iraq).

Contribution of innovative research on land degradation and desertification to achieve SDG 5 (Gender Equity)

To promote gender equity, a study was conducted on women, work and wage equity in the agricultural sector in Morocco. The main objectives were assessing the extent of a gender wage gap and to understand the working conditions and influencing factors to improve these conditions. Government policy increases irrigated areas of high value crops such as potato and onion in the Saiss region, creating work opportunities for the poor, mostly women laborers. This stimulates internal rural-rural migration from more marginal regions with high unemployment to high potential regions. The gender wage gap for these laborers and working conditions are important policy issues to improve those wages. With respect to the gap in gender wages following was observed:

- There is a 25% gender-based wage gap, mainly related to gender differentiated tasks where equipment-intensive tasks with higher wages exclusively involve men (up to 3 times higher wages than women-inclusive tasks).
- The gender wage gap on family farms is more pronounced
- There is no social protection during the lean period in winter time

- Migrants have insecure tenure of their dwellings where they have settled, thus making them more vulnerable.
- Results indicate that job creation for the rural poor is not enough; equal attention should be paid to the gender-equity in living and working conditions (gender wag gap, social protection, and tenure security).

Another important study was on land ownership and gender equity in the New Lands in Egypt with the objective to understand what role might women's rights in land property play in structuring, maintaining, and changing women empowerment and gender inequalities. Unlike the Old Lands in the Delta of Egypt, where women constitute 4% of landholders, women constitute 11.5% in the newly reclaimed lands. The role land ownership plays in women's empowerment and gender equity is an important policy question. The debate on land rights for woman is not a prominent subject in The Middle East. The findings of the study included the following:

- Land ownership alone without equitable access to water, training, microcredit and local acceptance of women as farm managers, is not empowering and may in fact increase poverty for those women.
- Participation in public space on land-related committees offer women landholders greater opportunities to transgress gender norms and gain greater access to resources (financial, social, and natural, such as water rights).
- Intergenerational gender inequity is perpetuated where land is inherited by sons and not daughters.
- Joint titles are more likely to be inclusive of women (on a non-competitive basis with men) who largely contribute to farming and reclaiming the New Lands.
- The Old Lands have more entrenched gender norms for what women and men can be hired for, also a more pronounced gender wage gap of 50% vs 10% in the New Lands.
- The New Lands offer far more wage work opportunities for men and women enabling them to save and start their own small businesses, and the younger generation in attending school and preparing for their adult life.

Since their labour is still the most important asset for the poor, particularly women, it is important to pay attention to improving working conditions for women. There is evidence suggesting that income generation, equitable working conditions and opportunities, and the presence of routes for challenging problematic working conditions (e.g. union groups and progressive gender norms) empower women.

The impact of technologies on improving the livelihoods of women in rural areas is covered in the IFAD Project on the improvement of goat production and management in Afghanistan and Pakistan. The outcome of the Goat Project included the following:

- More than 200 women received goats.
- Dairy hygiene and processing improved skills and incomes of at least 600 women.
- Three times higher benefits by supplemental feeding of goats.
- Two times benefit through improved feeding during fattening.

- Three times increase in offspring survival due to vaccinations.
- Improved growth and income of women through crossbreeding of goats.

Contribution of innovative research to SDG 13 (Climate Action) besides contribution to SDG 1 (Reduced Poverty) and SDG 2 (Food and Nutritional Security) through plant genetic resources and crop improvement

ICARDA's Program on Biodiversity and Integrated Gene Management (BIGMP) is involved in developing high yielding, stress resistant/tolerant crop germplasm (wheat, barley and foods legumes) adapted to climate change implications in dryland areas globally in collaboration with national partners (Table 2). These varieties are already in the hands of farmers in Central and West Asia and North Africa (CWANA), Sub-Saharan Africa (SSA) and South Asia. In addition, the program is collecting, characterizing and conserving the landraces and wild relatives of wheat, barley, cool-season food legumes (kabuli chickpea, lentil, faba bean), forage legumes (*Lathyrus, Vicia, Pisum, Medicago, Trifolium*) and temperate rangeland species to mine genes for improving abiotic and biotic stress resistance/tolerance and protecting them from genetic erosion due to expansion of improved cultivars and climate variability and changes. BIGM breeding programs are contributing to six Sustainable Development Goals (SDGs) targeted by CGIAR SRF. The improved germplasm for high yield and stress tolerance (biotic and abiotic) of cereals and food legumes increased productivity of small holder farmers crops that can provide sufficient food and generate incomes so that it can reduce poverty and hunger (SDGs 1 & 2) as well as coping with climate change (SDG 13) in CWANA, SSA and South Asia regions. The spillover effects of the germplasm enhancement program will help in regions where CGIAR Research programs have less priority. The legume breeding program, mainly chickpea and lentil, is developing early maturing genotypes that can be used in double cropping of rice based (South Asia), barley and wheat based cropping (East Africa) to boost land productivity. The increased grain productivity of cereals and food legumes also increases the productivity of straw which is key sources of animal feed that will contribute to combat poverty and hunger (SDG1 and 2) and coping with climate change (SDG 13).

Examples on the large scale impact of innovative research to cope with serious implications of climate variability and change on agriculture is the winter chickpea (grown in December and January) developed by ICARDA to replace spring chickpea (grown late March) to cope with drought particularly terminal drought in West Asia and North Africa (Figure 11, left). The late Dr. K.B. Singh developed in the 1980's at ICARDA the winter chickpea cultivars after incorporating cold tolerance and Aschocyta blight disease resistance genes in spring chickpea. Spring chickpea is grown by the farmers on residual moisture and is subject to terminal drought which is common in the region. Winter chickpea makes good use of the winter rain and is harvested before the terminal drought; and as a result chickpea productivity is doubled as also the farmers' income.

Figure 11 Winter chickpea yields twice as much as the spring chickpea because of escaping terminal drought (left). Bumper yield of 'Gokce' variety in Turkey in 2006 (right).

Another good example on the large scale impact of innovative research to cope with serious implications of climate change (SDG 13) is 'Gokce' drought tolerant chickpea variety in Turkey (Figure 11, right) which is cultivated on about 85% of the chickpea production areas (over 550,000 ha) . With a yield advantage of 300 kg/ha over other varieties, and world prices over USD 1000/t, this represents an additional USD 165 million for Turkish farmers, in the very dry season of 2006-2007 alone.

Table 2. Crop varieties of major released by the NARS partners in collaboration with ICARDA in the last 10 years

Year	All crops	Wheat	Barley	Faba bean	Chickpea	Lentil	Grass-pea
2006	21	2	6	3	2	6	2
2007	27	9	6	1	4	5	2
2008	17	3	5		6	3	
2009	7	1				6	
2010	5	1	3			1	
2011	26	13	6	3	2	1	1
2012	27	8	8	1	5	5	
2013	43	12	10	3	9	9	
2014	23	5	4	4	5	4	1
2015	22	5	4	4	5	4	
2016	6		3		2	1	
Total	224	59	55	19	40	45	6

As a result of relatively higher temperatures in winter as a result of climate change new diseases and insect pests emerge that threaten agricultural productivity. An example is the emergence of more virulent races of rust in wheat which broke the stripe (yellow) and black stem rust resistance of all improved varieties and threatened global food security. Both CIMMYT and ICARDA developed new wheat varieties that are resistant to the new races of stripe rust and black stem rust. All wheat varieties released in the last five years globally are resistant to the new races, thus making a contribution to SDG13. For example in Ethiopia, where both diseases are devastating public and private sector, a 85,943 MT seed of rust resistant varieties sufficient to plant 573,000 ha of wheat area were distributed in 2012-13. Currently, about 50% of the 1.6 million hectares of wheat are now covered with wheat varieties resistant to both diseases. This was achieved by the Ethiopian Institute for Agricultural Research (EIAR) in collaboration with ICARDA and CIMMYT with financial support of USAID.

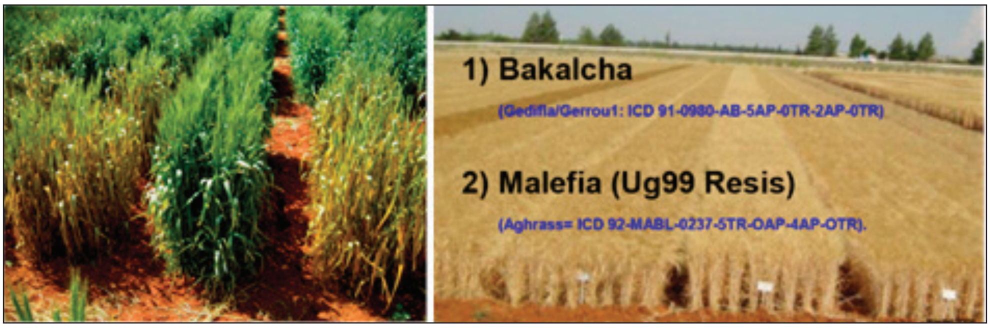

Figure 12. Wheat lines resistant to new virulent race of stripe (yellow) rust that emerged in West Asia in 2010 (photo to the left) and varieties resistant to Ug 99 black stem rust virulent race in Ethiopia.

Contribution of innovative research to SDG 13 (Climate Action), SDG 15 (Life on Land) besides contribution to SDG 1 (Reduced Poverty) and SDG 2 (Food and Nutritional Security) through Animal Plant Genetic Resources and Rangeland Management

Indigenous breeds of small ruminants are an important component of the integrated production system that are highly adaptable to changes in the environment. ICARDA in collaboration with national programs has characterized all the indigenous breeds in Central and West Asia, the Caucasus and North Africa. As a result of these studies were published for small ruminant (sheep and goats) characterization for West Asia & North Africa (Iniguez, 2005) and Central Asia & Caucasus (Iniguez and Mulleur, 2008). The published books describe the small ruminant production systems, breed phenotypic characteristics, traits and performance and adaptation to climate change besides identification of the threats to animal genetic diversity. Figure 13 shows examples of diversity in sheep and goats animal genetic resources. The studies clearly demonstrated that the indigenous breeds of small ruminants are highly adaptable to changes in climate and the environment; the study is a contribution towards the achievement of SDG 13.

ICARDA's rangeland research aims at combatting desertification, halt and reverse rangeland degradation, and halt biodiversity loss through sustainable rangeland management practices. The initiatives below contribute to SDG 15 (Life on Land): *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss; Target 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and by 2020,* *protect and prevent the extinction of threatened species*. Given the complexity and nature of this research area, ICARDA addresses these goals through a package of technologies including:

- Promoting sustainable silvi-pasture practices in South Asia (an intensive land-use management combining trees and/or shrubs with crops and/or livestock). Link: Improving Dryland Agronomic Practices One Pastoralist at a Time. For more information about this silvopasture in India. http://drylandsystems.cgiar.org/systems-update/improving-dryland-agronomic-practices-one-pastoralist-time;Link: http://www.icarda.org/sites/default/files/Silvopasture_FactSheet.pdf
- Development of tools to monitor, assess and map rangeland degradation: Focus is on developing non-destructive technique which are low cost, reliable and quick. Website: http://www.vegmeasure.org/.
- Rangeland governance: Promoting institutional and policy support for sustainable management of communal rangeland resources. This activity was initiated under the umbrella of CRP DS in Tunisia; Link:http://drylandsystems.cgiar.org/news-opinions/speaking-common-rangelands-truth-power; and under CRP DS in Tajikistan and Uzbekistan; link: http://drylandsystems.cgiar.org/content/systems-approach-inclusive-rangeland-tenure-practices-uzbekistan
- Introduction of cactus (Opuntia ficus-indica) as a source of fodder to alleviate the pressure on already degraded rangeland resources. Link: A Prickly cactus journey: From hellish plant to farmers' darling. http://drylandsystems.cgiar.org/news-opinions/prickly-cactus-journey-hellish-plant-farmer's-darling Website: http://www.icarda.org/sustainable-and-versatile-plant-dry-areas

Contribution of innovative research to SDG 13 (Climate Action) besides contribution to SDG 1 (Reduced Poverty) and SDG 2 (Food and Nutritional Security) through Conservation of Agriculture

The ICARDA-led and ACIAR-funded project in collaboration with national programs in Iraq and Syria succeeded in designing effective strategies for enhancing the adoption of zero tillage (ZT) - a technology that involves minimum soil disturbance/zero tillage with stubble retention and many crops incorporated in rotations (legumes, oilseeds). It has several bio-physical and economic benefits: savings in time, fuel, machinery wear; better soil structure; better soil moisture conservation; improved trafficability – timely sowing; higher yield potential particularly in dry seasons; less soil erosion; and enhancing multiple cropping. The bottleneck for the adoption of conservation agriculture technology in West Asia and North Africa was the high cost of imported ZT machinery (costs between USD 30,000 to 70,000, unaffordable for small farmers. In collaboration with Australian institutions, local machinery was modify)ed to perform ZT with minimum cost. With involvement of the private sector, ZT machinery is now manufactured locally in Northern Syria and Northern Iraq. The machines are now being exported to several countries in the region with low cost (USD 1,500 to 5,000, depending on size). The ZT technology has not only proven bio-physical benefits but also livelihoods benefits. ZT machinery's major benefit, especially the ability to cope with dry weather and reduce cost of production, has resulted in several countries in the region to allocate micro-credits for small farmers and farm cooperatives to purchase it.

Figure 13. Examples on the diversity of indigenous breeds of small ruminants (sheep and goats) in West Asia & North Africa and Central Asia and the Caucasus (courtesy of Dr. Luis Iniguez - ICARDA).

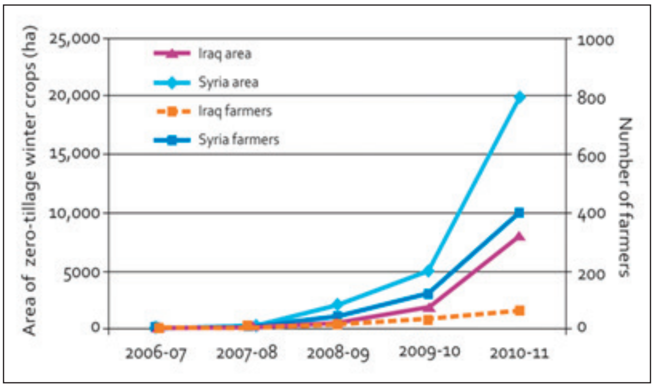

Figure 14. Expansion of Conservation Agriculture and zero tillage technology in Syria and Iraq (courtesy Dr. Colin Pigen and Mr. Atef Haddad).

As a result of its benefits, conservation agriculture technology has been adopted by large number of farmers in both Iraq and Syria and has been spreading rapidly in West Asia, from near-zero to more than 27,000 ha in four years. ZT technology has spread further even during the security difficulties in both Iraq and Syria. Figure 14 shows the expansion of conservation agriculture and ZT technology in Syria and Iraq. Data could not be procured beyond the 2010-2011 season.

Contribution of regional cooperation, networking and capacity development to SDG 17 (Partnership for the Goals)

Since its establishment in 1977, ICARDA's collaborative research and capacity development activities have been done through partnership with national programs in West Asia and North Africa first, then it expanded to the Central Asia, Sub Saharan Africa (SSA) and South Asia. In each of these regions, ICARDA established Regional Programs involving the national agricultural research systems of the countries in each of the regions. These countries usually share common agro-ecological conditions and common challenges facing sustainable agricultural development. The first Regional Program was in the Nile Valley, involving Egypt, Sudan and Ethiopia, and was established in 1979, two years after ICARDA's establishment. This was followed by the North Africa Regional Program (1982) involving the Maghreb countries, the West Asia Regional Program (1989), then Highlands Regional Program (1990), the Arabian Peninsula Regional Program (1995), the Central Asia and Caucasus Regional Program (1998) and the South Asia and China Regional Program (2008). Through the partnerships with the country's national programs of each region, ICARDA addresses common challenges facing agriculture through collaborative research and capacity development plans developed annually and implemented jointly. ICARDA organizes annually and biennially regional coordination meetings in each of the regions to discuss the outcome of partnership in collaborative research and capacity development activities to achieve the SDGs in each of the countries involved. Several regional and bilateral projects were developed to facilitate regional cooperation and more investment in research and capacity development to contribute to achieving the SDGs.

Human resource capacity development has been playing an important role in strengthening partnership and institutional development to support agricultural research for development in collaborating countries. Since its establishment in 1977, ICARDA has trained a total of 22,840 national scientist and technicians out of which 851 got their degree training (M.Sc. & Ph.D.) with their thesis research work done at ICARDA (Table 3). Several highly specialized intensive courses were conducted in various research and development disciplines, for 2015 as an example presented in Figure 15.

Table 3. Number of national scientists and technicians trained at ICARDA in non-degree and degree training in the period from 1977 to 2016

Type of Training	1978-2015	2016	Total (1977- 2016)
Post Graduate (PhD and MSc)	818	33 (newly enrolled)	851
Individual Non-Degree	2,259	13	2,272
Internship	159	7	166
Courses	18,892	659	19,551
Total	22,128	712	22,840

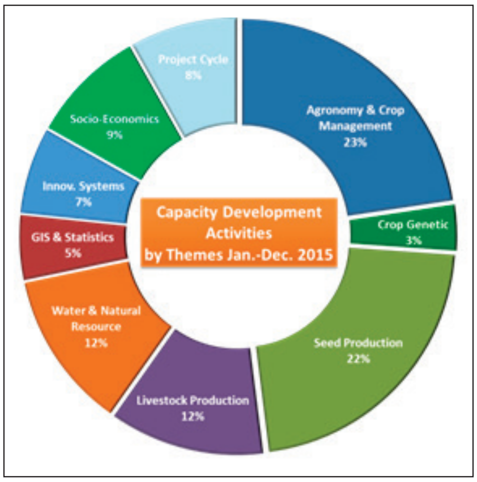

Figure 15. National scientists and technicians trained at ICARDA in various disciplines that contribute to sustainable agricultural development and relevant SDGs.

Conclusion

It is apparent that collaborative innovative research and capacity development conducted by ICARDA, in collaboration with national agricultural research systems and other partners, has contributed effectively towards the achievement of several SDGs (SDG 1, SDG 2, SDG 5, SDG 6, SDG 12, SDG 13, SDG15 and SDG 17). ICARDA's improved technologies have impacted all these SDGs. However, more investment and efforts are needed to link research with development, building on the experience achieved thus far. It is important to upscale and replicate the successes for further large scale impact to achieve the SDGs at the national level. We now have many new scientific tools available that we never had in the past: fast computers, satellite sensors, geographic positions systems (GPS), geographic information systems and remote sensing (GIS/RS) to develop similarity maps based on similar agro-ecologies, biotechnological tools, video & tele-conferencing and decision-support models to name a few. These should be used along with innovative training and education programs to tackle the new challenges to achieve the SDGs. In particular, we need to encourage young scientists to devote their energies and intelligence to innovative agricultural research for sustainable development.

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2. Sustaining water for desert agriculture

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Abstract

Although about 1/3 of the worlds land surface is covered by deserts and about 40% of the land surface is classified as arid or semi-arid, many of these arid lands can be among the most productive crop producing areas on earth. With abundant sunshine and generally long growing seasons, the primary limiting factor to crop production is water and, in order to have productive cropping systems in desert climates some type of irrigation is required. In fact, 40% of the world's agricultural crops are produced on just the 17% of cropland that is irrigated. However, as population in the arid regions increases and urbanizes, the competition between agriculture and non-agricultural water uses has resulted in significant pressure on desert agriculture to reduce its water "footprint". There are several ways that this is being achieved. First is the significant improvement in irrigation efficiencies that can be achieved by drip irrigation technology and, in particular, subsurface drip irrigation. Second is development and refinement of appropriate technologies for treating waste water and grey water for irrigation. Third is the improved understanding of how wastewater, both tertiary treated and only primary treated, can be safely used for crop production. Finally, continued improvement of water harvesting techniques and enhanced awareness of the role that water harvesting can play has led to a greater role for water harvesting in both agricultural and urban landscapes. This presentation will investigate each of these technologies and discuss how each or a combination of all can contribute to sustainable crop production in desert agriculture.

Keywords: Water harvesting, subsurface drip irrigation, wastewater irrigation

3. Towards second green revolution by making grey areas green

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Abstract

India has recently celebrated golden jubilee of Green Revolution, which enabled food self-sufficiency. Despite fourfold increase in population, the production of food grains rose by fivefold. In the process, two lessons were learnt. First, the second generation problems of Green Revolution such as: factor productivity decline, poor soil health, water table decline, higher incidence of pests and diseases, increased cost of inputs, decline in farm profits etc. emerged prominently besides adverse impact of climate change. Second, around 50 per cent rainfed area is still deprived of Green Revolution. Thus, the current challenge is to make these grey areas green, requiring a paradigm shift from uni pillar to twin pillar strategy i.e. adoption of both varietal improvement and good agronomic practices (GAP). Hence, the existing divide between irrigated and rainfed regions need to be bridged by insulating farmers against risk by scaling out innovations around pre- and post-production practices for improved livelihood of smallholder farmers. Fortunately, the drylands in India are different in many ways. It's flora and fona represent unique agrobiodiversity, and considered to be an asset to cope with emerging abiotic and biotic stresses, besides adaptation and mitigation to climate change. Existing agrobiodiversity for crops, including horticultural crops, grasses, shrubs, trees, animals, so typical of Indian Thar desert, offer ample opportunities for attaining second Green Revolution. Both research and development efforts relating to conservation of biodiversity through use, diversification in farming systems, secondary and specialized agriculture, natural resource management, post-harvest processing and value addition and inclusive market oriented development (IMOD) offer ample opportunity. In this context, exciting developments to scale out innovations around hybrid technology, GM crops, conservation agriculture (CA), watershed management, micro-irrigation, protected cultivation, arid-horticulture, agroforestry, integrated pest management (IPM), precision nutrient management (PNM) etc. are taking place. The presentation would centre around the existing constraints, possible options for scaling new innovations, and required policy interventions for sustainably managing the drylands through second Green Revolution in India.

Keywords: Green Revolution, Rainfed agriculture, Conservation agriculture, GM crops

4. The nanotechnological approaches for 2030 Sustainable Agriculture Development Strategy

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Abstract

The Egyptian Sustainable Agriculture Development Strategy 2030 (ESADS 2030) is established on knowledge-based economy approaches, using the most modern technologies and rapid technology transfer. Nanotechnology is one of the important components of ESADS 2030, especially for the reclamation of new lands. Implementation of a suite of nanotechnology applications is being attempted in most sectors of agriculture such as water treatment, nano-fertilization, nano-pesticides, nano-biosensors, treatment of plant and animal diseases and nano-foods, taking into considerations the safety requirements. The present paper will emphasize the role of green nanotechnology in the Egyptian Sustainable Agriculture Development Strategy 2030, with the aim of building up the Egyptian society on the bases of good knowledge and strong economy.

Keywords: Nanotechnology, Agricultural applications, Egypt, Sustainable development

Introduction

Nanotechnology has drawn on the field of green chemistry. The framework of the 12 Principles of Green Chemistry (Anastas and Warner, 1998] features significantly in work to design new nanotechnologies for economic, social, and health/environmental benefits (Hutchison, 2008). These efforts have been aided by awareness throughout the nanotech community that they need to address the potential negative impacts of nano from the outset (McKenzie and Hutchison, 2004). That has not meant, however, that green nanotechnology has gained widespread and popular acceptance in the scientific and business communities (Dahl *et al*., 2007). Awareness is still limited in many sectors, and green nanoscience, along with nanoscience more broadly, still faces significant challenges in transitioning from concept to reality (Matus *et al.,* 2011).

Nanotechnology has emerged as one of the most innovative scientific fields. The potential of nanotechnology to the agri-food sectors has been well publicised. In fact several products enabled by nanotechnology will be in the market very soon, such as antimicrobial agent, food packing, nano-fertilizers, nano-pesticides and veterinary diagnostic nano-systems. The application of nanotechnology to the agricultural and food industries was first addressed by a United States Department of Agriculture roadmap published in September 2003 (Joseph and Morrison, 2006). In 2010, Egypt addressed their agriculture nanotechnology roadmap by the Agriculture Research Center and established the first integrated central laboratory for the application of nanotechnology to the agricultural and food industries, named as the Nanotechnology & Advanced Materials Central Lab (NAMCL). The prediction is that nanotechnology will enhance the agricultural sectors and food industry, changing the way crops and food are produced, processed, packaged, transported, and consumed. Currently, there is a global interest to identify the potential of nanotechnology in the agri-food sector and countries are investing a significant amount in it. Since Egypt is one of the leading countries in Africa and Middle East, and agriculture is the backbone of Egyptian economy, with more than 60% of the population reliant on it for their livelihood, it is the right time for Egyptian Government to establish good R&D program for nanotechnology in agriculture and food industry for better future, health and economy.

The Egyptian Ministry of Agriculture has set out ambitious plans for agricultural nanotechnology to be achieved in the short, medium and long term through the Egyptian Sustainable Agriculture Development Strategy 2030 (ESADS 2030), and it aims to discover novel phenomena, processes and tools to address challenges faced by the agricultural sector. Equal importance has been given to the societal issues associated with nanotechnology and to improve public awareness. The ministry is also planning to hold training programs to develop specialized Human resources in the field. In this case, there is an unusual opportunity to use science, engineering and policy knowledge to design novel products that are as benign as possible to human and environment health. Recognition of this opportunity has led to the development of the "green nano-science" concept.

The present review represents green nanotechnology potential to revolutionize the agricultural and food industry with new tools for water treatment and rapid disease detection by smart nano-biosensors that will help the agricultural industry combat viruses and other crop pathogens. In the near future nanostructured products will be available which will increase the efficiency of fertilizers, pesticides and herbicides, allowing lower doses to be used.

Water treatment nano-filtration approaches

In spite of the flow of Nile River along Egyptian lands, Egypt will be facing a great water scarcity crisis in the coming decays. Sewage water treatment becomes the first choice to meet the increased water demand, mainly for irrigation, in addition to the use of ground water. Nanotechnology introduces new modality to generation of nano-filtration system based on multi-technological hypothesis such as adsorption, chemical deposition, electro-deposition, flocculation, etc. Nano-filtration approaches are highly selective and perfect in efficiency with lower cost compared to the conventional filtration systems. Nano-filtration systems are simultaneous multi stage purification systems for the removal of heavy metal, organic residues and microorganisms.

Heavy metal nano-filtration approaches

Several approaches have been employed to remove heavy metal ions from wastewater such as the chemical precipitation, adsorption, cation-exchange, reverse osmosis, electrodialysis, and electrochemical reduction (Mohan and Singh 2002). However, generally, the adsorption process has been proved convenient in terms of cost, simplicity and flexibility (Rengaraj *et al.,* 2002). In this regard, several sorbents have been recommended for the removal of Pb^{2+} ions, such as the activated carbon, and mesoporous and nanoporous materials as clays, zeolites, chitosan and apatite (Ziagova *et al.* 2007). Of these sorbents, calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, abbreviated as HAp), has shown a remarkable sorption efficiency for long-term containments (Sun *et al*., 2013). Biological molecules like chitin, chitosan, lignin have also been recommended for the removal of toxic metals (Gonzalez-Davila, and Millero,1990). Chitosan biopolymers (Cs), in particular, with their non-toxicity, hydrophilicity, biocompatibility, and biodegradability, exhibited effective sorption efficiency for heavy metals (Okuyama et al., 1999).

In our investigation, artificially made calcium hydroxyapatite nanorods (nHAp) and hydroxyapatite/chitosan nanocomposite (nHApCs) have been employed by our group in the removal of lead ions from lead-containing aqueous samples using the adsorption technique. Several parameters including the adsorption time, initial Pb^{2+} concentration, adsorbent dosage, and pH have been investigated to evaluate their influence on the sorption efficiency. The kinetics of the sorption process could be fitted to a pseudo-second-order reaction model, and the sorption capacity of Pb^{2+} by nHAp increased with the initial Pb^{2+} ions concentration. The Freundlich and Langmuir adsorption isotherms have been employed to evaluate the adsorption behavior, but the Langmuir model was much better, and a maximum adsorption capacity for nHAp of 250.0 mg/g was obtained. Interestingly, the Pb^{2+} ions sorption by nHAp increased with pH and nHAp dosage while the sorption capacity decreased with the nHAp dosage (Salah *et al.,* 2014).

Organic contaminants nano-filtration approaches

Treatment of organics contaminated wastewater and industrial effluents is a challenging topic in environmental science and technology, and the removals of the hazardous dyes from wastewater have attracted much attentions in recent years (Ambashta and Sillanpaa, 2010). So, it is highly desirable to develop eco-friendly, simple and economical techniques for the removal of the hazardous dyes. To date, a variety of methods have been developed for the removal of dye pollutants from colored effluents, such as biological treatment (Kornaros and Lyberatos, 2006), coagulation/flocculation (Guibal and Roussy 2007), ozone treatment [Zhao *et al.,* 2006), chemical oxidation (Dutta et al., 2001), membrane filtration (Capar *et al.*, 2006), ion exchange (Liu *et al*., 2007), photocatalytic degradation (Muruganandham and Swaminathan 2006) and adsorption (De Lisi *et al.* 2007). Among them, adsorption technology with no chemical degradation is attractive due to its advantages of the effectiveness and economy (Rengaraj *et al*. 2002). Graphene (G) is a newly found carbon-based nanomaterial with fascinating two-dimensional atomic thickness structure and large theoretical specific surface area It has attracted great attention in a broad range of application concerning environmental challenges. The large theoretical specific surface area ensures excellent adsorption capacity for dyes or some other organic matters (Gao *et al.* 2012) as the large delocalized π electron system of G can form strong π stacking interaction with the benzene ring. Importantly, on the basis of its chemical properties, large surface area and geometry, graphene has great potential for the applications in dealing with environmental pollution.

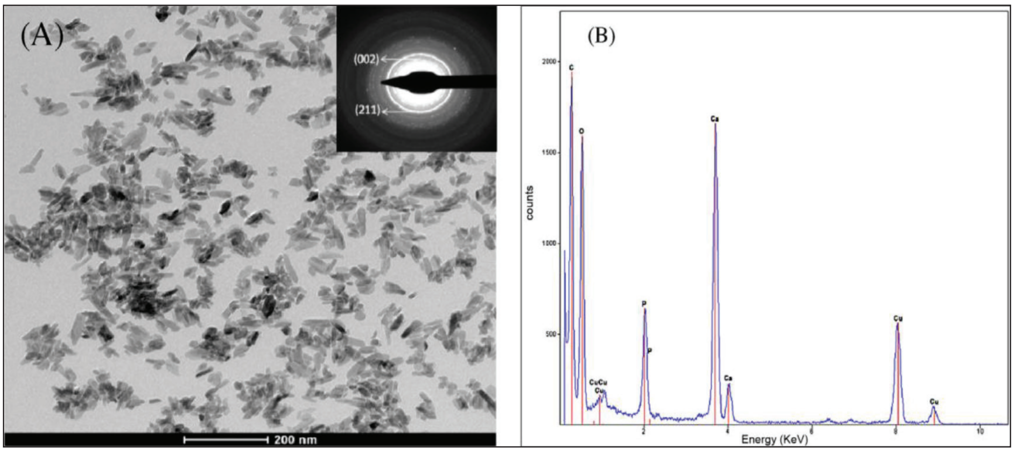

Figure 1. (A) HR-TEM image of hydroxyapatite nanorods (nHAp). (B) EDX of TEM image of hydroxyapatite nanorods (nHAp) (Salah et al., 2014).

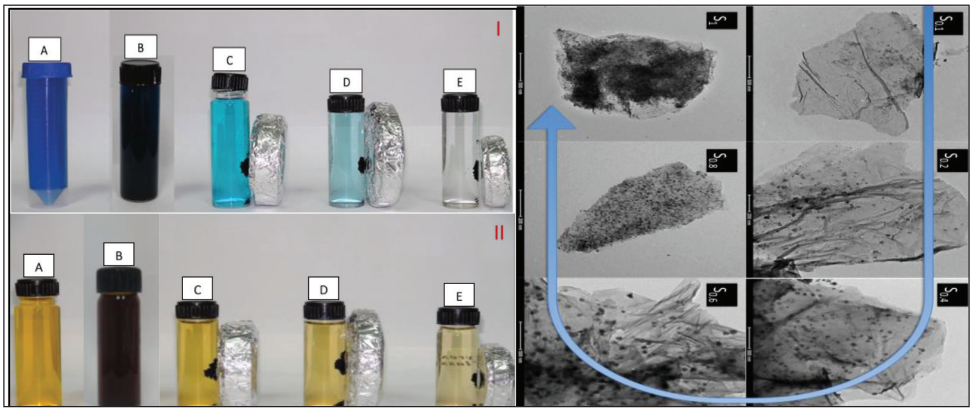

Figure 2. (I) Removal of Methylene blue organic dye by GO/ Fe_3O_4 nanocomposite
(II) Removal of methyl orang organic dye by GO/ Fe_3O_4 nanocomposite
(III) Graphene oxide (GO) loaded with different ratios of Magnetite nanoparticles (Fe_3O_4) (Farghali et al., 2015; Farghali, 2014).

The use of graphene as an adsorbent for removal of dye has not yet been reported. This is due to difficulty to separate carbon nanomaterials from aqueous solutions because of their small particle size, leading to serious health and environmental problems once they are released into the environment. Magnetic separation has been one of the promising techniques for environmental water purification. Moreover, this technique is particularly desirable in industry because the capability for treating large amount of wastewater within a short time. Thus, the combination of graphene with magnetic NPs to produce a magnetic graphene-based composite would provide a new, functional hybrid with complementary behavior between each constituent, and thus will have great advantages for wastewater treatment. Fe_3O_4 NPs show advantages such as low toxicity, low cost, and eco-friendliness (Wang *et al.* 2011; Farghali *et al*., 2015].

Carbon nanotubes can be uniformly aligned to form membranes with nanoscale pores that are able to filter out contaminants. Their nanoscale pores make these filters more selective than other filtration technologies. The carbon nanotubes also have high surface areas, high permeability, and good mechanical and thermal stability. Though several other methods have been used, carbon nanotube membranes can be made by coating a silicon wafer with a metal nanoparticle catalyst that causes carbon nanotubes to grow vertically aligned and tightly packed. The spaces between the carbon nanotubes can then be filled with a ceramic material to add stability to the membrane. Laboratory studies report that carbon nanotube membranes can remove almost all kinds of water contaminants, including turbidity, bacteria, viruses, and organic contaminants. These membranes have also been identified as promising for desalination and as an alternative to reverse osmosis membranes (Srivastava *et al.,* 2004).

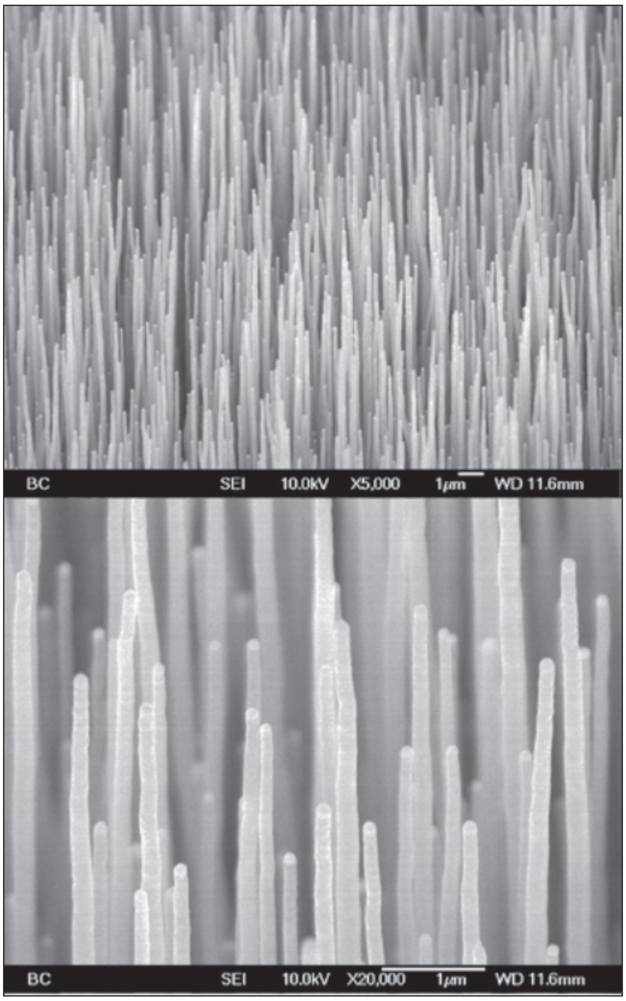

Figure 3. "Forest" of aligned carbon nanotubes. (Image courtesy David Carnahan of NanoLab, Inc.)

Although their pores are significantly smaller, carbon nanotube membranes have been shown to have the same or faster flow rates as much large pores, possibly because of the smooth interior of the nanotubes. The cost of producing carbon nanotube membranes continues to decrease as researchers develop new and more cost effective methods to mass-produce them. Some sources estimate that carbon nanotube membranes could become significantly less expensive than other filtration membrane technologies, including reverse osmosis membranes and ceramic and polymer membranes, as the price of carbon nanotubes falls (Risbud, 2006). Desalination using carbon nanotube filters could cost less than with reverse osmosis due to energy savings, since carbon nanotubes exhibit fast flow rate that reduce the amount of pressure needed to push water through carbon nanotube membranes. They are expected to be more durable and easier to clean and reuse than conventional membranes without a decrease in filtering efficiency.

Nano-biosensors

Nano-biosensors represent a recent sensitive and accurate diagnostic tool than conventional diagnosis of microbial pathogens. A lot of biosensor-based methods have developed and those are grouped as electrochemical, optical and thermo-metric. Advantages of nanobiosensor techniques are reduction of extraction and clean-up analytical steps and global time of analysis (1 min or only few seconds), possibility of online automated analysis, low cost and no need of skilled personnel. However, sensitivity has to be enhanced and the stability improved to allow long-term use (Bhunia, 2008).

Development of a rapid and simple detection method based on one-step membrane-based competitive dot immunogold filtration assay (DIGFA) for use in on-site assessment of aflatoxin B1 (AFB1) was studied. Results showed that gold nanoparticles (AuNPs) can be used as a probe for AFB1 detection with acceptable sensitivity and specificity compared to HPLC technique. Constructed DIGFA sensor detects AFB1 with high sensitivity (5 ng/mL) which is validated by HPLC. Assay is rapid (test completion time is 2 min), reproducible and does not require any equipment (Eldin *et al*., 2014).

Another study was performed using gold nanoparticles (AuNPs) as biosensor for detection of *E. coli* O157:H7 (Figure 4). A sensitive colorimetric method was developed using conjugated gold nanoparticles anti-E.coli O157:H7 sensor. The key point of gold nanoparticle based visual detection assay is to control dispersion and aggregation of colloidal nanoparticles by targets of interest (*E. coli* O157:H7). The existence of the target molecules can be translated into optical signals and monitored by the naked eye resulting in a dramatic color change from red to blue. The method takes a few minutes from bacterium binding to detection and analysis and could be adopted for a wide range of practical applications (Ali et al., 2014; Hadi *et al*., 2014].

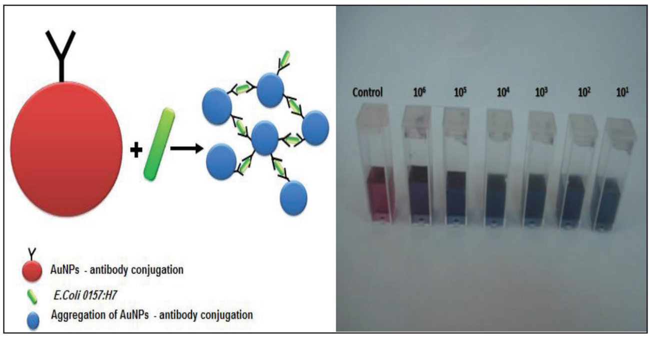

Figure 4. Schematic represent of conjugation process for probe preparation (left) and real naked eye color change from red to blue (Ali *et al.,* 2014).

Conclusion

Implementation of nanotechnology applications in most agriculture sectors such as water treatment, nano-fertilization, nano-pesticides, nano-biosensors, plant and animal diseases and nano-foods is growing, taking into considerations the safety requirements. An Egyptian agriculture nanotechnology roadmap has been prepared by the Agriculture Research Center and the first integrated central laboratory for the application of nanotechnology in agriculture and food industries has been established. The Egyptian Sustainable Agriculture Development Strategy 2030 (ESADS 2030) was established on knowledge based economy approaches using the most modern technologies by rapid technology transfer. Nanotechnology is considered as one of the important assets of ESADS 2030, especially for the reclamation of new lands.

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Plenary Session 3

1. Building a sustainable community in the Egyptian desert

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Abstract

Food security is a major problem in Egypt. Having a population of over 90 million as against less than 6% of arable land of its total land area has led to tremendous food imports. On the other hand, healthy wellbeing, quality education, clean water and sanitation, affordable clean energy, decent work, industry innovation, climate change, life on land, peace and justice - nearly all the sustainable development goals (SDGs) must be tackled by the Egyptian government, civil society and the private sector together.

One of the key solutions, as we have experienced, is to build living communities in the desert. In 1977, the SEKEM initiative for sustainable development started reclaiming the dessert land using biodynamic agriculture, through the economic pillar of the SEKEM Model, whereby families were hosted, and schools, theaters, medical centers and research facilities were established.

To address the environmental challenges, sustainable agriculture methods are exceptionally efficient in carbon sequestration by absorbing greenhouse gas emissions in the soil and trees, which in turn contributes to the countering challenges of global climate change. Moreover, compost production vitalizes the soil, due to being produced from animal manure through modern technology. The harvested organic produce is further processed to high quality phyto-pharmaceutical products, organic food and textile garments. The factories were built up on the same land, providing a job opportunity in the community. The aim of the SEKEM initiative is to demonstrate that a holistic approach to sustainable development is possible.

Keywords: Food security, Egyptian desert, SDGs, Sustainable agriculture, SEKEM model

2. Inquiry Based Science Education (IBSE) for sustainable dryland development

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Abstract

Economic development has been and remains the target and priority of each entity, community and country around the globe. However, the global climate and natural disasters pose great challenges especially to the dryland areas. Accordingly, the way of thinking and strategies to tackle the challenges have to be changed. Strategies and solutions developed for irrigated lands cannot be applied as such for the development of drylands. In addition, the socio-economic and cultural aspects of the communities atlarge, have greater influence on implementation of any development strategies and programs. Therefore, to face the known and emerging challenges to the drylands and to ensure sustainable dryland development, critical and innovative thinking across the board, specially among children- the future of nations, is of utmost importance. And to nurture critical and innovative thinking in the society, especially young children, the methodology of teaching, grooming and learning at school level becomes crucial. In this respect, the Inquiry Based Science Education (IBSE) approach, especially for the subjects of science, technology, engineering and mathematics (STEM) or STEAM ("A" stands for Arts) at schools, has been recognized globally, as the best methodology for learning of the scientific and technological processes and natural phenomena taking place in the environment and around us. IBSE is the way of teaching and learning, which instills the willingness of learner to explore new ideas and reliance on evidence and logic. The practical IBSE modules developed by dryland experts and pedagogy specialists, can be incorporated in the syllabi of school children, particularly in the dryland areas of the globe; which in-turn can assure the sustainable development of the dryland areas.

Keywords: Inquiry based education, STEAM, Dryland agriculture, Farmers field school

Introduction

Drylands cover nearly half of the earth's land surface and are home to one-third of the global population (Berrahmouni *et al.,* 2015). Drylands are limited by soil moisture, the result of low rainfall and high evaporation, and show a gradient of increasing primary productivity, ranging from hyper-arid, arid, and semiarid to dry sub-humid areas. Deserts, grasslands, and woodlands are the natural expression of this gradient. Drylands are widely affected by desertification, biodiversity loss, poverty and food insecurity. The potential water deficit in drylands affects both natural and managed ecosystems, and constrains the production of crops, forage, and other plants and has great impacts on humans and livestock. These problems are further exacerbated by climate change. Therefore, the livelihood sustainability in these regions is threatened by a complex and interrelated range of social, economic, political, and environmental changes that present significant challenges to researchers, policy makers, and, above all, rural land users (Safriel *et al.,* 2005).

Challenges to drylands

The drylands face extraordinary challenges, including those posed by desertification, biodiversity loss, poverty, food insecurity and climate change. Drylands are a vital part of the earth's human and physical environments (Berrahmouni *et al.,* 2015). Their ecosystems play a major role in global biophysical processes by reflecting and absorbing solar radiation and maintaining the balance of atmospheric constituents. They provide much of the world's grain and livestock, and form the habitat that supports many vegetable species and micro-organisms (Fraser *et al.,* 2011). Up to 20 percent of the world's drylands are degraded, and people living there are often locked into a vicious circle of poverty, unsustainable practices and environmental degradation. Thus, serious efforts are needed to arrest dryland degradation and restore degraded lands (Berrahmouni *et al.,* 2015).

The global climate and natural disasters pose great challenges to the dryland areas. Nearly all drylands are at risk of land degradation (desertification) as a result of climate change, increasing human population, land over-use and poverty and are a threat to the food security and survival of the people living in these areas. The preservation and sustainable development of drylands are essential to achieve food security and conserve the biomass and biodiversity (FAO, 2003). Reducing the vulnerability of dryland communities to climate change will require measures that diversify livelihood options, reduce pressure on natural resources, and restore and protect dryland ecosystems. The disaster and climate change response strategies contribute in a positive manner to the efforts to implement sustainable development, including enhancement of social equity, sound environmental management and wise resource use. Most of such measures are already in use in communities around the world, and can offer guidance to the adaptation processes for less developed countries (IISD, 2003). But the way of thinking and strategies to tackle the challenges have to be changed.

Today the world faces a situation of growing urgency. There is widespread lack of access to water; food security is affected by unprecedented price hikes for commodities (basic food), driven by historically low food stocks; there is a growing demand for bio-fuels; and environmental change such as drought, land degradation and desertification (DLDD) is creating growing problems. Inflated international cereal prices have already led to food riots in several countries during the last decade, while the most vulnerable are also seeing the food aid process being threatened by this economic context (UNCCD, 2008).

Need for new strategies to cope with dryland DLDD

An updated and innovative strategy to bind the international community and to build international cooperation to combat dryland DLDD must emerge from this context, in order to prevent negative impacts on the poorest countries and to improve food security and access to water (UNCCD, 2008). An integrated approach to food security and the environment should take into consideration the food, water, energy, environment and climate nexus, while reorienting food production, distribution and consumption. Food security, while minimizing environmental impacts and increasing natural resource efficiency, will require increasing agricultural productivity. Rapid increases in yields are deemed feasible, in particular where productivity gaps are high. At the same time, the protection of soil quality and crop and grazing land management, including restoration of degraded lands, have been identified as having the greatest agricultural potential to mitigate climate change, in addition to being cost-effective. Additional public investments in agriculture-related research and development will be crucial to increasing productivity (UN, 2013).

Strategies and solutions developed for irrigated lands cannot be applied as such, for the development of drylands, and the way of thinking and the strategies to tackle the challenges have to be changed. In addition, the socio-economic and cultural aspects of the communities have greater influence on implementation of any development strategies and programs; thus all dryland development programs have to be adjusted according to local socio-economic and cultural contexts. Therefore "critical thinking" that comes with education, especially science education at all levels, but particularly at grass root level, is vital for training the mind, understanding the world, making choices and solving problems. The concept of "inquiry" fosters the understanding of technological innovations, which need to be inculcated among children at primary and secondary school levels.

To nurture critical and innovative thinking in the society especially young children, the methodology of teaching, grooming and learning at school level, becomes crucial. In this respect, the inquiry based science education (IBSE) approach, especially for the subjects of science, technology, engineering and mathematics (STEM) or STEAM (where "A" stands for Arts) at schools, has been recognized globally, as the best methodology for learning of the scientific and technological processes and natural phenomena taking place in the environment around us. IBSE is the way of teaching and learning, which instills the willingness in learner to explore new ideas and rely on evidence and logic. IBSE develops understanding of different science concepts by the learners. IBSE approach is used for teaching of STEM subjects at schools with the objective to instill the willingness and enhance motivation of children to explore new ideas through evidence and logic. Therefore, IBSE approach is a critical and essential step to ensure sustainable supply of young talent for linking advance research with sustainable development in any sector including industrial and economic development. Hence, to face the known and emerging challenges to the drylands, and to ensure sustainable Dryland development, critical and innovative thinking across the board, especially among children- the future of nations, is of utmost importance.

In IBSE, different facts, questions, problems and scenarios are presented to the pupils for investigation by using their own skills of observation, raising investigative questions, planning and conducting experiments, reviewing evidence in the light of what is already known, drawing conclusions and communicating and discussing results for consequent actions. Therefore, IBSE is a step forward to nurture inquisitiveness and to ensure sustainable supply of young talent for linking advance research with sustainable economic development as a whole. The practical IBSE modules developed by dryland experts and pedagogy specialists, can be incorporated in the syllabi of school children, particularly in the dryland areas as well as in Biosphere Reserves of the globe, which in-turn can assure the sustainable development of the dryland areas. One such successful model is that of the *Farmer Field Schools (FFS),* originally developed by FAO in the 1980s; which has since spread around with certain modifications and has also been practiced by ICARDA projects, e.g. in Pakistan. The IBSE and FFS, both emphasize on "*inquiry based learning*" or the "*learning by doing*" and "*evidence based decision making*".

ECO Science Foundation (ECOSF) is supporting collaborative S&T research of applied nature among its 10 member countries viz., Afghanistan, Azerbaijan, Kazakhstan, Kyrgyzstan, Iran, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan. ECOSF is also promoting and linking IBSE with advance research and industrial development to ensure a sustainable supply of talent to feed the process of development, in line with UN Agenda 2030. For the purpose, the Foundation has developed partnership with international institutions such as UNESCO, ISTIC Malaysia, *La main a la pate* Foundation of France, Inter-Academy Partnership Science Education Program (IAP SEP) and Turkish World Educational and Scientific Cooperation (TWESCO).

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3. Rainwater harvesting in drier environments: Role in ecosystems restoration and resilience to climate variability and change

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Abstract

Rainwater harvesting is an ancient practice that people in dry environments have depended on for survival. It has been used also for agriculture and other purposes. The practice has lost importance in recent decades due mainly to developing practical and more feasible modern water resources technologies and practices. However, rapid development and increased water scarcity has led to reemphasizing water harvesting as a more sustainable practice especially under changing climate. Although its importance is decreasing for human water supply, its role in combating land degradation and improving rangelands for feed supply and ecosystems services is rather increasing.

This paper addresses the potential role of rainwater harvesting in the restoration and/or the rehabilitation of degraded dry ecosystems. As the vast majority of rangelands dry ecosystems in many parts of the word are severely degraded, it is questionable whether they can be brought back to their original state. The other option is to rehabilitate it to bring it up to new system equilibrium. Rainwater harvesting in both cases is essential to overcome the consequences of the degradation of the system by enhancing soil water and halting erosion so vegetation can grow again.

Reasons why most of the past attempts to integrated water harvesting in the system restoration had failed and conditions for success are highlighted in this paper. Failure to plan, design and implement suitable water harvesting practices together with lack of integration and follow-up grazing management are some of the important technical shortfalls. However, of most importance is the lack of attention and investment given to the restoration of degraded ecosystems. National policies need to be developed to create enabling environments for meaningful investment in both human resources and development projects for dealing with degraded lands in dry areas.

Keywords: Rainwater harvesting, Climate change, Rangeland degradation, Policies for restoration

4. Drought proofing through implementation of District Agriculture Contingency Plans in India

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Abstract

Deficiency in rainfall during crop growing season results into meteorological as well as agricultural drought causing substantial reduction in crop yields. The impact of drought on rainfed crops is much higher compared to crops in irrigated regions. The district contingency plans, containing technological interventions related to tolerant crops/ systems, contingency seeds, agronomic and water management, etc., are therefore prepared for different districts and are made available through Ministry of Agriculture & Farmers Welfare (MoA & FW)/ Indian Council of Agriculture Research (ICAR)-Central Research Institute for Dryland Agriculture (CRIDA) websites. Measures for coping with delay in onset of monsoon, break in monsoon, and mid-season and terminal drought for all field crops and horticultural crops are covered in these plans. So far, 614 district plans are ready out of 651targeted rural districts. During the years of 2014-15 and 2015-16, ICAR-CRIDA made significant efforts in sensitizing the line departments, particularly the department of agriculture, through national and state level interface meetings, to address the deficient monsoon scenarios in terms of preparedness and real time response to various kinds of droughts. Due to continuous efforts, alternate contingent crop seeds were made available to farmers for sowing in delayed monsoon areas thus bringing the agricultural lands into cultivation which otherwise would have remained fallow leading to distress in agriculture. Drought proofing through contingency plan implementation consists land treatments, cover crops with pre-monsoon summer rains, tank silt application, normal/ contingency seed arrangements with needed inputs and crop management strategies in the case of delay in onset of monsoon (drought tolerant, short duration cultivars, alternate crops, intercrops, changes in plant population etc.), mid-season droughts (thinning, mulching, foliar sprays, life saving irrigation of harvested rain water) and terminal drought (life-saving irrigation, harvesting for fodder) with suitable post rainy *rabi* action plan depending upon rains received at the end of the season or in the off-season. If implemented properly, the contingency plans ensure stable food production and sustained livelihood in the rainfed drylands and contribute to country food security.

Keywords: District agriculture contingency plans, Drought proofing, Climate change, India

Introduction

The rise in temperature of the earth surface and in atmosphere, fluctuations in rainfall, flooding due to high intense rainfall events, frequent droughts, high velocity winds, sea level rise due to melting of glacier, increased frequency of severe cyclones, unseasonal heavy rains, hail storms etc., are all the clear evidences of climate change phenomenon. Though, it is a natural process, but in recent years, the process is hastened due to human activities. Many examples across countries make it evident that growing population, rapid urbanization, higher industrialization, use of modern technology, improper crop management practices, economic development, building construction, reduction in forest area, etc. have significantly contributed to climate change. The extreme weather events are climatic anomalies, which have major impact on food and nutritional security of human and animal populations. In recent times the frequency of these events is increasing causing enormous damage not only to agriculture but also to other sectors like horticulture, livestock, poultry and fisheries (Figure1).

The projected increase in droughts, cyclones, extreme precipitation events and heat waves will result in greater instability in food production. Reduction in number of rainy days, heavy rainfall events, late on-set of monsoon, mid-season droughts etc. have been witnessed in recent years, adversely affecting the crop production. At country level, during last 15 years, 7 years recorded lower than normal rainfall, 6 years recorded more than normal rainfall and 2 years recorded average rainfall (Srinivasrao and Rao, 2016). The deficit was more than 10% in 6 years (i.e. 2001, 2002, 2004, 2009, 2014 and 2015) with maximum deficit being 23% in 2009 followed by 19% during 2002. The increased incidences of extreme weather events (Table 1) as witnessed in recent decades pose serious challenges to sustaining agriculture and this could be attributed to climate change.

Table 1. Southwest monsoon rainfall (SWMR) departure from normal and extreme weather events during 2001-2015 in India

Year	SWMR departure (%)	Extreme events
2001	-15	**Drought**
2002	-19	Twenty days heat wave during May 2003 in Andhra Pradesh
2003	+2	Extreme cold winter in the year 2002-03
2004	-13	Abnormal temperatures during March 2004; **Drought** like situation in India in July 2004
2005	-1	Flood in 2005
2006	-1	Cold wave 2005-06; Floods in arid Rajasthan and Andhra Pradesh, and **drought** in North-Eastern regions in 2006
2007	+5	Abnormal temperatures during 3rd week of Jan to 1st week of Feb
2008	-2	None
2009	-23	Severe **drought** 2009 all over India
2010	+2	One of the **warmest** years
2011	+1	Failure of September rains in Andhra Pradesh
2012	-8	**Drought** in Punjab, Haryana, Gujarat and Karnataka. Cyclone, floods in Andhra Pradesh
2013	+6	Floods in Uttarakhand, Phalin cyclone, and hailstorms
2014	-12	Delay in onset of monsoon by 40-50 days
2015	-14	Normal onset but midseason **drought** for 50 days

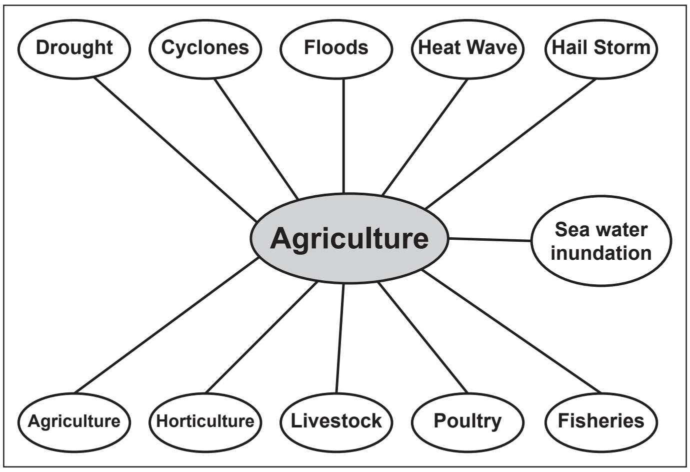

Figure 1. Weather aberrations and affected agriculture sector

District Agriculture Contingency Plan (DACP)

District level contingency plans are technical documents containing integrated information on agriculture and allied sectors (*i.e.,* horticulture, livestock, poultry, fisheries) and technological solutions for all the major weather related aberrations including extreme events *viz.,* droughts, floods, heat wave, cold wave, untimely and high intensity rainfall, frost, hailstorms, pest and disease outbreaks and are aimed to be utilised by district authorities. A standard template was developed in consultation with all stakeholders to cover prevailing agro-ecological situations in the district, possible in-season contingencies and suggested adaptive strategies. The challenge was to bring uniformity through a single standard template for the purpose of digitalization for retrieval and at the same time to accommodate the regional variations in climate and cropping systems (Venkateswarlu *et al.,* 2011, Srinivasarao *et al.,* 2015). The template consisting of two parts deal with (a) agricultural profile of a district with information on resource endowments such as rainfall, soil types, land use, irrigation sources, more dominant crops and cropping systems along with their sowing windows; livestock, poultry and fisheries information; production and productivity statistics; major contingencies faced by the district and digital soil and rainfall maps; and (b) the detailed strategies for weather related contingencies anticipated in crops/cropping systems such as delay in onset of monsoon of different duration; mid-season monsoon breaks resulting in drought both in rainfed and irrigated situations and adaptation strategies for weather related extreme events. These contingency plans contain information on alternate crop varieties/ crops to be chosen in case of delay in onset of monsoon or early season drought and also on agronomic measures for mid and terminal season droughts. Further, strategies for contingency situations in livestock, poultry and fisheries have also been included (Umate *et al.,* 2011; Prasad *et al.,* 2012; Rajendra Prasad *et al.,* 2013). Various components of contingency plan (Table 2) and an example of contingency measures in terms of crop variety change to be followed for delay in onset monsoon are given in Table 3.

Table 2. Components in DACP Standard Template

Part 1	Part 2
District agricultural profile at a glance	**Strategies for weather related contingencies**
*Agro-climatic / Ecological zone	***Drought-rainfed situation**
*Rainfall –Seasonal, total, rainy days	• Early season drought
*Land use	• Delay in onset by 2, 4, 6 & 8 weeks
*Soils	• Normal onset of monsoon followed by early, midseason and terminal drought
*Gross and net sown area	***Drought-irrigated situation**
*Irrigation – gross area, net area	• Delayed release of water due to low rainfall
*Major field and horticultural crops	• Limited release of water due to low rainfall
*Livestock- large and small ruminants	• No release of water in canals
*Poultry	• Lack of inflows into tanks
*Fisheries	• Insufficient groundwater recharge
*Production & productivity of major crops	***Unusual rains (untimely/unseasonal) for both rainfed and irrigated situation**
*Sowing window	* **Floods**
*Major contingencies in the district	* **Hailstorm**
*Location map and soil map of the district	* **Heat wave/ cold wave**

Table 3. Suggested contingency measures to be followed during delayed monsoon in Mahabubnagar district of Telangana; Major farming situation: Rainfed, Red soils

Normal: Monsoon onset time, crop (and cultivars)	**Suggested contingency crops/ cropping systems and cultivars**			
Normal onset (2nd week of June)	**Delay by 2 weeks (4th week of June)**	**Delay by 4 weeks (2nd week of July)**	**Delay by 6 weeks (4th week of July)**	**Delay by 8 weeks (2nd week of August)**
Maize (DHM-103,105,113)	Maize (DHM -103,105,113)	Maize (DHM -109, 115, Prakash)	Pigeonpea (PRG-158, Lakshmi, Maruthi)	Pearl Millet (ICTP-8203,ICMV-221, HHB -67)
Castor	Castor (Kranthi, Jyothi, GCH -4,6, DCH-519)	**Castor + Pigeon pea(1:1)** Castor (GCH-4,6 , DCH-519) Pigeonpea (Maruthi, Lakhshmi, PRG -158)	**Castor + Pigeon pea (1:1)** Castor (Kranthi, Jyothi, Kiran) Pigeonpea (Durga, PRG -100)	**Castor + Pigeon pea (1:1)** Castor (Kranthi, Jyothi, Kiran) Pigeonpea (Durga, PRG -100)
Pigeon pea	Pigeonpea (LRG-41, Maruthi, Abhaya)	Pigeonpea (Maruthi, PRG- 100)	Pigeonpea	Pigeonpea (Maruthi, Lakhshmi, PRG -158)
Groundnut	Groundnut (Vemana, Prasuna, ICGV-91114)	**Castor +Pearl Millet / Finger Millet** (1:1)	Pigeonpea	Castor + Pigeonpea (1:1)
Sorghum	Sorghum/ Sorghum + **Pigeonpea Sorghum** (PSV-1, Palem-2, CSV-15, CS-4,18)	Pearl Millet (ICTP-8203, ICMV -221, HHB-67, RHB -121)	Pearl Millet (ICMH-67, RHB -121)	**Castor + Pigeonpea (1:1)** / Horsegram Horsegram (PZM-1, VHG-62, VHG -9)

Process of preparation

Department of Agriculture and Cooperation (DAC), Ministry of Agriculture requested the Indian Council of Agricultural Research (ICAR) in the ICAR-DAC interface meeting to take up the responsibility of preparing contingency plans at district level for all the 126 agro-climatic zones of the country to deal with weather related aberrations.

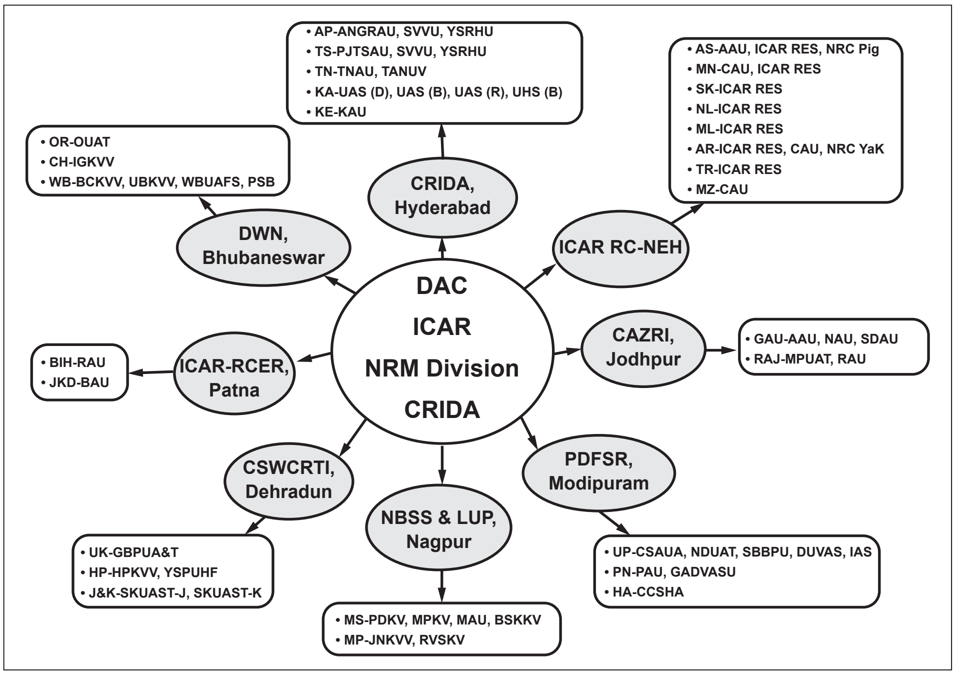

Figure 2. Process of preparation followed for District Agriculture Contingency Plans (DACPs) for different states (AP- Andhra Pradesh, AR-Arunachal Pradesh As-Assam, BIH- Bihar, CH-Chhattisgarh, GAU-Gujarat, HA- Haryana, HP- Himachal Pradesh, J&K- Jammu and Kashmir, JKD- Jharkhand, KA- Karnataka, KE-Kerala, ML-Meghalaya, MN- Manipur, MP-Madhya Pradesh, MS-Maharashtra, MZ-Mizoram, NL-Nagaland, OR-Orissa, PN-Punjab , RAJ-Rajasthan, SK-Sikkim, TN- Tamil Nadu, TR-Tripura, TS- Telangana, UK-Utaranchal, UP-Uttar Pradesh, WB-West Bengal) of India.

At ICAR, the Natural Resource Management (NRM) division was entrusted with this task and ICAR-CRIDA, Hyderabad was identified to act as the Nodal Institute with the overall responsibility of planning, coordination and submission of the district level plans. Regional level coordination was done by ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur (Western Region); ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar(Eastern Region); ICAR-Indian Institute of Farming Systems Research (IIFSR), Modipuram (Northern Region) and ICAR Research Complex for NEH, Barapani (North-eastern Region) and ICAR-CRIDA, Hyderabad with an additional responsibility for the Southern Region. Further, ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur; ICAR-Indian Institute of Soil & Water Conservation (IISWC), Dehradun and ICAR Research Complex for Eastern Region (RCER), Patna were roped into the activity for scrutiny of some plans. Five regional orientation workshops were conducted for nodal officers of state agricultural universities (SAUs) covering all states.

Following the regional orientation workshops during the year 2010, respective SAUs along with *Krishi Vigyan Kendras* (KVKs) prepared the district contingency plans. Vetting workshops were organized in different states to scrutinize and finalize the plans in the presence of ICAR institutes and respective university authorities.

Status of Contingency Plans

The district based contingency plans have been prepared for 614 districts in the country and hosted on ICAR / DAC websites (http://farmer.gov.in/, http://agricoop.nic.in/acp.html, http://crida.in/) and circulated to all state agriculture departments. Distribution of completed districts and state-wise number of districts for which the plans have been made is given in following Figures 3&4.

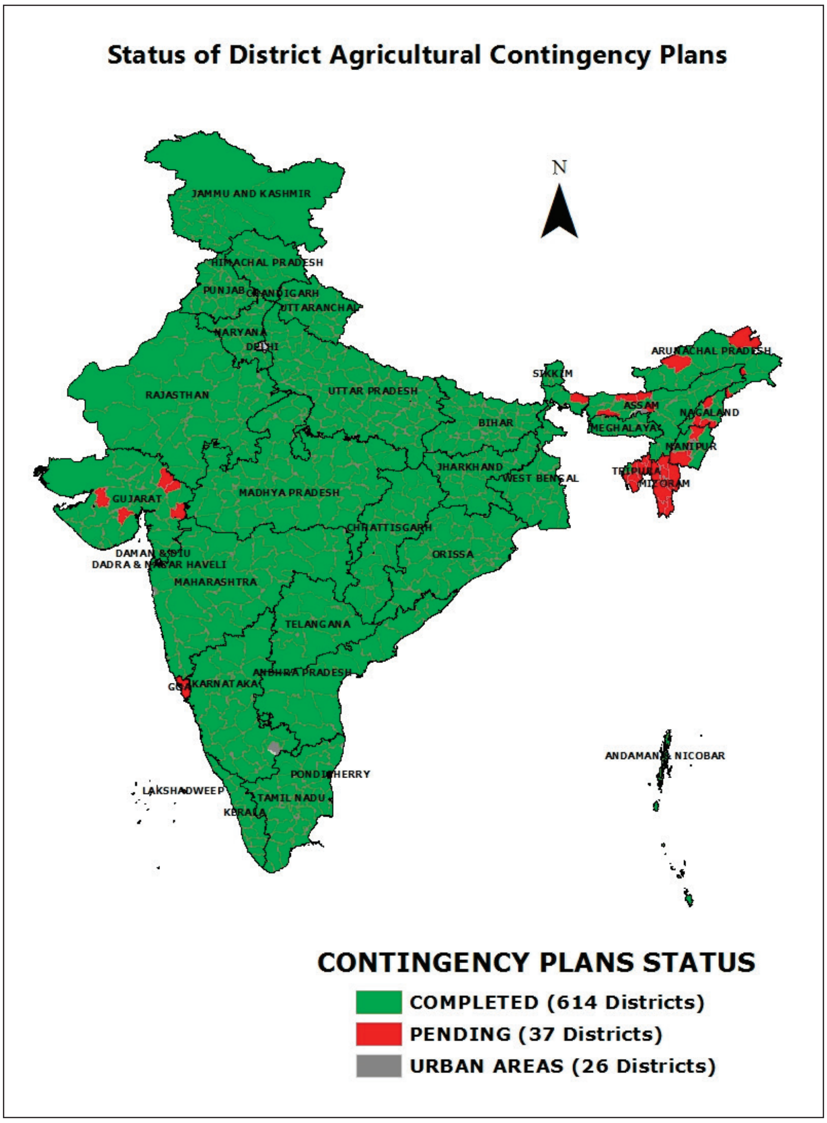

Figure 3. Status of district agricultural contingency plans as on May, 2016

Figure 4. Region and state-wise district agricultural contingency plans developed till date (2016).

Implementation process

Implementation of contingency plans requires extensive planning both at district and state levels, which needs to be coordinated and facilitated by several departments of Government of India. Currently, at the Government of India level, the Crop-Weather Watch Group, under the Ministry of Agriculture, monitors the weather situation and helps the other departments under the ministry to coordinate the preparedness for droughts and other contingencies. At the state level, the Commissioner, Department of Agriculture, Planning Department/ Disater Management Authority monitor the weather situation. At district level, the information on weather along with progress of sowings and storage of water in different reservoirs is collected through the state planning department cells located at the *taluk* /*mandal* level. Based on this information, weekly reports are prepared and consolidated at district/state level. By and large, this process is in operation in many states. In most states, the Relief Commissioners/ Commissioners of Department of Agriculture coordinate the overall implementation of the contingency plans during droughts, floods and other natural hazards after notification by the respective state Governments. In case of droughts, it is the Department of Agriculture, which is vested with responsibility of monitoring of the weather and crop sowings and initiating suitable contingency measures. Notification of drought-affected areas is made in association with revenue department. Such measures are basically targeted to save the crop season and minimize the losses with some broad interventions at the agro-climatic zone or district level.

Though it may take some time to an state government to declare drought, the district team needs to gear up with appropriate adaptation measures based on theinformation on rainfall and progress of sowings collected continuously during the season. Similarly, in case of command areas, delays in water release can be assessed based on inflows into and outflows from reservoirs. In case of floods due to sudden release of water from reservoirs, the district team needs to coordinate with irrigation authorities to ensure controlled release of surplus waters which otherwise may cause submergence of crops.

In order to make use of plans on near real-time basis, interface meetings were organised with concerned line departments of the State Government before the commencement of *kharif* season, 2014 in Patna (Bihar), Ahmedabad (Gujarat), Jaipur (Rajasthan) and Bangalore (Karnataka).

Following the forecast of Indian Meteorological Department in April, 2015 about the possible deficit rainfall during south-west monsoon, immediately a high level national consultation meeting was held at ICAR-CRIDA, Hyderabad on 24th May, 2015. This was followed by a state-wise interface meetings in 12 states across India with department of agriculture, KVKs, SAUs, seed agencies and other stakeholders, conducted jointly by DAC and ICAR in various states. The deliberations covered drought management, suggested alternative crops, seed availability, and preparedness strategies of line departments.

During the year 2016, though the Indian Meteorology Department (IMD) predicted above normal rainfall for the country, the seasonal forecast across states indicated the eastern region might be receiving less than normal rainfall and western region might receive above normal rainfall which called for different ways of preparation i.e. to address mid-season/late season droughts, high rainfall events and to enhance the cropping area and possibility of increasing cropping intensity.

Figure 5. Interface meetings to enhance the preparedness for agriculture contingencies.

The DACPs, due to their wide coverage in terms of sectors and weather aberrations, could be implemented through different developmental initiatives (Figure 6).

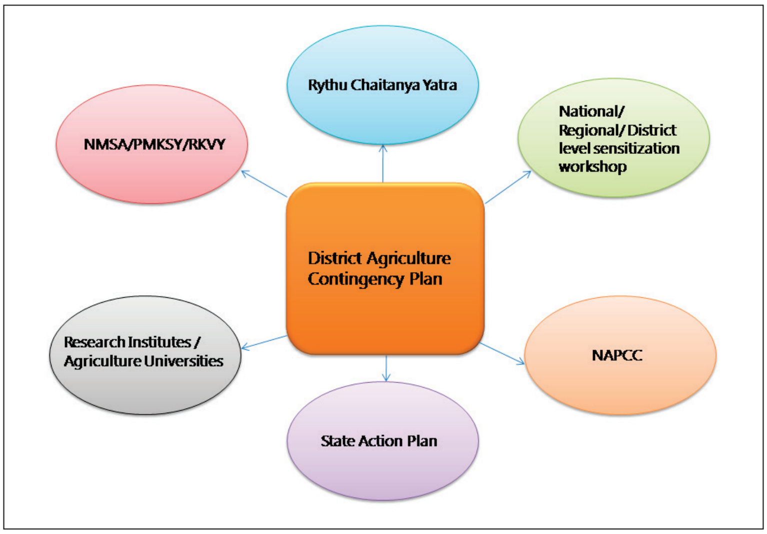

Figure 6. Implementation strategies of contingency plans through national programs.

As part of making the agriculture plans more dynamic, a plan for post rainy season (*rabi* season) is prepared for enhancing the crop production in the season through suggestion of alternate crops such as pulses, oilseeds etc. A process has been developed to assess the ground water recharge based on weekly rainfall and its deviation from normal and suggestions were made on cropping pattern to be followed (Srinivasarao *et al.,* 2014; Srinivasarao *et al.,* 2015; Srinivasarao and Rao, 2016).

Impacts of contingency plan implementation

An effort was made to assess the process and impact of contingency plans during the year 2014-15**.** Aberrations in rainfall, especially in its distribution during crop season lead to droughts in many parts of the country. In 2014, the onset of monsoon was delayed and its progress across the country was erratic which impacted the sowing of food grain crops to an extent of 2.5 million ha. Though the deficit was 12%, the estimated reduction in production compared to 2013-14 was about 5.3% in total food grains and sector-wise 16.5% in oilseeds, 9.7% in pulses and 6.6% in nutritious cereals because of implementation of contingency plans.

The experiences of some of the states in implementing the contingency crop plans in consultation with SAUs and ICAR and their impacts are summarized below:

- Despite the deficit rainfall (-20 to -59% of normal) in 30 districts out of 51 districts in Madhya Pradesh during 2014-15 cropping season the total sown area in the state increased from 4.621 million ha to 5.471 million ha, resulting in total food grain production increase from 8.353 million MT to 9.599 million MT. Productivity of soybean, total oilseeds and total pulses in Madhya Pradesh increased from 0.733 to 0.937 t/ha, 0.52 to 0.6 t/ha and 0.75 to 0.94 t/ha, respectively.

- Though East Gujarat, Central Gujarat, Kutch & South Gujarat received 77 to 88% of normal rainfall during 2014-15, the impact of deficit rain on area and production during the year was negligible except for groundnut, sorghum and pearlmillet in Gujarat.
- The deficit monsoon situation during the year 2014-15 was managed in Karnataka by (a) encouraging the sowing of maize, cotton, pearlmillet in the unsown areas of sorghum, pigeonpea, groundnut and sunflower; (b) encouraging farming community to take up land configuration, soil management practices; (c) utilizing the common property resources for fodder production and drought safety net programmes i.e., crop insurance. Promotion of community nurseries for rice seedlings to overcome the delayed sowing of paddy on a village basis was the major intervention initiated to meet the demand of the entire village. Similarly, lining of ponds and strengthening of bunds were promoted for effective water storage in Jharkhand.
- Additional power supply for irrigation purpose to maize crop at critical growth stages in Warangal district, promotion of *in-situ* conservation measures, promotion of short duration rice varieties (MTU 1011 rather than 'Sonamasuri') in case of delay in monsoon, change in sowing practices in rice *i.e.,* direct seeded rice and drum seeded mechanism, crop diversification from cotton to soybean, green gram, groundnut, integrated farming systems as a flagship program in rain fed areas and practices of growing cotton with micro irrigation were some of the major interventions taken up during 2014-15 to overcome delayed monsoon in Telangana. Such real time responses and quick actions impact positively to protect the existing crop and bring overall stability to agriculture production systems (Srinivasarao *et al.,* 2013).
- *In situ* water conservation measures on large scale, micro irrigation technologies, high density planting of *desi* varieties of cotton, raising soybean with broad bed furrow technology, mulching in horticultural crops, sprinkler irrigation for soybean, hybrid pigeonpea promotion and use of greengram as substitute for soybean were the major interventions promoted during 2014-15 to overcome the adverse effects of delayed monsoon in Maharashtra.
- In Andhra Pradesh, during 2014-15, measures such as (a) campaign to sow the crops only after the soil soaking rains were received (b) widespread publicity about contingency crop plan through scrolls in all local TV channels (numbering 14) (c) promotion, on a mission mode, of direct seeded/ drum seeded rice cultivation covering 400,000 ha of rice cultivated area out of a total of 1.6 million ha (d) sowing of horsegram seed in unsown areas of groundnut in Anantapur district (e) growing fodder crops as intercrops in horticultural plantations, (f) flood waters diversions to Rayalaseema region to enhance the ground water recharge and to irrigate horticultural crops were taken up to overcome weather aberrations such as delayed monsoon onset and delay in release of canal water because of rain deficit.

Way forward

The overall implementation strategy of contingency plans involves (a) initial preparedness, (b) real time response to weather aberrations, and (c) relief and rehabilitation (Figure 7). The district agricultural contingency plans (DACP) are technical documents detailing the interventions to be taken up by individuals/line departments in the face of various weather aberrations.

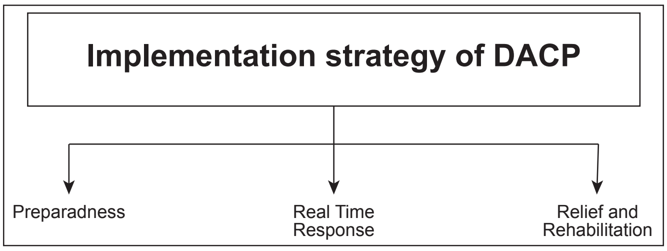

Figure 7. Key elements of implementation of DACPs.

With climate change looming large, as witnessed during last few years across different states in India, it is necessary to make these plans dynamic by updating the information on: (a) new technologies developed, (b) improved seed varieties, (c) linkage with new developmental programs and (d) experiences on handling the recent weather aberrations across states etc.

The way forward is addressed under research and development (R&D) and policy fronts.

Research and development front:

- Research to be initiated at state agricultural universities by simulating the contingencies and developing adaptation strategies to demonstrate the benefits to the farmers.
- Technological advances in other scientific fields to be dove-tailed with R&D efforts to develop efficient and cost-effective technologies.
- Research to be taken up on dissemination tools focused on spread of contingency adaptation measures with innovative extension approaches.
- Establishing multi-disciplinary teams at SAUs to respond to the technical requirements of the implementing line agencies.
- Enhanced research efforts across different states for reducing adverse effects of hailstorms, frost, unseasonal rains.
- Research on use of satellite-data for understanding the nature and extent of contingency situation to plan and implement the plan for the adaptation strategies.
- At the moment, the yearly agricultural plans at the district level are prepared considering the normal monsoon pattern. Such plans should be dynamic in nature and be prepared in consultation with State Agricultural Universities and ICAR institutes to make timely use of the new technologies being developed. They should be used as guiding principle and form the basis for identifying input requirement and mobilization for updating the district agricultural contingency crop plans from time to time. This will harmonize the efforts of all stake holders to transmit relevant agro advisory to the farmers.
- Since drought is a slowly creeping phenomenon and spreads across the areas during the season, it is necessary to develop protocols for initiation of interventions for drought occurring at different times in the crop growing season. For example, the duration of dry spell that would call for the initiation of drought measures would be smaller during initial season as compared to the mid season or terminal stage of crop growth. Similarly, the protocols would differ from crop to crop, and will have to take in consideration the soil type and local farming conditions.

- There is a need to identify drought prone districts/t*aluqs* utilizing the recent weather data and special emphasis need to be made for preparation of agricultural plans, process of implementation and effectively monitoring them by district/state authorities. The ICAR institutes/local agricultural universities can be made partners in the plan preparation and monitoring while the departments can be made responsible for implementation.
- Weather forecast plays an important role in preparation of agricultural plans. There has been a demand from state authorities for the forecast information for their respective states (and if possible for districts) on the seasonal forecast especially for precipitation (total and its distribution across months). At the moment the IMD provides forecasts on country/ regional basis before the commencement of season (April/May) and this serves only limited purpose. Concerted efforts need to be made to improve the advance forecast. Down-scaled forecasts and value-added services to the forecast will help both SAUs and the line deportments to efficiently utilize the information for agricultural planning.
- There is a need for interfacing mechanism at the district level with regional IMD centres in order to better utilize the weekly forecast at district level made by IMD and to provide advisories to farming communities. In the identified drought prone districts, the proposed contingency cell can have mechanism for better interaction with regional IMD centres for preparation and dissemination of agro advisories. With large scale spatial variability in rainfall (especially in low to medium rainfall zones), the IMD need to provide sub-district weather forecast which could well integrate with block level rainfall information being collected by state governments forming the basis for agro advisories preparation.
- Dissemination of information to farming communities on prevailing weather conditions, and support being provided by state and central governments is also very important. Without the required inputs and information reaching the farming community, any amount of preparedness would not benefit farming community. Hence, all the media such as TVs (local language), radio, internet, leaflets/brochures need to be utilized for disseminating the information to farming community.
- There is a need to create widespread awareness on agricultural insurance to farming community that can bring in the much needed assistance to farmers.
- The information technology should be extensively used for two-way communication i.e. for ground-truth information collection at a short-time as well as transmitting back the adaptation strategies. Drone-technology could also be used for gathering information under such circumstances.
- The digitization of cropped area across the country should be done on real-time basis. Such effort will help in not only prioritization of Research & Development activities based on extent of spread of the problem but also developing agro-ecological regional level policies to combat the effects of weather aberrations.

Policy front:

- There is a need to bring a change in the planning process at the district level. The present mechanism of plan preparation does not address the issues of climate variability/ change. The new method should reflect the area targeted for contingency implementation, necessary inputs requirement, particularly for contingency crop seeds, for delay in monsoon onset by different durations, other inputs such as nutrients, chemicals etc. for foliar spray, their availability and pricing, distribution mechanism, diesel pump sets for providing critical irrigation, location of water sources for mobilizing required water for sprays, irrigation etc. on village/*taluk* basis, and aggregating to district level. These are the minimum requirements to address weather aberration scenarios such as droughts, floods, unseasonal rains etc.

- A long term strategy is needed for seed multiplication for contingency groups/ self- help groups/ *rytu sangams* etc.
- Establishment of agricultural contingency cells at district levels in the department with staff from other sectors such as Dairy, Horticulture, Ground Water etc. These cells need to be vested with responsibility to monitor the unfolding agriculture scenario in different seasons and initiate the plans as and when necessary and providing inputs to the respective departmental heads in the implementation of plans.
- These DACPs should also indicate the developmental projects/schemes, which could be leveraged to provide funds for various interventions during the implementation process of contingency plans. This is an essential requirement as projects /schemes such as IWMP, MGNREGA, PMKSY etc. are implemented by departments such as Rural Development, Water Resources etc., and each state has a different process of implementation.
- Among the weather aberrations witnessed, floods, hailstorms, un-seasonal rains etc., provide little time for responding with relief measures. Gearing up the line departments and farming community to overcome impact of these events, it is essential to empower the line departments with a flexible fund to immediately start the response measures in the affected areas. Districts could be prioritized for these purposes and funds could be provided accordingly.

Conclusions

In order to address the climate variability/ change, a coordinated effort by Ministry of Agriculture, Indian Council of Agriculture Research through NARES along with state department of agriculture was started on a continuous basis to provide suitable contingency plans. The preparation and implementation of contingency plans is the way chosen by both federal and state governments as an important adaptation measure to make the agriculture sector more resilient in the country. Anticipatory research will have to be conducted to prepare effective contingency plans in a proactive manner so that timely implementation could occur as soon as a contingency arises. With time, thorough protocols would have to be put in place where by meteorological division and agricultural research systems provide valuable inputs through advisories to farmers through real-time collection and analysis of weather data at micro level and the support for implementation of advisories would have to be ensured by extension agencies.

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Plenary Session 4

1. Crop diversity - a prerequisite for food security

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Abstract

A growing world population and a constantly changing climate is challenging the global community's ability to feed the world. The clear message from the International Panel on Climate Change is that business as usual is not an option. The world requires more and more nutritious food while a business as usual scenario would reduce food production over the next years. Agriculture is probably facing its biggest challenge ever. We need game changers in the way we do agriculture. The diversity contained within plant genetic resources provides a universe of untapped possibilities. It holds the variability needed for adaptation, and has the potential to serve as a key element in maintaining food production under novel temperature, precipitation, pest and disease conditions. This diversity is increasingly threatened, and there is an urgent need to collect and secure plant genetic resources for the global community.

Keywords: Plant genetic resources, Genetic diversity, Climate change, Food security

2. Exploitation of useful genes in wheat-wild species for sustainable agriculture in dry areas to achieve SDGs

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Abstract

Wheat related wild species are potential source of genes to improve bread wheat. However, these genes have not always been evaluated properly as the traits of bread wheat. We introduced a chromosome or its segment to the genetic background of wheat cultivars. We evaluated alien chromosome addition lines, translocation lines, and multiple synthetic derivative population and found the useful characters as biological nitrification inhibition, bread-making quality, heat stress tolerance, aluminum tolerance and others. This article reviews the efforts of gene exploitation in wheat prebreeding mainly based on our research.

Keywords: genetic resource, germplasm, climate change, drought, breeding

1. Introduction

Since the Green Revolution in the 1960s, wheat has been improved to produce high yields in response to high inputs of water and fertilizers. As a result, production has tripled. Reduced-height or semi-dwarfing genes (*Rht1*, *Rht2*, and *Rht8*) were key to this breeding process. These genes were derived from the Japanese wheat cultivars 'Norin 10' and 'Akakomugi'. The distant origin of these genes from the birthplace of wheat shows the importance of exploring novel genes. To secure enough food for the world's still-increasing population, more productive wheat cultivars must be bred. Continued increases in yield have slowed down because of the ubiquity of improved semi-dwarf cultivars around the world and the lack of new genetic variation in the wheat gene pool. Thus, it is important to exploit novel germplasm for breeding, while recognizing the unsustainability of high-input agriculture under the new reality of scarce water and fertilizers. This paper describes efforts at the Arid Land Research Center to find useful genes from related wild species kept in gene banks.

2. Species crossable with wheat

Wheat is the collective name of several species in the genus *Triticum*, tribe Triticeae, family Poaceae. These species are classified into diploid, tetraploid, and hexaploid species, all sharing genome A, and include the economically important bread wheat (*T. aestivum*, $2n = 6x =$ AABBDD) and durum wheat (*T. durum*, $2n = 4x =$ AABB). Genomes B and D originated from species of the genus *Aegilops*, indicating that wheat arose by intergeneric hybridization. Spontaneous intergeneric hybrids can be seen in bread wheat fields where *Aegilops* species grow as weeds. However, gene transfer from *Aegilops* to hexaploid bread wheat is blocked because the hybrids, which do not have paired genomes, are sterile. Bread wheat is also crossable with rye (*Secale cereale* $2n = 2x =$ RR), *Dasypyrum villosum* ($2n = 2x =$ VV), and *Thinopyrum elongatum* ($2n = 2x$ = EE), and hybrids are easily produced. Although bread wheat genotypes in East Asia as 'Chinese

Spring' are easily crossed with these species, genotypes in Europe and West Asia are difficult to cross because these hold the *Kr* gene, which inhibits interspecific hybridization.

Using embryo rescue techniques, researchers can produce hybrids between bread wheat and more distant relatives within the tribe Triticeae such as barley (*Hordeum vulgare*, $2n = 2x$ = HH) and *Elymus tsukushiensis* ($2n = 6x$ = StStHHYY). We have made hybrids using *Leymus racemosus* and *Leymus mollis* (both $2n = 4x$ = NsNsXmXm); these species are vigorous perennials with strong rhizomes that grow on sandy beaches, and are recognized as promising germplasm for wheat improvement (Kishii *et al.,* 2004; Habora *et al.,* 2013; Gorafi and Tsujimoto, 2016). It is probable that all species within the Triticeae can be crossed with wheat by embryo rescue. In contrast, there are no reports of hybrids between wheat and non-Triticeae species; for example, when the pollen of non-Triticeae species such as Job's tears (*Coix lacryma-jobi*), pearl millet (*Pennisetum glaucum*), and maize (*Zea mays*) is used, only wheat haploids appear (Mochida and Tsujimoto, 2001; Mochida *et al.* 2003; Ishii *et al.,* 2010).

2. Production of alien chromosome addition lines

Once F_1 hybrids between bread wheat and wild species are produced by natural interspecific cross or embryo culture, the next step is backcrossing them to bread wheat to generate alien chromosome addition lines that have only one or a pair of alien chromosomes. Colchicine treatment in the embryo is used to double the chromosome number of the F_1 hybrids and to make amphidiploids. If doubling is difficult, the F_1 hybrids can be crossed with wheat, skipping the doubling procedure (Kishii *et al.,* 2004, 2010). The BC_1F_1 plants which has AABBDD genome and each one genome of related species (e. g., AABBDDNsXm), are further backcrossed with bread wheat, and plants with an alien chromosome are selected by chromosome markers (chromosome shape, banding pattern, or *in situ* hybridization signals) or DNA markers specific to the chromosome. The plants with a single alien chromosome will be self-pollinated and disomic addition plants with a pair of alien chromosome will be selected. We have produced many alien chromosome addition lines by this method or were presented by the other genebanks. The alien chromosomes in the disomic addition lines are stable and maintained in Tottori Alien Chromosome Bank of Wheat (TACBOW) supported by National Bioresource Project (NBRP)-Wheat in Japan.

3. Germplasm enhancement by alien genes

Using alien chromosome addition lines, we are able to evaluate the effects of alien genes on wheat traits. For example, we can study the effect of seed storage proteins of wild species on bread-making quality. Without these lines, it is almost impossible to evaluate traits by using the seeds of wild species because the seeds are too small to mill into flour. Instead, we selected addition lines that have specific high-molecular-weight glutenin subunits and milled their seeds. SDS (sodium dodecyl sulfate) sedimentation analysis of the flour indicated that some lines would have better bread-making performance than 'Chinese Spring', their genetic background (reviewed in Garg *et al.,* 2009a). Among the lines that we investigated, *Th. elongatum* chromosome (Chr.) 1E gave the best improvement. So we made a translocation chromosome in which the long arm of Chr. 1A (1AL) was replaced by that of Chr. 1E (1EL) and introduced it into the genetic background of a practical cultivar, 'Norin61' (Garg *et al.,* 2009b; H. Tanaka, Fac. Agr., Tottori Univ., pers. comm., 2016).

In the presence of ammonium-nitrogen fertilizer, *L. racemosus* inhibits the growth of nitrifying bacteria in soil (reviewed in Subbarao GV *et al.,* 2009; Subbarao SV *et al.,* 2007). Wheat does not have this biological nitrification inhibition, but some addition lines with *L. racemosus* chromosomes do. These lines will permit the breeding of nitrogen-saving wheat. We also found phosphorus-saving lines (Wang *et al.,* 2010), heat- or aluminum-tolerant lines (Mohammed *et al.,* 2013, 2014), and lines with higher iron or zinc contents in the kernels (Wang *et al*., 2011). Some addition lines showed chromosome breakage and transposon movement, which may have been induced in the wheat genome by the alien chromosomes (reviewed in Tsujimoto, 2005; Gorafi *et al.,* 2016).

To use alien genes for wheat improvement, we need to incorporate alien chromosome segments into wheat chromosomes by translocation or by homoeologous chromosome pairing and recombination. We produced an inducer of homoeologous recombination that has the Ph^{I} gene, which originated from *Aegilops speltoides* (Chen *et al.,* 1994).

4. Potential of synthetic hexaploid wheat for germplasm enhancement

If a useful gene is found in the A, B, or D genome, it can be introduced into the bread wheat genome by ordinary recombination in meiosis. *Aegilops tauschii* ($2n = 2x =$ DD) is widely used in breeding based on synthetic hexaploid wheat (SHW) as the bridge with bread wheat. SHW is amphidiploid between durum wheat and *Ae. tauschii*, the same cross combination as occurred in the original generation of bread wheat. Many SHWs have been produced from different accessions of *Ae. tauschii* and are used in breeding for pest tolerance and quality improvement (Ogbonnaya *et al.,* 2013).

5. Production of population to utilize intraspecific variation in *Ae. Tauschii*

Superior quantitative traits that appear in the genetic background of wild species will not necessarily be reproduced in the genetic background of bread wheat. We found large variation in drought-related traits among accessions of *Ae. tauschii*, but the traits did not appear in the corresponding SHW lines (Sohail et al. 2011); the most drought-tolerant *Ae. tauschii* accessions did not lead to the most tolerant SHW lines. Furthermore, we found it impossible to measure the drought tolerance of SHW in terms of yields because the spikes were too hard to thresh (Tsujimoto unpub.). Therefore, to evaluate the traits of SHWs, we made crosses between many SHWs with the bread wheat cultivar 'Norin 61' and backcrossed the offspring with 'Norin 61'. We mixed the BC_1F_1 seeds and maintained the resultant 'multiple synthetic derivative' (MSD) population as a bulk for several generations to fix the genes. Using this population, which holds the intraspecific diversity of *Ae. tauschii* in the genetic background of 'Norin 61', we can reliably select desirable genes of *Ae. tauschii* (Tsujimoto *et al.,* 2015).

6. Selection of useful genes from MSD population

To select genes for heat stress tolerance, we grew the MSD population in a heat-stressed field of the Agricultural Research Corporation, Sudan. Although plants from this population had similar morphology to each other in Japanese conditions, they showed large variation in Sudan. We selected lines that showed heat tolerance and analyzed their performance in temperature-controlled chambers. Some of the lines showed improved chlorophyll contents and photosynthesis under 'heat stress' (Elbashir *et al.,* 2017). Many diversity arrays technology (DArT) molecular markers revealed chromosome segments of the SHWs and 'Norin 61'. These lines are suitable materials for use in identifying QTLs and for investigating the physiological mechanisms of heat stress tolerance.

7. Concluding remarks

Germplasms of related species were frequently used in the history of bread wheat breeding. The most famous germplasm may be the short arm of rye Chr. 1R (1RS). The 1RS.1BL translocation chromosome has been widely used in wheat breeding for its conferral of multiple disease resistance and high yields. However, it has become unpopular because 1RS carries inferior genes for bread-making quality. Recently, Chen et al. (2013) created a chromosome carrying a gene for powdery mildew resistance from Chr. 7V of *D. villosum*. Several cultivars carrying this chromosome are now widely grown in China. To use genes from related species, cytogenetic techniques are necessary. In addition, deleterious genes linked to useful genes are problematic because of linkage drag. These problems are easily overcome by the availability of genomic markers allowing many individuals to be genotyped. Thus, advanced genomic research is a very important means for exploiting highly heterogeneous genetic resources.

In the Green Revolution, the use of semi-dwarfing genes and the application of nitrogen fertilizer achieved great increases in yields. The semi-dwarfing genes common in bread wheat arose in Japan, far from the center of diversity of wheat. Likewise, genes that will support agriculture under the era of climate change may be found in related wild species. It is time to explore the heterogeneous genetic resources now stored in gene banks.

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3. Paddy cultivation in dry regions - Implication and future directions

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Abstract

Paddy cultivation plays a significant and vital role in rice production. Most of the global population depends on the 480 million tons of rice produced each year as the basis for their lives. While about 90% of the world's 160 million hectares of paddy fields are in Asian countries, mainly in monsoon regions, paddies are also seen in North America and Africa, even in dry regions where irrigation has reclaimed dry land for paddy fields. Most of paddy fields are inundated naturally or artificially during rice production period. In the case that paddy fields are kept submerged artificially, some infrastructures like water intake and diversion devices and canals are required. Paddy fields with irrigation system produce traditionally high yields of rice, taking benefits of stable water supply and continuous ponding. Paddy fields simultaneously perform other functions for local environment, including climate mitigation, flood control, groundwater recharge, bio-diversity and ecosystem development, etc. Recently, these are recognized as the multi-functions of paddy fields. The sustainable water delivery and ponding has established local water management society, which is mainly represented by organization of water users, usually farmers. This society or organization could work not only for paddy cultivation but also for managing the total rural life of the region. On the other hand, since paddy fields require much water and modify the original and natural hydrological regime, they might cause adverse effect on local environment. Irrigation sometimes needs drainage system, which also might alter local water balance. Especially paddy fields in dry land, and even in dry condition in humid region, might modify hydrological regime to much extent inducing problems with too less water in some areas and too much water in others. In this paper, paddy cultivation in dry region is reviewed comprehensively with various aspects, for establishing much sustainable system.

Keywords: Paddy rice, Submerged paddy cultivation, Upland rice, Irrigation

1. Introduction

1.1 Paddy field as a farmland with rice and flooded water

To define "paddy field" is a bit intricate. Fundamentally "paddy" means "rice" especially in the husk. Consequently, a "paddy field" means a filed planted with rice. Some dictionaries describe that only "paddy" could mean "paddy field". Since rice is usually grown in level basins flooded with water throughout most of the growing season, paddy field generally means "a field planted with rice growing in water" or "flooded field where rice is grown". Actually, in some areas in the world, rice is cultivated without flooding. In this paper, "paddy field" is used as just "a field planted with rice". Paddy fields in dry lands or dry areas are basically irrigated and flooded due to shortage of rainfall, and then, paddy fields in this paper imply flooded fields.

Production of rice is one of the most important agricultural activities on the earth, and rice farming, or paddy field, is the largest food producing land use of the world, resulting in the total 696 million tons of rice in 2010, of which 90% was in Asian countries and of which only 7% was exported from its producing countries.

1.2 Paddy fields in the world and in dry regions

The “Rice Almanac” of IRRI summarizes the present rice-growing area of the world (GRiSP, 2013). Rice is produced in a wide range of locations and under a variety of climatic conditions, from the wettest areas in the world to the driest deserts. It is produced along Myanmar’s Arakan Coast, where the growing season records an average of more than 5,100 mm of rainfall, and at Al Hasa Oasis in Saudi Arabia, where annual rainfall is less than 100 mm. Temperatures, too, vary greatly. In the Upper Sind in Pakistan, the rice season averages 33 °C; in Otaru, Japan, the mean temperature for the growing season is 17 °C. The crop is produced at sea level on coastal plains and in delta regions throughout Asia, and to a height of 2,600 m on the slopes of Nepal’s mountains. Rice is also grown under an extremely broad range of solar radiation, ranging from 25% of potential during the main rice season in portions of Myanmar, Thailand, and India’s Assam State to approximately 95% of potential in southern Egypt and Sudan.

Rice occupies an extraordinarily high portion of the total planted area in South, Southeast, and East Asia. This area is subject to an alternating wet and dry seasonal cycle and also contains many of the world’s major rivers, each with its own vast delta. Here, enormous areas of flat, low lying agricultural land are flooded annually during and immediately following the rainy season. Only two major food crops, rice and taro, adapt readily to production under these conditions of saturated soil and high temperatures.

The highest rice yields have traditionally been obtained from plantings in high-latitude areas that have long daylength and where intensive farming techniques are practiced, or in low-latitude areas that have high solar radiation and cool nights. Southwestern Australia, northern California, southern Brazil, Uruguay, and the Nile Delta provide the best examples. In some areas, such as South Asia, the crop is produced on miniscule plots using enormous amounts of human labor. At other locations, such as in Australia and the United States, it is raised on huge holdings with a maximum of technology and large expenditures of energy from fossil fuels. The contrasts in the geographic, economic, and social conditions under which rice is produced are truly remarkable.

This summary implies that rice production and paddy fields are developed in a wide range of environments even in the arid region of the world and during the dry season. The paddy fields in dry areas sometime show very high and stable yields with much solar radiation. Figure1 depicts the world rice producing areas with their regional average yields, where we find the distribution of paddiy fileds in the dry regions.

The paddy fields or the environments of the rice production are classified usually based on hydrological characteristics, since they are most essential condition to the production scheme. The most basic classification includes: 1) irrigated lowland, 2) rain-fed lowland, 3) upland, and 4) flood prone. Almost all paddy fields in dry region are irrigated, where rice is grown in bunded fields with irrigation. The fields are usually puddled and after that rice seedlings are transplanted. The bunded plots maintain 5 to 10 cm of water.

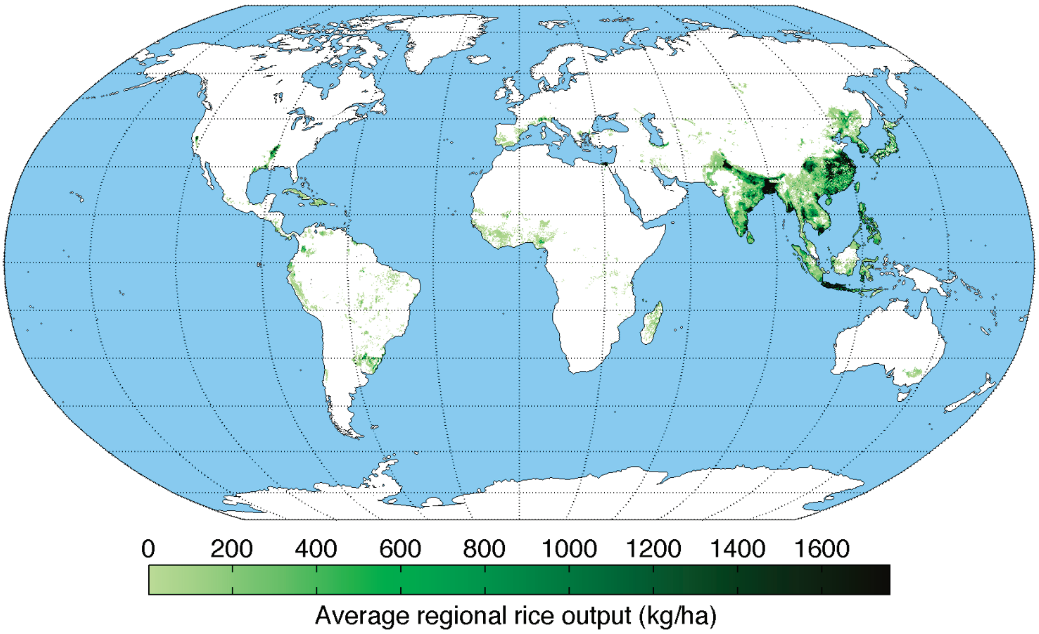

Figure 1. World rice producing area (Andrew, 2016).

1.3 Advantages of paddy cultivation

Paddy fields are usually flooded and require much water to maintain flooding, since ponded water evaporates into the atmosphere and seeps into the soil profile. Generally, in the dry region or dry condition, water availability is limited and consequently development of paddy production or paddy fields is avoided. Even with this constraint, actually there are many paddy fields in those conditions because of definite advantages.

Firstly, the people in the dry region like the taste of rice. Secondly, rice contains much nutrients compared with wheat and maize as main cereal crop. Calorie per grain weight of rice is larger than wheat and maize. Protein content of rice is less, but quality is better than other two cereals for human health. Maize contains more lipids, while rice and wheat have almost same content. In addition to the nutritional advantage of rice, land productivity of this crop is quite high, almost 1.5 times of wheat. Furthermore, rice can be cultivated every year continuously in the same field and the land used as paddy field can produce stable harvest. Rice grain is easy to cook and can be stored for longer period. Although paddy cultivation needs much labor in terms of time and efforts to maintain the bunded field and water management, its advantages promote expansion of paddy fields in dry region or condition.

2. Significance of water ponding in paddy fields

2.1 Water management in paddy plot

The main reason why paddy fields are flooded is that most rice varieties realize better growth and produce higher yields in flooded farmland than in dry field. In most cases, the water layer in a field is established after transplanting of rice seedlings and maintained until few weeks before harvesting. Figure 2 depicts a typical water management, especially the depth of flooding, for each growing stage (FAO, 1989).

Actual water management practices on water application and flood depth control are affected by field conditions including: 1) cultivar, 2) climate and weather, 3) soil profile (water holding capacity, permeability, fertility, etc.), 3) fertilizer and chemicals (pesticide and herbicide), 4) irrigation water availability (timing and quantity), 5) drainage capacity (water conductivity of soil profile, groundwater table, etc.), 6) farm machinery, 7) labor inputs, and 8) other farming techniques.

In the improved paddy field with stable water supply and enough drainage capacity, independent water management practices of farmers are implemented, where the farmers can apply and drain water whenever they want and they introduce advanced techniques and materials. Under these conditions, flooding period and depth is controlled considerably. For some periods, they drain water intentionally resulting in no submergence, which is called intermittent irrigation or flooding (Watanabe, 1995). If this kind of water management is practiced, water movement in the area would be accelerated and it would affect local hydrological regime.

2.2 Advantages and disadvantages of water ponding in paddy fields

The fact that rice is cultivated under water ponding condition in most cases implies the water ponding has the advantages even if it requires much water. Main advantages of the water ponding are: 1) stable water supply to rice, 2) suppression of weeds, 3) control of harmful insects, 4) control of temperature of rice and field (warm up and cool down), 5) supply of nutrients and control of fertilizer effects, 6) supply of necessary minerals, 7) avoidance of adverse effects of continuous cultivation, 8) leaching out accumulated salts, and 9) enhanced land productivity.

On the other side, the water ponding induces some adverse effects on rice production and local environment. They include: 1) soil reduction due to longer submergence resulting in shortage of oxygen and emission of undesirable gases like hydrogen sulfide and methane, 2) requirement of much work to maintain ponding in the fields, 3) much water requirement for maintaining ponding resulting in need for water resources development, 4) difficulty in introduction of heavier machineries due to increased soil water contents, 5) growth of undesirable insects like malarial mosquito, and 6) influence on local climate due to much evapotranspiration and modified ground surface temperature.

Consequently, taking both merits and drawbacks of water ponding into account, in addition to field irrigation and drainage conditions, actual water management in the fields is performed.

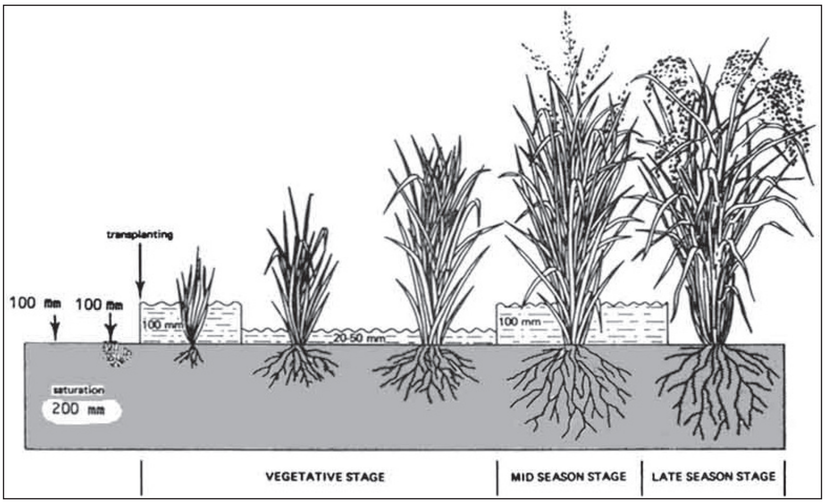

Figure 2. The depth of water layer during the growing season (FAO, 1989).

2.3 Water requirements for paddy irrigation

Water ponding in the fields requires much water. Water requirements of paddy fields compose mainly of transpiration of rice plant, evaporation from ponding water or soil surface, and percolation into soil profile. In some cases, requirement to re-establish water layer after intentional drainage and to implement flow-through irrigation for saving management labor or for control of temperature might be included.

For designing irrigation facilities and making water use plan, water requirement is basically estimated base on evapotranspiration of rice crop. Other demands are often recognized as "loss".

Table 1 Water requirement of paddy field per irrigation season (Watanabe, 1995)

Country or Region	Water Requirement mm/season	Remarks
Senegal	500-1,000	percolation: almost nil
Northern China	900-1,500	direct sowing: 1,200 to 1,500 mm, transplanting: 900 to 1,050 mm
Brazil	1,000	equivalent to 8.6 mm/d
Texas, USA	1,200	intake: 759 mm, rainfall: 432mm
Italy	1,600	
Australia	1,500-1,700	evapotranspiration: 1,200 mm
India	1,680	percolation: 1,200 mm
Cote d'Ivore	1,920	percolation: 5 mm/d
Egypt	1,800-2,500	
Japan	1,500-2,500	wide range of percolation: nil to 50 mm/d
Mayasia	2,810	evapotranspiration: 1,570 mm
Kazakhstan	3,930	
East Africa	4,500	intake: 3,600 mm, rainfall: 900 mm

(Note: Listed in order of the total amounts, Source: JSIDRE, 1995)

Table 1 shows the total water requirements for one irrigation season reported by JSIDRE (1995). The total requirements range from 500 mm in Senegal to 3,900 mm in Kazakhstan or 4,500 mm in East Africa. This wide range is caused fundamentally by the significant difference in the seepage rates, which are estimated as none at minimum and more than 30 mm/day at maximum. The effects of water management on water requirements are to be considered. Water requirement of paddy field in dry area, like in Egypt or Kazakhstan, is not always small compared with those of humid region.

3. Multi-function of paddy cultivation and irrigation

The water ponding for rice production needs much water and also irrigation and drainage system to supply and withdraw water to and from the fields. While the system, of course, should function well for local rice production, it could also perform well for improvement of local environment. It is called as "multi-function" of paddy cultivation. The functions are fundamentally based on 1) widespread establishment of stable and shallow water body for some specific period, 2) stable water supply, and 3) adjustment of local hydrological regime.

The outcomes of the multi-function include: 1) reduction of flood damage in a region or basin with water storage in the fields and acceptance of flood water, 2) control of soil erosion with bunds of flat fields, 3) stable groundwater recharge with continuous percolation from water layer in the fields, 4) mitigation of local climatic variability especially drastic temperature changes based on higher specific heat of water ponded in the field, 5) establishment of conditions for fish cultivation, and 6) establishment of habitats for wildlife including aquatic flora and fauna. Paddy cultivation and irrigation in dry area might create local water rich environment. This impact of the artificial modification on local hydrological regime could be much larger and critical to the sustainability of cultivation and irrigation development.

4. Typical examples of paddy fields in the dry regions: Egypt and Kazakhstan

In the dry region of the world, paddy fields have been developed extensively. Here, brief overviews of the cases of Egypt and Kazakhstan are presented including summary by GRiSP (2013) as follows.

Egypt is one of the typical countries that produce rice in dry area. It has a fast-growing population with 82.5 million in 2011 leading to increased food demand. Almost all of water demand in Egypt is supplied by the Nile River, of which water is used extensively to irrigate crops including rice. Rice is one of staple crops in Egypt; the consumption was 38.6 kg milled rice per person per year in 2009. Rice is grown in the summer on about 600,000 ha, mainly in the northern Nile Delta. The yield is quite high, about 9t/ha in 2000, due to abundant solar energy. The area for rice is officially regulated by the government due to limited water resources, while farmers prefer cultivating rice for its higher profit. The areas for producing rice located in the northern Nile Delta have potential risk of soil salinization. Paddy cultivation has been functioning to leach out accumulated salts in the soil profile. This is supported by prevailing subsurface drainage.

In Kazakhstan, where most of the land is classified as steppe or desert with annual average precipitation of 100-200 mm, wheat is a predominant crop in the northern part, whereas rice, cotton, fodder and fruit crops are produced in the southern part in summer season. Its cropped area had increased due to rapid land reclamation mainly in the Syr Darya Basin since the 1950s to the 1980s, and the irrigated land became one of the big food supplying sources of the Soviet Union and Eastern Europe in that period. While rice occupies only 5 to 6 % of the irrigated area, its water requirement is about 15% of the total irrigation requirement in that period. Most of the rice cropping area in Kazakhstan is distributed mainly in the Kzyl-Orda area of the Lower Syr Darya River Basin and some in the Ili River basin. The present total rice area is about 113,000 ha, which is equivalent to 17% of the total irrigated area. In the irrigated area in Kazakhstan, the crop rotation system is dominantly practiced with several rotation patterns, and rice is grown usually in this crop rotation system.

In Kazakhstan, large-scale irrigated agriculture has been developed since the 1960s with crop rotation including rice. In the irrigation scheme, water is applied only to paddy fields, which consists about 30 % of the total scheme, and paddy fields are continuously ponded. Basically upland crops are not irrigated directly, and they get their water need met through the percolation from paddy fields. The efficiency of conveyance and distribution is quite low because the canals running through sandy soil are not lined. Water requirement of paddy fields is around 3,000 mm. Seepage from irrigation canals and deep percolation from paddy fields raise local groundwater table, and it functions as water source for upland fields surrounding the paddy fields. According to the study of the Tottori University Group, this water distribution system induces soil salinization (Shimizu *et al*., 2016). In upland fields, salts accumulate during crop production with upwards water movement, while most of the salts are leached out when that field is cultivated with rice and flooded continuously for the entire growing season. The large amount of water requirement for the large irrigation schemes, including much loss from the systems, needs much water diversion from the Syr Darya River, which is the main water resource in this dry region. This large quantity of diversion is recognized as the main reason for serious desiccation of the Aral Sea.

5. Paddy fields in local hydrological regime

Based on the discussion presented above, one can raise the question again: Is the paddy cultivation appropriate and should it be allowed even in dry region? Considering the limited availability of water resources, generally, it is reasonable to recognize that paddy cultivation in dry region is not realistic or acceptable in terms of sustainability of economics and environment in many cases. Actually most of paddy fields are developed in humid region with much rainfall and much available water resources. It brings that paddy fields are suitable to humid condition. This is not wrong, while it simultaneously brings another question on significance of “suitability”.

Let us consider the case of Japan. The Japanese paddy fields have been reclaimed and developed historically, and recently improved much with large investments for advanced irrigation and drainage system. With advanced farming techniques including introduction of modern cultivars, nutrients, chemicals, machineries, and so on, Japanese are proud of higher yield and productivity of rice as well as its quality. However, much lasting investments and labors is needed to maintain the systems. There is always a risks of flood and drought damage, and the cool and hot weather damage during rice growing season. The paddy fields and the system are maintained by continuous and very labor intensive human activity, which involves development of infrastructures, institutions and inter-connectedness in the society. This situation has been developed under the condition of climate and small-scale topography and river system, which are relatively controllable compared to the continental conditions. Thinking over these history and present system, we can ask that paddy fields in Japan are suitable to the Japanese condition. The point to be recognized here is just that the “suitability” of the paddy fields to the natural and climate condition is not to be evaluated absolutely. It needs comprehensive conclusion, especially assessment in terms of sound hydrological cycle of the region or basin. Paddy cultivation and fields are to be arranged appropriately in the hydrological regime of the region. Then, we might find “suitable” and “sustainable” development of paddy fields in dry region, located in good place in the local hydrological system.

6. Conclusion

In this paper, implication of paddy cultivation and paddy fields are reviewed, focusing on flooding in the fields including its reasons and consequences. Based on the review, development of paddy fields in dry region is reconsidered. Since the paddy fields need much water and might alter the local water balance and eco-environmental system with adverse effects, they are to be arranged appropriately in the hydrological and environmental regime of the region. To evaluate the role and implication of paddy cultivation and fields in the local system, the advanced integrated model should be developed and applied, utilizing the state-of-the-art information and communication technology (ICT) and artificial intelligence (AI). It is also urgent to evaluate them under changing climate.

Acknowledgements

Discussion in this paper about implication of paddy cultivation and field has been elaborated with communication in the society on paddy filed including PAWEES. This study is partially supported by the Sosei Program of MEXT, Japan and JSPS KAKENHI Grant Number JP16H02763.

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4. Can selection in pasture grazing systems reduce methane production from ruminants?

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Abstract

Greenhouse gas (GHG) emissions are of major concern globally. Methane is one of the most potent heat-trapping gases with half of CH_4 emissions from the agricultural sector coming from ruminal enteric fermentation. Pasture species differ widely in fermentative traits, including methane production, indicating that the choice of fodder species may offer a way to reduce the environmental impact of enteric fermentation in drylands. A stand-out in this regard in Australia is biserrula (*Biserrula pelecinus* L.) with its particularly low levels of methane output when fermented by rumen microbes. The Mediterranean species biserrula is an important annual pasture legume for the wheatbelt of southern Australia. The anti-methanogenic activity of biserrula can be linked to compounds contained in selected bioactive fractions, with specific fractions found to strongly affect key rumen methanogenic archaea (methanogens). In addition to differences in methanogenic potential between species, there are also heritable differences in methanogenic potential within species such as biserrula and subterranean clover *(Trifolium subterraneum* L.) - the dominant pasture legume in southern Australia. In the light of this information on feed, the paper discusses novel strategies to control methanogen populations and activity in the rumen, and consequently contribute to a reduction in greenhouse gas emissions from ruminants while maintaining system productivity.

Keywords: Green House Gases, Enteric production of methane, *Bierrula pelecinus*, Anti methanogenic activity

Plenary Session 5

1. Greater Central Asia as the new frontier in the Twenty-first century

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Abstract

This paper is an analysis of developments in the relationship between China and the neighboring countries with special reference to likely impact of Chinese initiatives to bring about closer integration. The countries of Greater Central Asia (GCA) have always acted as a land bridge along the major commercial routes between Europe and Asia. Central Asia (*sens lat*) was once the hub of the Silk Road and if a Silk Road Economic Belt is realized, it would be so again. The development of this economic area hinges on the full development of Central Asia. Although the Central Asian area is rich in mineral resources, it remains an underdeveloped area. And the total population of the Central Asia is only 60 million, almost equivalent to a middle-sized province of China. So, in China's push for westward opening-up, it is incumbent for it, on the basis of a good Central Asia development strategy, to foster a broader cooperation of 3 billion population involving the Central Asia, West Asia, South Asia, even dozens of European countries. The significance of the concept lies in the creation of a Silk Road Economic Belt that links China's most vigorous Yangtze River Delta, Pearl River Delta and Bohai Sea economic zones to the European economy. The special role of the proposed New Silk Road Belt being promoted by China is examined against the historical past (distant past and since the independence of the post-Soviet republics in 1991). The implications of the newly developed and planned transport networks (road and rail-road shipping and air routes) for trade in goods and services and the potential for one or more of the 5 '*stans*' to be a hub is considered. There are barriers to be overcome if the dream of an integrated and cooperative GCA is to be realized. I believe that China does not seek to create a sphere of influence, and instead strives to construct with the Central Asian countries a community of shared destiny and a community of shared interests. Only by jointly building a Silk Road Economic Belt can Central Asian countries create a new geopolitical situation and promote GCA to its place as a hub between Asia and Europe. By 2030 (under this scenario) the entire territory of GCA will be covered with a great infrastructure of highways, railways, airports, and logistics centers that will handle goods and passengers moving between Europe and Asia

Keywords: Silk Road Economic Belt, Integration with European economy, China, Greater Central Asia

1. Preamble

Greater Central Asia (GCA) has been variously defined as the five post-Soviet Central Asian republics (the five '*stans*'), plus Mongolia, Iran, Pakistan and Afghanistan and the far western parts of China but we should be mindful of the significance of the neighboring countries like Pakistan (one of the keys to the proposed *New Maritime Silk Road)* and Iran and Afghanistan.

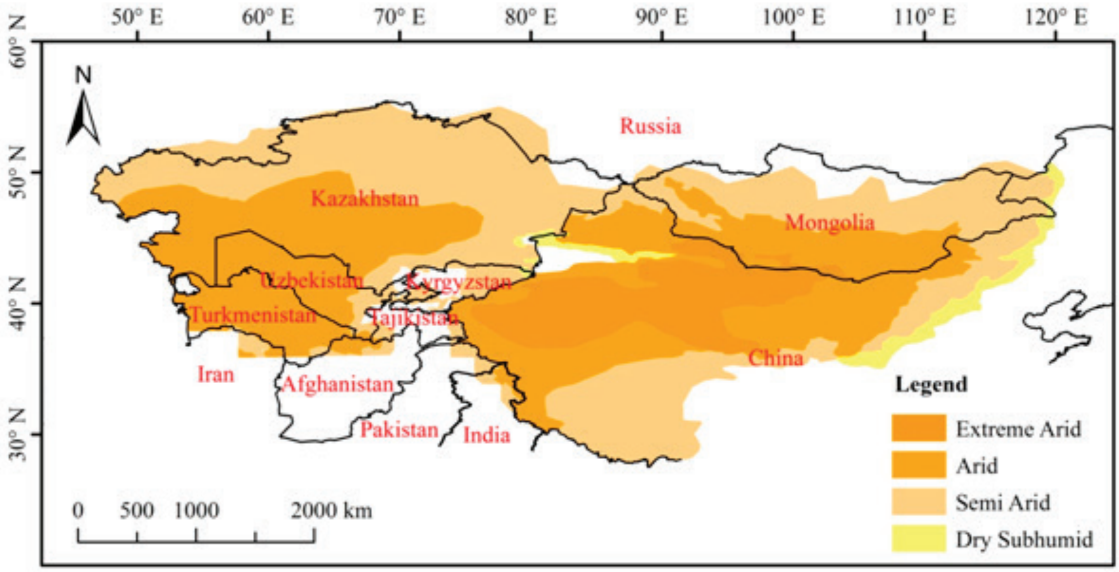

Figure 1. Greater Central Asia encompasses nine countries (or parts thereof). A key characteristic is that they are generally classified as drylands.

At one time the five 'stans' plus Mongolia, Iran, Pakistan and Afghanistan used to form a coherent and inter-connected sub-region for millennia until the impenetrable Soviet border sliced through the continent in the early 20th century and destroyed the old trade and cultural routes. Impressive levels of trade and cultural exchanges, but also military and political competition that had effects far beyond the region itself characterized GCA (*sens lat*) in earlier times. Historically, Central Asia, a confluence of three major civilizations, sits on the hub of the Silk Road but it has failed to evolve into an independent area or region. In the second half of the 19th century, this region was a scene for struggles and rivalry between Russia and Britain, and ended up with its annexation by Tsarist Russia.

This has not hampered the importance of GCA, on the contrary, its importance has been accelerated with the Russian retreat (and partial return) from Central Asia (and Afghanistan and Mongolia), combined with a rising China that has begun to challenge Russian preeminence on several accounts, but also with an increased interest from India, the EU, the United States and other actors in the region and beyond. This has begun to redefine the strategic landscape in GCA, with profound implications for strategic thinking within and outside the region. This is not to say that any external power views the region as their most important focal point.

GCA (however defined) is important for many reasons, not only in terms of energy security. GCA has increasingly positioned itself as a nexus for inter-regional trade between many of the concerned states, such as China, Iran, the EU and Russia. This has significantly increased the importance of the region in a very positive way. There is no doubt that the chief engine of growth in the region has been the abundant natural resources of Kazakhstan, Uzbekistan, and Turkmenistan. By 2030 the entire territory of GCA will be covered with a great infrastructure of highways, railways, airports, and logistics centers that will handle goods and passengers moving between Europe and Asia thanks to New Silk Road initiative (see below). For many GCA countries, however, envisioning such future is a complex matter. Political, economic, and social crises caused by the sudden collapse of the Soviet Union have dominated the relatively short history of independence enjoyed by these states. In 2011, they celebrated only the twentieth anniversary of the end of Soviet rule. Fortunately, the most difficult times have been left behind, though a few crucial challenges persist. The countries of GCA are now at the stage of development where they must complete their political and economic transitions and choose a path that would lead them into the ranks of prosperous developed nations.

2. Euro-Asian trade: The big picture

The countries of GCA have always acted as a land bridge along the major commercial routes between Europe and Asia. The Silk Road trade brought wealth and prosperity to the region's inhabitants at different stages in history. The exchange of goods introduced new ideas and technologies, enriching and advancing the development of these societies. The disruption of the ancient trade routes, however, brought suffering and hardship to the region with long-lasting impact. Some regions were gradually able to recover, while others never did. Over time, a number of commercial cities faded away as they lost the prominence they once held in the Silk Road trade, and new vibrant megacities emerged in their places. Euro-Asian trade was the economic backbone of most GCA countries for centuries. Today, the majority of this trade bypasses the region, and so do the attendant benefits. Large ships that can carry thousands of containers at a time have replaced the ancient caravans of the Silk Road.

3. Development initiatives in the GCA region

Much as North America built its strength from the opening of the west in the 19th century, an analogous strategy is assumed to undergird China's westward engagement. To promote cross-border trade, China has also sponsored a number of upgrades of already existing railroads and highways that link up with Central Asian, Pakistani and Iranian infrastructure. China has for long been implementing integration policies in the GCA region, the future of Xinjiang (China's western-most province that borders four countries) is to a significant degree linked to the economic and political development in GCA. Xinjiang is today a springboard for economic cooperation with the GCA region that lies to China's west, something that is seen in the extensive improvements in border trade and rapidly increasing trade volumes from Xinjiang to the five 'stans' and beyond.

Today, Chinese capital and trade interest is penetrating an area stretching from Azerbaijan and Iran in the West, to Pakistan in the south, and Mongolia and the five 'stans' in the north. This landmass is tied together by a number of Chinese-sponsored infrastructural interconnections, a number that is rapidly increasing, creating a Chinese economic presence as far away as Moldova. Highways have also been built or upgraded between Xinjiang and the three neighboring ‘stans’ as well as the Karakorum highway linking Pakistan with Xinjiang. The Chinese government has actively promoted trade and invested heavily in ways to improve the conditions for trade and transport. This being said, there are still major difficulties in .handling the Sino-GCA trade

4. China’s economic concerns and resource hunger

Economic concerns, especially energy resources, are considered by many as China’s main motivation today in GCA, something that is not entirely true. It is true that China has adopted an “open door policy” to increase its economic benefit which has led to an inflow of capital, energy and traded goods as well as a pooling of resources from eastern to western China. Millions of Han Chinese have migrated to the western borderlands, and China has invested massively into roads, railroads, and energy infrastructure. China has sponsored a number of upgrades of already existing railroads and highways that link China with Central Asia, Pakistan and Iran. Today, Chinese capital and trade interest are penetrating an area stretching from Azerbaijan, Moldova and Iran in the West, to Pakistan in the south, and Mongolia/Central Asia in the north and the five ‘stans’ have become the focal point of Chinese infrastructure investments, especially related to the energy sector and trade. The energy resources of GCA are important sources of diversification for China’s energy needs.

The reason behind China’s expansive strategy (as evidenced by the New Silk Road ‘One belt, One Road’ initiative and the New Maritime Silk Road initiative) is not only to secure natural resources, increase trade-related economic gains and establish trans-regional trading links (primarily with the Middle East and Europe), but also to influence and secure friendly governments in the region. This is not without problems for China as Central Asia is one of the most corrupt regions in the world and one in which organized crime has the greatest political leverage. Few political, economic or political changes in GCA can be made without involving organized crime and illegal transactions (Swanston, 2011).

5. China’s land acquisitions in GCA

In the past five years, China has become a major player in the global land market. New unexpected agreements have emerged under which the Chinese government seeks to acquire large tracts of land and to access overseas resources. Global land acquisitions are high on the socio-political agenda today. The recent developments have resulted in numerous research initiatives and reports in the last five years, with fierce debates about the impacts of the investments on local livelihoods and the environment. A frequently mentioned issue by critics is that the socio-political processes through which the landuse changes are implemented are undemocratic and a testimony of “bad land governance”. The recent land acquisitions regularly contain formally arranged lease or concessionary rights, ranging from 30 to 99 years. Due to shortages in food and fuel, rapidly emerging economies have begun to outsource agricultural production by leasing or buying rural land in developing countries including some in GCA.

Interest in farmland is rising. And, given commodity price volatility, growing human and environmental pressures, and worries about food security, this interest will increase, especially in the Greater Central Asia (GCA) region. Many GCA countries have suitable land available that is either not cultivated or produces well below its potential. This is a development challenge in GCA. Seventy-five per cent of the GCA's poor are rural, and most are engaged in farming. The need for more and better investment in agriculture to reduce poverty, increase economic growth, and promote environmental sustainability is clear.

One of the highest development priorities in GCA must be to improve smallholder agricultural productivity. Smallholder productivity is essential for reducing poverty and hunger, and more and better investment in agricultural technology, infrastructure, and market access for poor farmers is urgently needed. When done right, larger-scale farming systems can also have a place as one of many tools to promote sustainable agricultural and rural development, and can directly support smallholder productivity, for example, through 'out sourcing' programs (see below). However, recent press and other reports (Pannier, 2011) about actual or proposed large farmland acquisition by big investors have raised serious concerns about the danger of neglecting local rights and other problems. They have also raised questions about the extent to which such transactions can provide long-term benefits to local populations and contribute to poverty reduction and sustainable development. Institutional gaps at the country level can be immense. Too often, they have included a lack of documented rights claimed by local people and weak consultation processes that have led to uncompensated loss of land rights, especially by vulnerable groups a limited capacity to assess a proposed project's technical and economic viability; and a limited capacity to assess or enforce environmental and social safeguards.

In recent years, China's rapid economic growth has been coupled with a rising demand for natural resources. Great international concern has arisen over China's land acquisitions for agricultural and biofuel production, pejoratively called "land grabbing". The significant rise in China's global activities in agriculture with particular reference to its alleged "land grabbing" should not be seen as separate from the country's global expansion in other sectors.

Over the past decades China's sustained economic growth has put a rising pressure on the country's domestic natural resources. The oft cited numbers portraying the country's dire situation are that China boasts 21% of the world's population, while the country possesses only 8.5% of the world's available arable land, and 6.5% of the world's water reserves. To complicate matters, China lost 8.2 million hectares of arable land between 1997 and 2010, due to urbanization and environmental degradation.

The pressure on China's land and water resources is unquestionable. It is manifested in the different strategies that the authorities undertake to increase domestic food production. For the government, affordable food prices are perceived as being crucial to maintain social stability and guaranteed supplies are of utmost importance. To fuel its economic development, China increasingly projects its domestic shortages to other countries and regions abroad. The stimulus for this development has become even more pressing since the country's growing middle class pursues more luxurious life styles and consumption patterns (Figure 2).

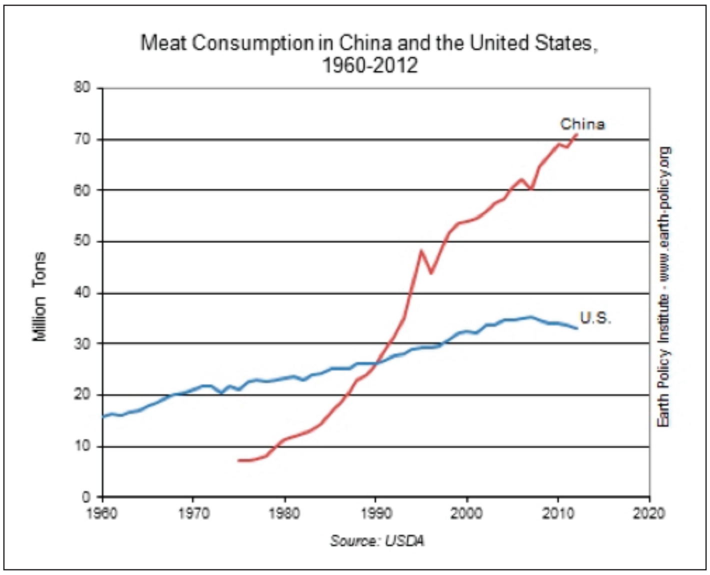

Figure 2. As the middle class develops so too does consumption of luxury items such a red meat.

An increase in a range of particular food products, such as coffee, cacao, wine, but also animal feed, are more efficiently produced overseas, and thus imply new grounds for Chinese investments. The diversity of Chinese investments involves multiple Chinese actors which may have distinct interests to operate overseas and expand their endeavors. Land is now acquired for industrial farming (in order to produce biofuels), timber extraction/ logging, tourism, aquaculture, establishment of special economic zones (SEZs) and industrial centers.

6. Acquisition of minerals, oil, gas

China's huge population that represents a third of the world and its unprecedented economic growth have resulted in the country's supplies of food, energy and metals and minerals falling far short of demand. This has prompted China to step up efforts to acquire farmlands, oil fields and mining assets abroad. China has been viewed as the "dragon" that strives to swallow mineral commodities and assets around the world. It is one of the largest consumers and producers of ores and metals. Even though China is the largest consumer of certain minerals such as copper, its domestic production accounts for less than 6% of global production. There is a widening gap in China between its mined production and consumption demand, which it is trying to fill through imports and promoting companies for overseas acquisitions. The government of China is encouraging consolidation in its domestic mining sector through mergers and acquisitions in order to reduce in-house competition and shore up finances for overseas projects.

The contexts in which Chinese (and other) actors acquire land (including mining leases) differ widely in socio-economic, political, cultural and environmental conditions, as do the particular resources that Chinese companies aim at and the approach they pursue. This influences the way Chinese companies approach the host society. Several studies have been conducted on China's expansion in resource extractive industries and other sectors. Yet, China's global expansion in general is still poorly understood (Hofman & Ho, 2012).

7. Future development of GCA

Just as Central Asia was once connected via trade routes into the mainstream of world history and linked great civilizations of the past, today the future development of Central Asia depends on its ability to deepen infrastructure and communications linking it into east-west and center-south flows of goods and information. Some positive steps have already been taken in this direction. One of the most important of these was the completion of the railway line between China's Xinjiang province and Almaty during 1991-1992, which helped facilitate trade and contact between Kazakhstan and Xinjiang. More recently, efforts have been made by Kazakhstan to improve the operations of the Druzhna rail transport center near the Chinese border, while regional railway and highway links among Kazakhstan, Uzbekistan, Tajikistan and China are being improved. Other trends are increased rail and road links through Iran to the Persian Gulf and Indian Ocean, with new rail links from northern Iran into Turkmenistan, and the extension of the existing rail system to go westwards from Almaty to join other Central Asia states to Turkey and then to Europe (see Maps in Razumov, 2001). At present it is possible to speak of two major Asia-Europe Continental Bridges based on the linkage of railway systems. The first of these is the Trans-Siberian Railway, with the associated Baikal-Amur (BAM) that passes north of Lake Baikal and then runs down near the coast to Vladivostok, the little BAM branch-line, and earlier western branches. The Second Asia-Europe Continental Bridge is a network of rail links that connects 10 provinces and autonomous regions in China with countries in Central Asia and western Europe, with a new southern branch linking China, Kyrgyzstan and Uzbekistan, and then westward into Europe.

Along with the Qinghai-Tibet Railway, this is part of China's effort to reduce developmental disparities between eastern and western zones of China. In parallel, a major transport project is also being developed to connect Europe, the Caucasus Region, and Asia. Called the Transport Corridor Europe-Caucasus-Asia (TRACECA), it has received serious support from the European Union in an effort to rebuild sea, road and railway links. Traffic across this 'new' Silk Road grew by 60% between 1996 and 1998, with up to a $1 billion of infrastructure investment and loans eventually being needed (for the western areas being largely drawn from the EU and from the European Bank for Reconstruction and Development).

The paucity of communications, links, and pipelines had greatly slowed the development of Central Asia in the post 1992 period. This is evident in the fact that in the past most oil and gas pipelines had been directed into the old Soviet Union. In spite of Western deals for access to Azerbaijan's three largest fields, and to the huge Tengiz field in Kazakhstan, the volume of exports through alternative routes has been very limited until recent times. There have been proposals for major east-west pipelines to cross the Caspian Sea, and then go either overland through Azerbaijan and Georgia, or via longer routes through Turkey. Other pipelines routed through Iran have also been slow to develop.

Since 1993 China has accepted that its rapid industrial development means that it will need to be a net importer of oil, with China currently importing up to 25% of its current oil needs. China is therefore emerging as one of the major petroleum importers in the Asian region and as Asia's largest refiner of oil. In the long term, aside from developing its own oil resources, China is also deeply interested in the possibility of accessing oil from Kazakhstan's western oil fields via connections into its Xinjiang area, with large funds committed already to improving regional cooperation and transport corridors. Xinjiang itself has sizeable energy deposits of oil and gas in the Tarim Basin, the Junggar basin, and in the Turfan-Hami area, which are currently being developed, though more slowly and with fewer proven reserves than had been at first hoped. Oil is being imported from Siberia in Russia's far eastern regions.

Central Asia (*sens lat*) was once the hub of the Silk Road and if a Silk Road Economic Belt is realized, it would be so again. The development of this economic area hinges on the development of Central Asia. In this sense, the Silk Road Economic Belt would reach the Atlantic and Indian Oceans. Although the Central Asian area is rich in mineral resources, it remains an underdeveloped area. And the total population of the Central Asia is only 60 million, almost equivalent to a middle-sized province of China. So, in China's push for westward opening-up, it is incumbent for it, on the basis of a good Central Asia development strategy, to include the Atlantic as well as the Indian Ocean into a broader cooperation of 3 billion population involving the Central Asia, West Asia, South Asia, even dozens of European countries. The significance of concept lies in the creation of a Silk Road Economic Belt that links China's most vigorous Yangtze River Delta, Pearl River Delta and Bohai Sea economic zones to the European economy. India has the view that it can be a key player (Maini, 2012).

8. Remaining challenges to closer cooperation in GCA

Major issues of concern for the future of Greater Central Asia include: -

- The ability to restrain ethnic violence and prevent narrow forms of ethnic or religious nationalism, a problem for the region as a whole and the Russian Federation in particular.
- The need to create viable states which have legitimate, democratic governments that can undertake economic reform and avoid corruption and manipulation of power.
- Relationships with a potentially assertive Russia with a strong foreign policy under President Putin.
- The types of Islam which will penetrate the region. Fortunately, the mystical and individualistic trends of the Sufism common to the region will tend to counterbalance various forms of 'fundamentalism'. At the same time, militant Islamic groups have forced a stronger security clamp down in the region from time to time.
- Access to the sea ports via improved road, rail and air links (something that is being addressed by attempts to develop the New Maritime Silk Road – see below).
- Relationships with China and other regional traders especially India.
- Stabilization of local currencies and inflation rates, as well as avoiding loan defaults that might reduce foreign investment.
- The issue of the continued treatment of Russian minorities, who form a powerful but resented group with needed technical skills. This has complicated the politics of Kazakhstan, Kyrgyzstan and Turkmenistan.
- The problem of illegal drug flows, smuggling (arms and people), and misdirected efforts to control drug production, including research for bio-engineered fungi designed to attack opium plants.

However, certain challenges remain for China and GCA in the creation of stable Eurasia. The ability to restrain ethnic violence and prevent negative forms of ethnic or religious nationalism is important, but must be balanced by the effort to support the genuine needs of different nationalities and ethnic groups. Likewise, religious issues will require careful consideration. The possible dilemma of development which does not balance regional and inter-ethnic needs can lead to further instability along China's borders with its Central Asian neighbors.

9. The need for an integrated development strategy

The emergence of this Greater Central Asia will rollback the forces that give rise to extremism and enhance continental security. It will bring enormous benefit to all the countries and peoples of the region, and, significantly, also to major powers nearby, notably Russia, China, and India. Close examination of the ongoing and planned infrastructure and transportation projects in the region, particularly in the resource-rich states, would reveal a lack of coherence with regards to a non-oil economy strategy. Important and useful projects are being planned and initiated independently of one another, without the necessary cross-sector and intra-sector coordination. In other words, these projects do not seem to be guided by a unified objective or directed by a cohesive state policy. Unless a clear, integrated "big picture" strategy is set forth today, the development trajectory of any country in the GCA region, for that matter, is likely to be halting and subject to chance. Most of the GCA states are landlocked, and they depend on each other's transportation infrastructure. Building highways, railways, ports, and airports is a necessary part of strategy to develop transport hubs, but it is not a sufficient one. Without a bird's eye approach and a coherent policy, which will view all these projects as components of a single strategy, the transportation and infrastructure projects are likely to have limited outcomes. That will be insufficiently efficacious, because they would lack complementarity. Hence, the compartmentalized mindset has to give way to an integrated vision that will direct each project towards a common goal that includes *inter alia* more sustainable land management to be enjoyed by present and future generations.

10. Conclusions

It must not be forgotten that the concept of a "Silk Road Economic Belt" first 'floated' by USA[1] as now envisioned by China could provide an unprecedented opportunity for China's overall development and its relatively backward western regions. But of course it has other value to those countries to China's west. Today, one end of the Eurasia continent is the highly developed European economy and the other the fast-growing Asia-Pacific economy, with the vast, less developed, middle region in between. The notion of a Silk Road Economic Belt exactly stands for great cooperation in this broad region aimed at connecting the Asia-Pacific and European economic economies.

[1] Frederick Starr and the John Hopkins University 'Think Tank"

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2. The role of Sinai University in achieving sustainable development in dry land ecosystem of Sinai

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Abstract

The liberation of the holy land of Sinai inspired me to focus all my investments intensively to contribute in rebuilding the economy of the peninsula through projects in the industrial and tourism sectors. During the course of our investments, I decided to establish a university at Al-Arish /North Sinai despite being challenged by many of my colleagues, business partners, experts and even my family expressing their doubt on the financial feasibility of having a private university in dry land area with limited human and natural resources.

Contrary to common wisdom, my perspective was that education in marginal areas such as Sinai would enable development and accordingly optimize the economic opportunities for investment. Therefore, my insistence to establish Sinai University was based on sincere belief and full understanding that education has the power to reverse all negative impacts of insecurity on societies and economies in Sinai, which have been always exacerbated by political marginalization of the local communities and slow growth of health and education infrastructure. Given the fact that Sinai University is surrounded by poor communities, high consideration has been given, since its inception in 2006, to the social dimension which has annually amounted to10 % of the total budget in the form of full scholarships, tuition fees discount, and small projects to serve the local communities and create jobs. After ten years of witnessing the socio-economic impacts of Sinai University, I feel proud and satisfied irrespective of all challenges and constraints. The main factor of success was our intention from the beginning to design our own educational curricula that specifically meet the social and environmental challenges of Sinai and connecting scientific research with community needs. However, the success of Sinai University in Al-Arish has encouraged the Board of Trustees to establish another campus in EL-Qantra city, which is located in Suez Canal area in Ismailia governorate. The new campus is equipped by all means and tools representing the state of the art technologies. It is worth to note that Sinai University is very keen to conduct extensive research directly addressing the dry land ecosystem challenges of Sinai as desertification control, rehabilitation of degraded land, ground water management, preventing sand dune encroachment and plant genetic resources conservation and utilization. Moreover, the dry land ecosystem challenges are included as crosscutting issues in the educational curricula in order to make graduate generations capable of achieving real sustainable development.

Keywords: Economic opportunities for investment, Education, Scientific research, Community needs, Dryland ecosystem challenges, Desertification control

3. The role of the Sustainable Development Center for Matrouh Resources in the development of drylands in Matrouh Governorate

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Abstract

The North Western Mediterranean Coastal Belt, which extends from Alexandria westward to El Sallum, is considered the richest part of Egypt in flowering plants, owing to its relatively high rainfall. In addition, the area has several *Wadis* running from south to north and represent suitable environment for cultivating fruit, vegetables, barley, and growing native plants. The North West Coast (NWC) and its inland desert suffer from a fragile socio-economic structure, with a modest contribution to the country's GDP not exceeding 0.7%, although covering over 16% of Egypt's geographic area. The major constraints include: limited water resources (low rainfall, low WUE, shortage of water harvesting technology); degraded plant resources (deterioration of plant cover, over grazing, fire wooding, poor rangeland management), and degraded soils (low soil fertility, salinity and erosion). In 1994 the Egyptian Government, with a World Bank (IDA) credit and contributions from its beneficiaries, established the Matrouh Resource Management Project with a total budget of 29.4 million USD. The objectives were to conserve the natural resource base (water, land and vegetation), implement programmes for sustainable natural resource management and alleviate poverty and improve the livelihood of the local Bedouin population, and provide support to improve resource management practices, agricultural production improvement and socio-economic development. With a strong adaptive research and technology base, the Project served an area that stretched 320 km along the NWC, from Ras El-Hekma in the East to El-Salloum on the Libyan border in the West, and about 60 km inland. At the end of the World Bank funding in 2002, funding started from the national budget as the project was very successful in improving Bedouin livelihoods. Later, it was named as 'Sustainable Development Center for Matrouh Resources' (SDCMR) and affiliated to the Desert Research Center, with a special budget allocation from the Ministry of Finance. The budget was lately reduced to about 1 million EGP, necessitating a curtailment of activities. The SDCMR follows a participatory approach in the development of the area giving the local community greater responsibility in managing, implementing and evaluating their activities (construction of cisterns for the rain water harvesting, construction of the dykes, rangeland management, participatory plant breeding for selecting the superior barley genotypes, etc.). It is currently the primary stakeholder in research and development of drylands of Matrouh Governorate, cooperating with several international partners in conservation and development of Matrouh ecosystems. As a part of the Mediterranean region, NWC is a hot spot for climatic changes, affecting agriculture, rangeland livestock production, and ecosystems services. Although the average annual precipitation is 1 billion m^3, less than 30% is harvested. SDCMR has constructed 9413 cisterns with a total capacity of 1.4 million m^3, 530 reservoirs with a total capacity of 70,000 m^3 and rehabilitated 245 Roman cisterns with a total capacity of 100,000 m^3. The area has 258 *Wadis*, but only 70 are developed (59 by the SDCMR). Thus, there is an urgent need for more rainwater harvesting structures. More international and national cooperation is being sought to strengthen project activities to alleviate poverty and satisfy the rural development needs of Bedouins in NWC region.

Keywords: Northwest Mediterranean Coast, Water harvesting structures, Wadis, Rangeland management, Participatory plant breeding

Plenary Session 6

1. Vegetative landscaping of desert

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Abstract

Desert native plants play an important role under arid and semi-arid conditions. These plants provide the main source of food for most organism living under desert conditions (i-e. animals, insects and microorganism). The vegetative cover of desert plants depend on rain density and distribution. These plants are adapted to all hard desert conditions and can grow and propagate well under arid and semi-arid conditions. There is a wide range of plants that can be used in desert landscape, having low water requirement, salt and heat tolerance, low maintenance requirements, sand storms tolerance, ability to grow under low fertility soils and easy to propagate. Native plants nurseries play an important role nationally and internationally for desert landscaping, desert reclamation for increased food production and production of high cash exportable crops (peanuts, fodder crops, fruit trees, vegetables, medicinal and aromatic plants, native ornamental plants and ornamental plants and cut flowers). National and global attention is needed to protect desert native plants by governments, civil societies and political parties by formulating appropriate regulations and policies.

Keywords: Native plants, Vegetative cover, Desert landscape, Medicinal and aromatic plants

Introduction

Deserts are often defined as areas that receive less than 250 mm of average annual rainfall, but a more accurate defining factor is aridity. In addition to low rainfall, deserts are characterized by a high rate of water loss from the ground (evaporation) and through plants (transpiration), the evapotranspiration. In deserts the rate of potential evapotranspiration exceeds the average annual rainfall by factors ranging from 2:1 to 33:1 or more. In other words, a desert is arid. Wide temperature fluctuations are another important feature of deserts. Warm air rises, and cool air sinks; rapid temperature change causes desert air to move rapidly from place to place. Deserts are windy, and windy conditions contribute to high evaporation. Clear dry air transmits about 90% of available sunlight to the ground on a typical day in desert compared to 40% in a typical humid climate. The intense sunlight includes ultraviolet radiation, which is capable of causing severe tissue damage to plants and animals. Sand dunes in the Rub' al Khali ("Empty quarter") of Saudi Arabia represent severe arid land without vegetation. Xerophytes Cardón cacti in the Baja California Desert, Cataviña region, Mexico represent Simi arid desert with little rains.

Effect of civilization and development of human activities on native desert plants

Role of desert native plants

The vegetation and organic residues play a very important role in desert ecology. By providing shadow the plants cool soil surface and reduce evaporation. They create micro-climate by changing the vegetative cover and shade. The organic layer deposited on the sandy surface has a sponge effect, which helps in retaining moisture and improving fertility of the desert soil. It also improves percolation of water and its conservation in the soil.

Table 1. The world's largest non-polar deserts

Rank	Desert	Area (km²)
1	Antarctic Desert (Antarctica)	14,200,000
2	Arctic Desert (Arctic)	13,900,000
3	Sahara Desert (Africa)	9,100,000
4	Arabian Desert (Middle East)	2,600,000
5	Gobi Desert (Asia)	1,300,000
6	Patagonian Desert (South America)	670,000
7	Great Victoria Desert (Australia)	647,000
8	Kalahari Desert (Africa)	570,000
9	Great Basin Desert (North America)	490,000
10	Syrian Desert (Middle East)	490,000

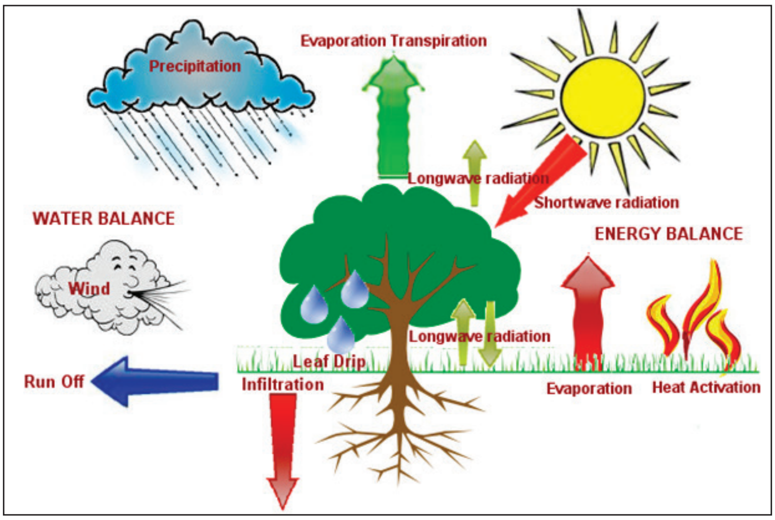

Figure 1. Desert ecology and water balance.

Effect of anthropological interventions

Industrial revolution saw large scale clearing of vegetation and deforestation. Lands under permanent vegetation were cleared for agriculture using heavy machinery. The result was the vegetation depletion, and occasional monoculture of crops using irrigation under desert conditions resulted in loss of precious water through high evaporation. It exposed soil, sand and rock, and encouraged quick run off of rainwater, particularly during the high intensity storm events, because of the creation of subsurface hard layer. Also, overgrazing of natural vegetation exposed soil surface and led to loss of good soil by erosion. Urbanization of desert areas involved development of infrastructure of roads, buildings etc. which prevented infiltration of water in the soil and cause increased erosion of soil because of runoff. It is important that the desert areas should be protected from the anthropogenic interventions that are counter to ecological balance in those areas. Native vegetation can permit rehabilitation of these areas, prevent desertification and permit development of landscape, which could provide good environmental services and even reverse the process of desertification. This becomes important as the urbanization and settlement of people in the reclaimed desert areas is undertaken.

Native desert plants for desert landscape

While desert's native plants have graced gardens worldwide for over a century, few of the landscapes designed for our desert's gardens reflect the natural splendor. By gardening with native plants, one can bring the beauty of desert into our own landscape while also receiving numerous benefits. Native vegetation evolved to survive in the local climate, soil types, and the habitation. The use of these plants brings us several gardening advantages :

- ***Saving water:*** Once established, many native plants need minimal irrigation beyond normal rainfall.
- ***Low maintenance requirements:*** Low maintenance landscaping methods are a natural fit with native plants that are already adapted to the local environment. Using less water, little to no fertilizer, little to no pesticides, less pruning, and less of the time needed for supervision.
- ***Pesticide freedom:*** Native plants have developed their own defenses against many pests and diseases. Since most pesticides kill indiscriminately, beneficial insects become secondary targets in the fight against pests. Reducing or eliminating pesticide use lets natural pest control take over and keeps toxic pesticides out of our creeks and watersheds.
- ***Wildlife:*** Native plants, birds, butterflies, beneficial insects, and interesting critters are "made for each other." Research shows that native wildlife prefers native plants.
- ***Support local ecology:*** As development replaces natural habitats, planting gardens, parks, and roadsides with desert natives can provide a "bridge" to nearby remaining wildlands.

The desert plants are also very suitable for developing green roofs for dwellings in desert environments. Some benefits provided by green roofs include storm water management (through retention/filtration), water and air quality improvement, smog reduction, increased life expectancy of roof membranes, noise reduction and increased energy efficiency and biodiversity preservation.

Native plants adaptation to harsh desert conditions

Desert plants tend to look very different from plants native to other regions. They are often swollen, spiny, and have tiny leaves that are rarely bright green. Their strange appearance is a result of their remarkable adaptations to the challenges of the desert climate. Aridity is the sole factor that defines a desert and is the primary limitation to which desert organisms must adapt. Desert plants have developed three main adaptive strategies: succulence, drought tolerance, and drought avoidance. Each of these is a different but effective suite of adaptations for prospering under conditions that would kill plants from other regions. Environmental stresses for desert plants include long periods of drought; unpredictable precipitation, high soil and leaf temperatures, and saline soils. Plants use anatomical, physiological and life cycle mechanisms for coping with hard desert environments.

Cacti, "century" plants, and euphorbias contain spongy parenchyma to store water, have low surface-to-volume ratio; grow slowly, but some can become quite large, photosynthetic stems, shallow roots absorb water whenever possible, and have adaptation to minimize herbivory (spines, camouflage e.g., stone plants, *Lithops* sp.). Many species have frost resistance (e.g. *O. polyacantha* can tolerate –17°C). Physiological adaptations, e.g. CAM physiology and high water use efficiency, give them additional advantage.

Cactaceae is a New World family. The plants have succulent stems with areoles, multi-lobed stigma, many stamens. A cactus is adapted to survive in a hot climate. Cacti are well adapted for survival in the desert. They have stems that can store water, wide spread root system that can collect water from a large area and they have spines instead of leaves that results in reduced area for transpiration. These minimize the surface area and so reduce water loss by transpiration. The spines also protect the cacti from animals that might eat them.

Agave and other succulent plants store water in fleshy leaves, stems or roots. All cacti are succulents, as are such non-cactus desert plants as agave, aloe, elephant trees, and many euphorbias. Several other adaptations are essential for the water storing habit to be effective..

A succulent must be able to absorb large quantities of water in short periods. Desert rains are often light and brief, and the soil dries rapidly under an intense sun. To cope with these conditions, nearly all succulents have extensive, shallow root systems. The roots of a saguaro extend horizontally about as far as the plant is tall but are rarely more than four inches (10 cm) deep. The water-absorbing roots are mostly within the upper 1.5 cm layer.

Many succulents also employ a special type of photosynthesis, CAM (Crassulacean Acid Metabolism) (Figure 2). Instead of synthesizing carbohydrates, they synthesize Crassulacean acid during the day while their stomata are closed and store it in their tissues. At night, when temperatures are lower and humidity higher, they open their stomata and break down the acids into carbohydrates using carbon dioxide from the air. CAM plants are therefore extremely efficient at using water, consuming only about 10% of the water other plants consume to synthesize the same amount of carbohydrates. The overall rate of photosynthesis is slower however, so CAM succulents are usually slow-growing. When conditions are extremely arid, CAM plants leave their stomata closed night and day. Oxygen given off in photosynthesis is used for respiration and CO_2 given off in respiration is used for photosynthesis.

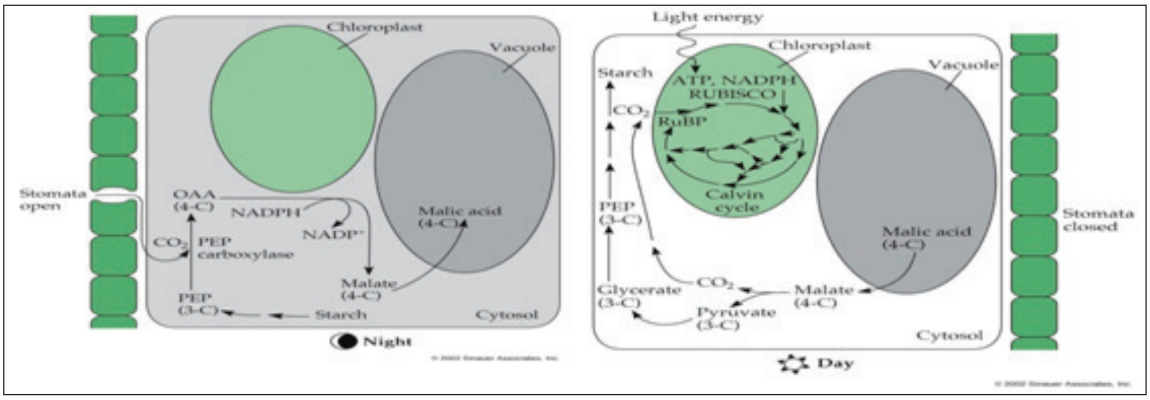

Figure 2. CAM photosynthesis used by many succulent species

Drought tolerant plants, such as this brittlebush, often shed leaves during dry periods and enter a deep dormancy. Owl's clover, California poppy and other drought avoidance plants die after channeling all their energy into producing seeds

Salt tolerant seaside plants

The combination of desiccating factors in coastal gardens can severely stress a landscape plant growing in seaside conditions. However, there are salt tolerant perennial plants that can thrive in these coastal garden conditions. Salt adapted perennials are what should be planted in the exposed beach landscapes. As a general rule of thumb, coastal native plants and desert plants / succulents tend to be salt tolerant plants. The most extremely salt tolerant plants are known as halophytes. True halophytes can even grow in seawater. Most salt-adapted garden perennials are not true halophytes, but they are still better than most other perennials. Salt tolerant or salt resistant plants are often divided into "very salt tolerant or resistant", "moderately salt tolerant" and "mildly salt tolerant" groups. Some halophytes found in Egypt include *Agapanthus ellamae (* Ellamae lily of Nile*), Anisacanthus wrightii, Amsonia hubrichtii, Asclapeas incarnate,* and *Artemisia* spp.

Where to find native desert plants?

Botanical gardens harbor exciting and important native plant collections with all kinds of variation and diversity. Native plants in botanic gardens feature regional flora and are often displayed as "plant communities" - or groups of plants - much like they would grow in a naturally occurring ecosystem. Cultivars are identified in each display or grouping of plants. Interpretive panels are often posted so one can read brief, but first rate information about the plants and plant communities while strolling through the gardens. .Many botanic gardens feature classes, workshops, and lectures, or sponsor field courses and trips

Collecting plants without a permit is illegal on Global Desert public lands, and wild transplants often have a poor survival rate. National research centers and environment authorities encourage all to grow locally available native plants to conserve and promote gene pool diversity. Loc native plants are available from restoration nurseries which propagate plants from local watersheds and track the source of their stock

Desert reclamation and cultivation with high value desert native fruit trees, fuel crops, ornamental and medical plants

Desert greening is the process of man-made reclamation of deserts for ecological reasons (e.g. conserving biodiversity), farming and forestry, but also for reclamation of natural water systems and other life support systems. It is done by various methods. Selecting the right vegetation is important and it should also have an economical value, e.g.: used for making biodiesel, as firewood, or for their fruit etc. It is advisable to start a small area and plant closest to some source of nutrients and water and extend from there. Organic material (compost) should be used to retain moisture. Watering can then be done with rainwater harvesting for the first two years after which the tree would have established themselves. In Egypt, the plantation is supported by Government and Private Grant funding projects and there are programs that ensure that enough and adequate skill development is done. These projects needs continuous extension and support, .not only for the sake of the community that will benefit but also for protecting the environment

Medicinal plants found in the deserts contain a variety of chemical compounds that may benefit the host plant. These compounds may protect the plant from herbivores, attract pollinators or prevent competitive germination within a plant's growing space. Of the more than 5,000 identified alkaloids found in angiosperms include caffeine, nicotine, morphine and quinine. In contrast, glycosides, chemical compounds with one or more sugar molecules, are found in plants like ginseng, almonds and foxglove. There are numerous ways in which these and other plants are prepared for use. For example, roots, stems, leaves, flowers and berries may be used in their natural form or processed into capsules, powders, extracts, tinctures, creams or oil products. The treatment of injuries or illnesses with these products is common—it is .a $1.5 billion annual industry, a number that is probably underestimated

Reclamation and mining - bringing the landscape back

Resolution Copper' is located in the Copper Triangle, where mining has been done for more than 100' years. We have already started reclaiming historic mining sites on our property, and have spent $30 million to clean up a 130-acre site that once housed a copper concentrator and smelter. From now through 2020, we will invest about $20 million more to complete our reclamation work. Once we complete mining operations at the proposed locations, we would reclaim the site, shaping the land to blend in with the surroundings, planting native vegetation and making sure the land and water are safe. This reclamation work creates employment for local people, and we are required by law to put aside money before operations .begin, so we, not the taxpayers, foot the bill

Proposal for desert native plants Vegetation Program

The mission of Vegetation Program is to develop and disseminate quantifiable definitions of all types of vegetation in Global Deserts. These definitions will be used to promote science-based conservation at the natural community and ecosystem level throughout the World. The principal goals of the Vegetation Program are to develop, promote, and maintain a uniform vegetation classification that will be adopted by private, state, and Non-Government resource agencies with jurisdiction over land management, and to develop defensible definitions of the rare vegetation of the Global Deserts.

2. Role of farm level water harvesting in drought mitigation in smallholder dryland farms in India

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Abstract

Despite extensive development of irrigation over the years, nearly 50 per cent of the net sown area in India is under dryland agriculture. Delay in monsoon arrival and midseason breaks cause considerable yield reduction in cereal grain crops, pulses, oilseeds and cotton. Research across India over several years has revealed that *in situ* and *ex situ* water conservation are key strategies to mitigate the impacts of droughts on agriculture production and farmers' livelihood. Harvesting surplus runoff during heavy rainfall events in dug out ponds and using it for providing supplemental irrigation during dry spells is one of the most important strategies experimented successfully across the country. The dug out ponds can vary between 500 to 2000 m^3 and require to be lined in case of alfisols. Such ponds have been dug on farms of small holders under the Government of India's employment guarantee scheme, and the cost of lining, lifting water through portable pump sets, yield benefits due to supplemental irrigation have been worked out for a number of crops. The economic performance of 500 such ponds dug in different agro climatic regions of the country was evaluated with crops such as sorghum, cotton, oilseeds, vegetables and tobacco. The designs of ponds for various rainfall zones, soil types and the volume of water that can be harvested annually have been computed. Currently the Government of India has included the farm ponds scheme as a flagship program in the *Pradhan Mantri Krishi Sinchan Yojana* (Prime Minister's Irrigation Scheme).

Keywords: Dryland agriculture, Water harvesting, Farm ponds, Alfisols

1. Introduction

India, receives the major quantum (74%) of its annual rainfall during southwest monsoon season (June to September). Due to large inter and intra-annual variability in rainfall, the country witnesses frequent droughts in some parts or the other in each year and at times, over large area. In extreme northwest region, rainfall deficits are recorded over consecutive years, leading to near famine conditions. Although no part of India is immune from the adverse impacts of drought, the arid and dry semi-arid regions in the western, northern, and peninsular parts of the country experience more frequent droughts, at times leading to crippling impact on national economy. The Indian economy, thus, has been described as a 'gamble in monsoon'.

The frequency of droughts (Figure 1) computed based on rainfall departures over the last 200 years indicated that maximum number of droughts were observed in north-western India followed by central parts of the country and least in NE and hilly regions. The impacts of droughts have increasingly drawn the attention of scientists, planners and the Government. The vulnerability to drought in relation to increasing food needs of the growing population has become a point of great concern to Government of India.

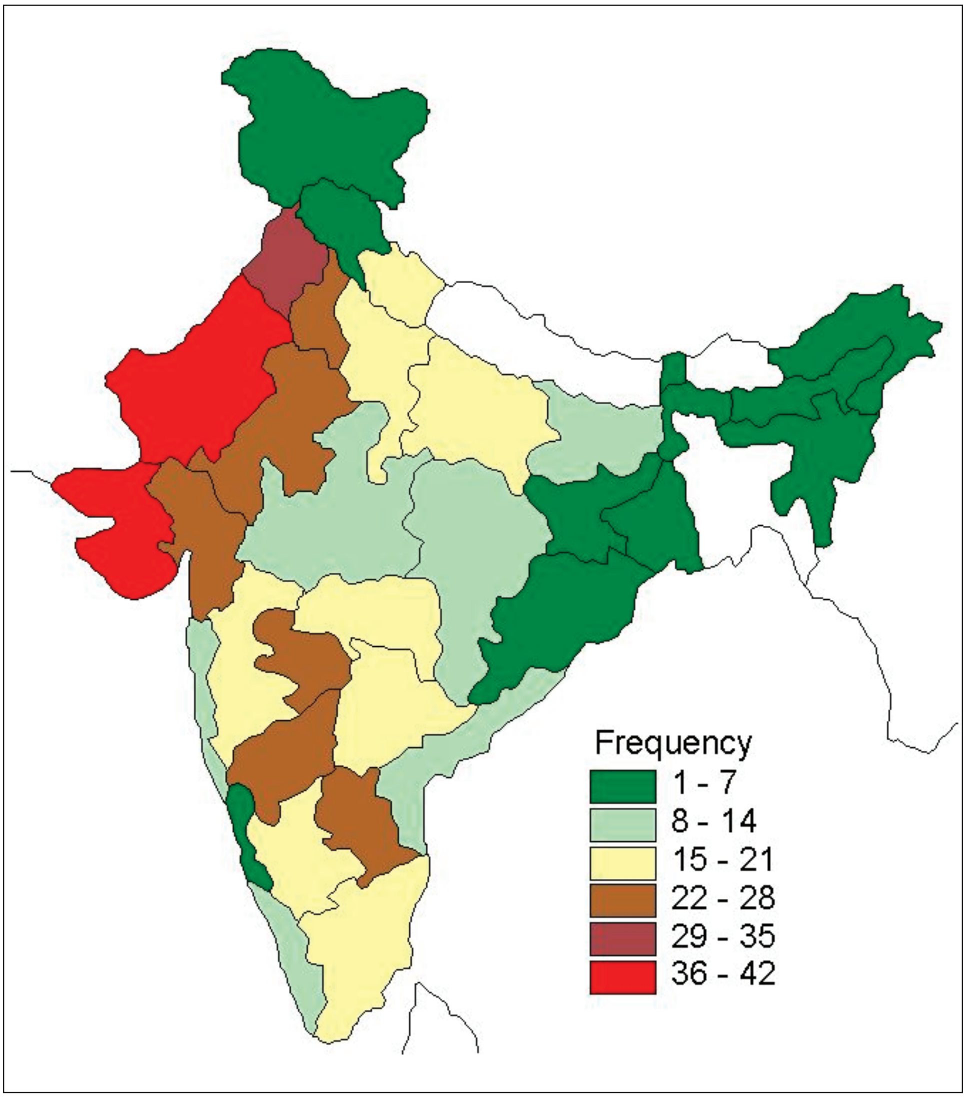

Figure 1. Drought frequency in India during 1870-1999.

1.1 Definition of drought

Drought is a climatic anomaly, characterized by deficient supply of moisture resulting either from sub-normal rainfall, erratic distribution, higher water need or a combination of all the factors (Ramakrishna *et al.*, 2000). It is called as disaster in slow motion and the area covered is large. If it persists over two to three years, it may lead to famine condition. It would affect various human activities and lead to problems like widespread crop failure, un-replenished ground water resources, depletion in lakes/reservoirs, shortage of drinking water, reduced fodder availability etc. Often a region adopts itself to a certain level of water shortage based on the long-term climatic conditions experienced by it. Because drought affects many economic and social sectors, scores of definitions have been developed by variety of disciplines and the approaches taken to define it also reflect regional and ideological variations (Wilhite, 2000).

Broadly droughts have been classified into three categories, *viz*. meteorological, hydrological and agricultural droughts.

Meteorological drought	→	A situation when there is significant decrease (> 25%) of normal rainfall over an area.
Hydrological drought	→	Meteorological drought, if prolonged, will result in hydrological droughts with marked depletion of surface and ground water level.
Agricultural drought	→	It occurs when both rainfall and soil moisture are inadequate during growing season to support a healthy crop.

1.2 History of droughts in India

The severe drought years that occurred over the past 210 years in the country, as reported by Kulshreshta (1997) and updated by CRIDA in 2009, are shown in Table 1.

Table 1. All India droughts during past 200 years (Kulshrestha, 1997)

Period	Drought years	No. of years
1801-25	1801,04,06,12,19,25	6
1826-50	1832, 33, 37	3
1851-75	1853, 60, 62, 66, 68, 73	6
1876-1900	1877*+, 91, 99*+	3
1901-25	1901*, 04, 05*, 07, 11, 13, 15, 18*+, 20, 25	10
1926-50	1939, 41*	2
1951-75	1951, 65*, 66, 68, 72*,+, 74	6
1976-2000	1979*, 82, 85, 87*+	4
2000-2009	2002*+, 2009*	

* Severe drought years = 10 (> 39.5% area affected)

\+ Phenomenal drought years = 7 (> 47.7% area)

The first quarter of the last century recorded 10 drought years out of which 3 years, *viz*., 1901, 1905 and 1918 were severe drought years. Again, the last quarter of the 20th Century also recorded two severe drought years, 1979 and 1987. Similarly, first decade of the current century recorded two severe drought years that affected the agricultural production over the country considerably. Over the last 210 years, there were a total of six phenomenal drought years, *viz*., 1877, 1899, 1918, 1972, 1987 and 2002, when the affected area was roughly 50 percent. The northwestern parts of the country have experienced continuous three-year drought especially in west Rajasthan and parts of Gujarat during 2000-2002.

1.3 Spatial and temporal distribution of droughts in India

A study of moderate and severe droughts that occurred in India indicates that, except for very small pockets in the Northeastern India and Kerala, there were no areas, which have not been affected by drought at one time or the other. While the entire country could thus be considered as drought prone, there are certain areas, which are chronically subject to such condition and merit the appellation ‘drought prone’ (Table 2).

Table 2. Probability of Occurrence of Drought in Different Meteorological Subdivisions of India

Meteorological subdivision	**Frequency of deficit rainfall (75% of normal or less)**
Assam	Once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
South interior Karnataka, Eastern Uttar Pradesh and Vidarbha	Once in 4 years
Gujarat, East Rajasthan, Western Uttar Pradesh	Once in 3 years
Tamil Nadu, Jammu and Kashmir and Telangana	Once in 2.5 years
West Rajasthan	Once in 2 years

Technical Committee on Drought Prone Area Programs and Desert Development Program identified about 120 million ha of the country’s area, covering 185 districts (1173 development blocks) in 13 states as drought prone (Anonymous, 1994). Based on the historical records, Jaiswal and Kolte (1981) reported 120 drought /famine like incidences in one or other part of the country between 1291 and 1978. Chances of experiencing moderate droughts greater than 20 percent spread across greater part of the country whereas higher probabilities of experiencing severe drought are most confined to extreme northwest portion of Gujarat and Rajasthan (Table 2).

2. Impact of droughts

The usual impact of droughts is in terms of loss of crops, malnutrition of human being and cattle, land degradation, loss of other economic activities, spread of diseases, and migration of people and livestock (Kulshrestha, 1997). Droughts result in crop losses of different magnitude, depending on their geographic incidence, intensity and duration. The droughts not only adversely affect the food supply at the farm level but also impact national economy. Predicted losses to agriculture in India were 50 percent during the drought of 1957-58. Ramakrishna and Rao (1991) observed that during the 1987 drought in India, the productivity of pearl millet in western Rajasthan dropped by 78, 74 and 43 percent in rainfall zones of < 300, 300-400 and > 400 mm, respectively. Victor *et al*. (1991) reported reduction in the productivity of groundnut and millet in Andhra Pradesh during 1987 drought year. For eastern India, the loss in production of food grains due to drought averaged over 1970-96 has been estimated to be $ 400 million, which is equivalent to 8 percent of the value of food grain production in the region (Pandey *et al*., 2000).

The effect of drought was more pronounced on fodder availability as compared to that of food grains. The food grain production was reduced by 29.0 and 17.6 mt during 2002 and 2009 drought years due to reduction in net sown are in *kharif* season compared to previous years that received good rains. Though the rainfall departure during 2009 was higher than in 2002, the fall in food grain production over the previous year was comparatively less in 2009 than in 2002. This has been mainly due to better contingency strategies planned and adopted during 2009-10 season and the greater resilience of Indian agriculture to drought now than in the past.

The duration of availability of water in surface water bodies was reduced significantly during 1987 drought year (Narain *et al*., 2000). The water storage in major reservoirs was 33 percent less than the average of previous 10 years (Samra, 2004). Around 150 million cattle were affected due to lack of fodder availability. The groundwater table in drought affected areas declined by 2 to 4 m below the normal level.

Droughts affect the livestock in several ways. Reduced productivity and mortality are the direct effects. Driven by enhanced livestock pressure due to depletion of forage resources during drought, overgrazing and indiscriminate cutting of vegetation takes place leading to land degradation. This is followed by first distress sale of cattle and even small ruminants. Migration of livestock is the next step extending the problems of uncontrolled and overgrazing, thus degrading land in other areas. There have been instances that large-scale mortality of livestock and mismanagement in disposal of their carcass caused epidemic situations and environmental hazards. Decrease in size of herd (up to 52%) was reported due to frequent occurrence of droughts in Rajasthan (Anonymous, 1994).

3. Management of drought – Research & Development

3.1 Research initiatives

The Climatology Group at the Department of Meteorology, Andhra University, Visakhapatnam initiated studies on drought in 1960 using water balance approach and India Meteorological Department established a Drought Research Unit and classified droughts based on rainfall departures. Simultaneously, ICAR has also initiated work on impacts of droughts on agriculture through its Research Institutes, *viz*., Central Soil & Water Conservation Training & Research Institute, Dehradun; Central Arid Zone Research Institute, Jodhpur; Indian Agricultural Research Institute, New Delhi and Central Research Institute for Dryland Agriculture, Hyderabad since their inception.

Keeping in view of the productivity gap between irrigated and rainfed areas, the Fourth Five Year Plan (1969-74) emphasized the need for extending the advancements in science and technology to dryland areas. More emphasis was laid on research related to dryland agriculture. The All India Co-ordinated Research Project on Dryland Agriculture (AICRPDA) was established at 24 centres in 1970 to tackle the problems of dryland agriculture, which are highly location-specific.

The ICAR started an All India Coordinated Research Project on Agrometeorology, which is operating at 25 centres from 1995 onwards. These centres are providing weather-based agro-advisories to farmers in different agroclimatic regions of the country in addition to agroclimatic planning, and contingency measures for different weather situations disseminated through ICT facilities including mass media involving State Agricultural Universities as the main vehicle.

International Crop Research Institute for Semi-Arid Tropics (ICRISAT), started in 1972, has also helped semi-arid farmers in managing dryland crops, *viz*., sorghum, pearlmillet, pigeonpea and groundnut for stable production under aberrant weather conditions. Enhancing production through watershed and farming system approach are strategies suggested by ICRISAT for climate risk management. A number of research institutes of ICAR and State Agricultural Universities are conducting considerable research work on developing drought and heat tolerant varieties and soil and water conservation measures, which help in combating drought and stabilizing crop production. A brief summary of these technologies is given in the following section.

3.2 Strategies and technologies to combat drought

Following are the various improved techniques and practices recommended for drought management in rainfed areas:

- ***Crop planning***: Crop varieties for dryland areas should be of short duration and drought resistant/tolerant. Such crop varieties can be harvested within rainfall periods or can be grown on residual moisture in soil profile in the post-monsoon period.
- ***Crop substitution***: Traditional crops which are inefficient utilizers of soil moisture (due to long duration), less responsive to external inputs and low yielders should be substituted by more efficient ones.
- ***Cropping systems***: Increasing the cropping intensity by using the practice of intercropping and multiple cropping results in more efficient utilization of resources. The cropping intensity would depend on the length of growing season, which in turn depends on rainfall pattern and the moisture storage capacity of the soils.
- ***Fertilizer use***: Dryland soils are not only 'thirsty', but also 'hungry'. Therefore, application of fertilizers should be done in furrows below the seed. The use of fertilizers not only helps in providing nutrients to crop but also leads to efficient use of soil moisture. A proper mixture of organic and inorganic fertilizers not only improves soil fertility but also improves moisture holding capacity of soils and enhances drought tolerance.
- ***Rain water management***: Efficient rainwater management can increase agricultural production from dryland areas. Application of compost and farmyard manure and raising legumes add organic matter to the soil and increase the water holding capacity. The water, which is not retained by the soil, flows out as surface runoff. This excess runoff water can be harvested *in situ* by proper land treatments or stored in dugout ponds and recycled for supplemental irrigation.
- ***Watershed management***: Watershed management is an approach to optimize the use of land, water and vegetation in an area and thus, to provide solution to droughts, moderate floods, and soil erosion, improve water availability and increase fuel, fodder and agricultural production on a sustained basis.
- ***Alternate land use***: All drylands are not suitable for crop production. Some lands may be suitable for range/pasture management, ley farming, dryland horticulture, and agro-forestry systems including alley cropping. All these systems, which are alternative to crop production, help to generate off-season employment in mono-cropped drylands and also, minimize risk, utilize off-season rains, prevent degradation of soils and restore balance in the ecosystem.

3.3 Managing drought during different crop stages

Specific recommendations to mitigate dry spells occurring in different crop stages are available for different regions of the country.

a. Early Season Drought

Early season droughts occur due to delay in commencement of sowing rains. Sometimes, early rains may occur tempting the farmers to sow the crops followed by a long dry spell leading to withering of seedlings :and poor crop establishment. The management options to cope up with early season drought are

- Raising community nurseries for cereal crops and transplant the seedlings with the onset of rainy season.
- Sowing of alternate crops/varieties depending upon the time of occurrence of sowing rains. The seeds may not be available to the farmers and government should provide seed through seed banks promoting seed villages.
- If there is a poor germination and inadequate plant stand, resowing is recommended. Seed priming helps in better crop establishment.

b. Mid-Season Drought

Mid-season drought occurs due to long gaps between two successive rainy events when the moisture available in the soil falls short of water requirement of the crop during the dry period.

The management options to cope-up with the mid season droughts are:

- Rain water harvesting and recycling for life saving irrigation
- Reducing crop density by thinning
- Weed control and mulching
- *In situ* moisture conservation
- Dust mulching, repeated harrowing
- Use of anti-transpirants

c. Late Season Drought

If the crop encounters moisture stress during the reproductive stage due to early cessation of rainy season, there may be rise in temperature, hastening the process of crop maturity. The grain yield of crops is highly correlated with the water availability during the reproductive stage of growth. Short duration high yielding varieties may escape late season droughts. Another possibility is to provide supplemental irrigation from harvested rainwater. Organic mulches are found to be useful in improving crop yields. When crops are sown late, terminal drought can be anticipated with greater certainty. Therefore, varieties that respond better to terminal droughts have to be preferred.

3.4 Soil and water conservation measures

The Soil and Water Conservation (SWC) are the most important components of drought management (both temporary and permanent). SWC measures are essential for *in situ* conservation of soil and water. The main aim of these practices is to reduce or prevent either water erosion or wind erosion, and enhancing moisture in soil for sustainable production. The suitability of *in situ* soil and water management practices depend greatly upon soil type, topography, climate, cropping system and farmers' resources. Some of the most common *in situ* conservation practices followed in India are described below:

a. Contour cultivation

Contour cultivation is a simple method of cultivation across the slope which effectively reduces the runoff and soil loss on gentle sloping lands. In this, all field operations such as ploughing, planting and inter-cultivation are performed on the contour (Figure 2, first picture). It helps in reduction of runoff by impounding water in small depressions and reduces the development of rills. Maximum effectiveness of this practice is on medium slopes and on permeable soil.

b. Conservation furrows

Developing conservation furrows is a simple and low cost *in situ* soil and water conservation practice for areas with moderate slope. This practice is suitable for soils with problems of crusting, sealing and hard setting. In this system, series of furrows are opened on contour or across the slope at 1-3 m apart (Figure 2, second picture**).** The spacing between the furrows and its size can be chosen based on the rainfall, soils, crops and topography. The furrows can be made either during planting or interculture operation using country plough. Two to three passes in the same furrow may be needed to obtain the required furrow size. These furrows harvest local runoff and improve the soil moisture in the adjoining crop rows particularly during the period of water stress. This practice increases crop yields by 10-25 percent and it cost around Rs. 250-350 (US $ ~6) ha^{-1}. To improve its effectiveness further, it is recommended to use this system along with cotour cultivation or cultivation across the slope (Ram Mohan Rao *et al*., 1981, Mishra *et al*., 2010)

c. Broadbed and furrow system

On black soils, the problem of water logging and water scarcity occurring during the same season are quite common. The *in situ* conservation practice should store water in the profile and drain excess water. The "Broadbed and Furrow" (BBF) system successfully meets these goals. The BBF system consists of a relatively raised flat bed or ridge, approximately 90 cm wide, alternated by a shallow furrow about 30 cm wide and 15 cm deep. The BBF system is laid out on a grade of 0.4 – 0.8 % for optimum performance. It is important to attain a uniform shape without sudden and sharp edges because of the need to plant crop rows on the shoulder of the broadbed.

d. Vegetative barriers

Vegetative barriers or vegetative hedges or live bunds are effective in reducing soil erosion and conserving moisture. In many situations, the vegetative barriers are more effective and economical than mechanical measures, *viz*., bunding. Vegetative barriers can be established either on contour or on moderate slope of 0.4 to 0.8 percent. In this system, the vegetative hedges act as a barrier to runoff flow and slowing down its velocity resulting in deposition of eroded sediments and increased rainwater infiltration. It is advisable to establish vegetative hedges on small bund. This increases its effectiveness, particularly during the first few years when the hedges are not so well established. If the main purpose of the vegetative barrier is to act as a filter to trap the eroded sediments and reduce the velocity of runoff, then grass species such as vetiver, sewan (*Lasiurus sindicus*), sania (*Crotolaria burhia*) and kair (*Capparis aphylla*) are recommended. If the purpose is to stabilize the bund, plants like Gliricidia could be used. Gliricidia plants grown on bunds not only strengthen the bunds, but also provide N-rich green leaf biomass, which can be added on soil as mulch-cum-manure.

Figure 2. Most common *in situ* conservation practices (a) contour cultivation (b) conservation furrows (c) broad bed and furrow system.

3.5 Water harvesting and ground water recharge

While *in situ* conservation practices are appropriate at farm level, at community or landscape level, harvesting surplus runoff for surface storage or ground water recharge are more important measures for drought proofing. Different methods are given below:

a. Check dams

Masonry check dams are permanent structures used for controlling gully erosion, water harvesting and groundwater recharging (Figure 3, first picture). These structures are popular in watershed programs in India. These structures are preferred at sites where velocity of runoff in gullies/ streams is very high and stable structure is needed to withstand the flow. Masonry check dams are designed on the basis of rainfall-runoff relationship. Depending upon the assumed depth of structure and the corresponding area to be submerged, suitable height of the dam may be selected to provide adequate storage in a given topographic situation (Katyal *et al*., 1995).

Earthen check dams are very popular in the watershed programs in India for controlling gully erosion and for harvesting runoff water. These are constructed using locally available materials. The cost of construction is generally low. The size of the dam depends on the site conditions. In some cases, stone pitching may be required to protect the bund from scouring. Earthen check dams are used as surface water storage structures as well as for recharging groundwater.

b. Khadin system

'Khadin' is a land-use system developed centuries ago in the Jaisalmer district of Western Rajasthan. This system is practiced by single large farmer or by group of small farmers. It is highly suitable for areas with very low and erratic rainfall conditions. In khadin system, preferably an earthen or masonry embankment is made across the major slope to harvest the runoff water and prevent soil erosion for improving crop production. Khadin is practiced where rocky catchments and valley plains occur in proximity. The runoff from the catchment is stored in the lower valley floor enclosed by an earthen/stone 'bund'. Any surplus water passes out through a spillway. The water arrested stands in the khadin throughout the monsoon period. It may be fully absorbed by the soil during October to November, leaving the surface moist. If standing water persists longer, it is discharged through the sluice before sowing. Wheat, chickpea or other crops are then planted. These crops grow to maturity without irrigation. The soils in the khadins are extremely fertile because of the frequent deposition of fine sediment, while the water that seeps away removes salts. The khadin is, therefore, a land-use system, which prevents soil deterioration (Kolarkar *et al*., 1983). This practice has a distinct advantage under saline groundwater condition, as rainwater is the only source of good quality water in such area.

c. Farm ponds

Farm ponds are an age old practice of harvesting runoff water in India. These are constructed by excavating soil from a low-lying area of the field (Figure 3, second picture). Following guidelines are to be followed in design and construction of farm ponds.

- High-storage efficiency (ratio of volume of water storage to excavation) can be achieved by locating the pond in a gully, depression, or on land having steep slopes. Whenever possible, raised inlet system be used to capture runoff water from the upstream. This design will considerably improve the storage efficiency of the structure.
- Seepage losses can be minimized by selecting the pond site having subsoils with low saturated hydraulic conductivity. As a rough guide, the silt and clay content of the least conducting soil layer is inversely linked with seepage losses. Therefore, it is best to select the site having subsoil with higher clay and silt and less coarse sand. Also, the pond wetted surface area be reduced in relation to water storage volume. This can be achieved by making the pond of a circular shape or close to circular shape.

Evaporation losses can be minimized, if the ponds are made deeper but with acceptable storage efficiency to reduce water surface exposure and to use smaller land area under the pond.

Figure 3. Common water harvesting structures.

Water harvested in the pond could be used for providing supplemental irrigation to *kharif* crops during dry spells. Best returns are possible with cash crops or vegetables. Recent research by CRIDA resulted in design of low lift diesel run pumps (1.5 Hp), which are portable and can be used more profitably to lift water from ponds. This water can be conveyed either through sprinklers or drips (Figure 4).

Figure 4. Pond water for life-saving irrigations using portable pump set.

4. Development efforts in drought management

4.1 Short-term relief measures

Drought relief measures are implemented as soon as the distress signals are visible. These measures are location-specific and require good cooperation and coordination among various departments. Continuous flow of information from village to administrative units and back is essential. Some of the measures to reduce impact of drought implemented by Government of India through State Governments are described below.

4.1.1. Relief employment

Central and State Governments initiate relief works to provide employment during drought. Most recently, the Government of India has started the National Rural Employment Guarantee Scheme (NREGS) in 2005 by providing 100 days of employment per year to adult members of family who were willing to undertake manual work for creation/development of public assets at the statutory minimum wage. The Government is planning to increase employment days to 150 in drought years due to its success rate. The program also permits works for individual beneficiary such as construction of farm ponds, new wells/deepening of existing wells, new water channels, rainwater harvesting structures, all of which contribute to drought proofing.

4.1.2 Augmenting drinking water supply

Water is the basic need for human and cattle population. Supply of drinking water during droughts is the responsibility of the State Government. Measures taken by the Government for management of water resources includes (1) repair and augmentation of existing water supply schemes, (2) special measures and schemes for areas with acute drinking water scarcity, (3) construction of temporary piped water supply, (4) digging of new bore wells, and (5) supply of water through tankers and bullock carts.

4.1.3 Ensuing food grains availability

Supplying food grains through Public Distribution System (PDS) was initiated from 1965-66, jointly operated by the Central and State Governments. The PDS with a network of about 474000 lakhs fair price shops in the country is one of the largest networks in the world. Since 1977, targeted PDS was introduced which follows a two tier subsidized pricing for people "Below Poverty Line (BPL)" and "Above Poverty Line (APL)". Community kitchens for certain segments of people such as old, disabled and women are also run either by Government or through NGOs during extreme drought situations.

4.1.4 Cattle camps and fodder supply

To prevent the distress sale of cattle during drought years, the State Governments organize cattle camps in the affected regions and protect animals against starvation and diseases by transportation of fodder and feed from the areas where the situation is not as alarming and need based vaccination. Government also encourages farmers in drought prone areas to undertake fodder cultivation on the banks of canals, tank beds or other areas under irrigation.

4.1.5 Contingency crop planning

Contingency crop planning is the most important short-term strategy for drought management (see also Srinivasa Rao *et al.,* in this volume). The State Agricultural Universities and ICAR Institutes have formulated contingency plans for delayed monsoon, mid-season breaks and early withdrawal. These are available at state or agroclimatic zone level. In order to make them more useful and effective, ICAR, in collaboration with State Agricultural Universities and State Agricultural Departments are preparing district level contingency plans by pooling and analyzing all the relevant natural resources information of each district to cover all weather aberrations like droughts, floods, cyclones, heat wave, frost, etc. It is planned to prepare these plans for all 600 districts in the country. In addition to crops, livestock and fisheries are also covered in this program.

4.1.6 Agro-advisories

The India Meteorological Department (IMD) through its Integrated Agro-advisory Services are issuing weather-based advisories at the district level covering all 127 agroclimatic zones using the medium range forecast (3 to 4 days) and the crop conditions in collaboration with ICAR Research Institutes and the State Agricultural Universities. All the centres of the All India Coordinated Research Project on Agrometeorology are also participating and the research results generated through this project are being used for formulating advisories. These are disseminated through various mass media and placed on the websites of ICAR, IMD and SAUs. Scientists of State Agricultural Universities also reach farmers through radio, television, newspapers and contact farmers. The economic benefits accrued due to agro-advisories can be seen in **Table 3**.

4.1.7 Use of ICT: Decision Support System (DSS) for Drought Management

A Decision Support System (DSS) is an integrated interactive computer based system consisting of analytical tools and information management capabilities designed to aid decision makers. A

DSS typically consists of data bases, modeling tools and documentation of the decision making process. DSS could be used to provide timely information, which will support the decision makers.

Table 3. Impact of agro-advisories on farmers income

Location	Crop	Advisory given	Benefit to the farmer
Jammu	**Maize** **Rice**	**Timing of irrigation**	**Rs.750/ha**
Trissur	Banana	Timing of irrigation	Rs.1275/ha
Kovilpatti	Cotton	Pre-monsoon sowing	Rs.1000-1500/ha
Bhubaneswar	Kharif Rice	Delaying pesticide spray	Rs.850/ha
Ranga Reddy	Grapes	Spraying of fungicide	Rs.31000/ha

CRIDA has developed drought management plan for 1200 *mandals* and 22 districts of Andhra Pradesh. The mandals prone to drought were assessed and prioritized using bio-physical and socio-economic parameters. Drought severity indices were worked out for all the mandals. A DSS was developed with diverse modules dealing with assessment, mitigation and relief measures to reduce the time lag in collection, processing and transfer of data/information. Forewarning for agricultural drought was attempted for the first time on real time basis. The inputs include daily rainfall, maximum and minimum temperature for deriving PET, crop coefficient, available water content for a given soil type, maximum yield of crop, duration of the crop and sowing date. Information on groundwater, surface water and livestock management are also included in the DSS. Drought preparedness is much more cost-effective than expenditure on relief measures.

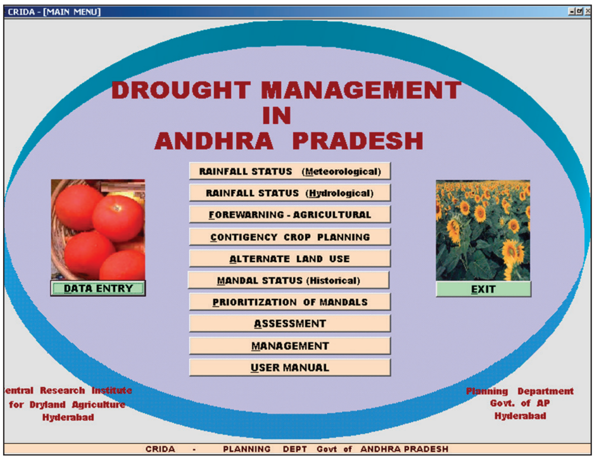

Figure 5. Drought management in Andhra Pradesh, India.

4.1.8 National Agricultural Drought Assessment and Monitoring System (N- ADAMS)

An agricultural drought information and monitoring system had been launched in India using satellite data under the project 'National Agricultural Drought Assessment and Monitoring System (NADAMS)' in 1989 by National Remote Sensing Agency (NRSA). Under NADAMS, agricultural conditions are monitored at state level using daily observed coarse resolution (1.1 km) NOAA AVHRR data for the entire country and at sub district level for Andhra Pradesh and Karnataka using higher spatial resolution IRS WIFS data (188m). Fortnightly bulletins were issued at district level for 11 states in the country during 1989 to 1991. Since 1992, detailed monthly reports at the end of August for June, July and August and the monthly updates thereon for the period of September and October are prepared and sent to the concerned authorities for preparation of contingency plans.

4.2 Medium-term strategies

4.2.1 Integrated Watershed Management Programme (IWMP)

The Government of India considers Watershed Program as the principal vehicle for drought proofing in rainfed areas. Till 2007 investments made by various agencies on watershed implementation are Rs.194,706 million (~US $ 3,000 million) and the area treated is about 56.5 m ha with an average investment of Rs. 3444 per hectare as per the assessment of Planning Commission.

In 1999-2000, National Bank for Agriculture and Rural Development (NABARD) has established a Watershed Development Fund (WDF) to enable states to access credit for treatment of large areas under watershed development (Government of India, 2000). National Rainfed Area Authority (NRAA) formulated new common guidelines for Watershed Programs in 2008 where large area up to 5000 ha are covered which provides opportunities for resource conservation and drought proofing.

4.2.2 Integrated Water Resources Management(IWRM)

Since water has an economic value, it is important that the competing uses for water must be reconciled in order to manage it sustainably. The Integrated Water Resources Management (IWRM) strategy of the Government of India aims to achieve this objective by considering water as a single resource unit regardless of different uses to which it is put to. IWRM aims to ensure the coordinated development and management of water, land and related resources by maximizing economic and social welfare without compromising the sustainability of the vital ecological systems.

4.2.3 Improving Water Use Efficiency (WUE)

Even after all the ultimate irrigation potential is developed in India, more than 50 percent of the cultivable land will still remain under rainfed cultivation. In addition to improving the performance of existing irrigation systems, higher efficiency in water use needs to be ensured to meet increasing demands. ICAR and SAUs, through their research efforts, have evolved many improved irrigation methods, zero tillage, raised bed planting, breeding low water requiring varieties, etc. for enhancing the WUE. However, micro-irrigation methods will be the key component for achieving high water use efficiency.

4.2.4 Crop Insurance Scheme (CIS)

Crop insurance was introduced in India during *kharif* 1985, a the Comprehensive Crop Insurance Scheme (CCIS). One of the basic objectives of the scheme was “to provide a measure of financial support to farmers in the event of crop failure due to droughts, floods etc.” But the scheme was voluntary and states were free to join the scheme. Only a few food grain crops such as wheat, paddy, millets (including maize) and oilseed and pulses were covered in the scheme. Based on initial experiences, the scheme was revised as Experimental Crop insurance Scheme (ECIS).

This was further improved and a Modified Comprehensive Crop Insurance Scheme (MCCIS) was introduced in *kharif*, 1999. In 2009-10, as many as 27 million farmers growing crops on 38 m ha were insured by Agricultural Insurance Company (AIC) alone.

4.2.5 Weather-based insurance

As the Crop Insurance Scheme has some limitations such as long time for settlement of claims, weather-based insurance is now becoming popular with the farmers. This is relatively a new concept and high level of transparency is maintained. Pay out structures are developed to compensate farmers to the extent of losses deemed to have been suffered using weather triggers.

4.3 Long-term strategies

4.3.1 Increasing irrigation potential

At present, out of 142 million hectares cultivated area in India, only 58 m ha is under irrigation. Ground water provides 60 percent of the irrigation and hence ground water recharge schemes, sustainable exploitation, and demand management are critical to maintain India's irrigation potential. Going by past trend, irrigation is extending by around four million hectares every five years. By extrapolating this trend, it is projected that about 20 million ha additional area is likely to be brought under irrigation in the next 25 years. This will still leave nearly 64 million hectares under rainfed conditions. Bringing all the area under irrigation is not possible in the near future and hence drought management continues to be an important agenda for India for long time to come.

4.3.2 River linking

Linking major rivers in India to transfer surplus water in some rivers to others experiencing deficit (where the basins are almost closed) is another option to manage droughts in India. Several feasibility studies have been commissioned on the subject and a few small rivers have been linked. High-level taskforces are working on the proposal but in view of immense political and environmental implications, it is difficult to see great progress in the near future.

5. National level coordination and future outlook

The Department of Agriculture and Coordination (DoAC) under the Ministry of Agriculture is the nodal department for coordination of drought management in India. Indian Meteorological Department (IMD), ICAR, Ministry of Water Resources, Department of Civil Supplies and Railways all take part in this effort. A weekly inter-ministerial weather watch group monitors the rainfall and crop situation and recommends appropriate contingency measures. A National Rainfed Area Authority (NRAA) was formed under the Ministry of Agriculture to provide technical support for development of rainfed areas including drought management. The Ministry of Agriculture has developed a manual on drought management, which describes the details of the institutional, technical and logistic systems to be followed by the Centre and States during droughts. The National Disaster Management Authority (NDMA) under the Home Ministry has also brought out national guidelines on drought management which cover all important aspects like institutional frame-work, prevention, preparedness, mitigation, capacity building and relief response.

Climate change is adding a new dimension to drought management. As per several global models the rainfall in some regions of India is likely to decrease while in other areas it would increase. Recent rainfall trend indicates that the number of rainy days are decreasing many parts of the country and the intensity of rainfall is increasing. Long dry spells and high rainfall events are becoming more common. These challenges pose new problems for drought management. The Indian Council of Agricultural Research has already initiated a network research program on understanding the impact of climate change on the frequency of drought and floods and evolving suitable adaptation and mitigation strategies.

Since agriculture is a State subject, all the States in India have also strong administration system for managing drought and under-taking relief measures. The Relief Commissioner and the departmental heads of agriculture, animal husbandry, fisheries and rural water supply have to work in tandem to implement relief measures. These measures are triggered once the State declares a particular district or blocks as drought hit. Many states in India have their own criteria for declaration of drought. However, the Government of India is now evolving uniform indicators which can be used across the country for declaring drought. The Government of India is also taking a number of measures to improve drought forecasting and early warming systems by enhancing the forecasting capabilities of IMD and increasing the rain gauge density and modernizing weather data collection and transmission infrastructure. CRIDA, Hyderabad is working as the nodal institute under ICAR for providing technical support in drought management and formulation of contingency crop plans across the country. National Remote Sensing Centre (NRSC) in Hyderabad is also using satellite information for assessing drought intensity through Normalized Differential Vegetation Index (NDVI). In future, it is planning to integrate more indicators for drought monitoring. All these measures hopefully will help in managing droughts more effectively in future.

6. Conclusions

India has a long history of tackling droughts and its successful management. However, due to the large size and geographical diversity of the country, effective drought management continues to be a major challenge at the ground level. Therefore, the country is strengthening its scientific capability in weather forecasting, infrastructure for weather data collection and dissemination, institutional framework for implementation of contingency strategies and policy measures for risk management in order to evolve an effective drought management system.

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3. African holistic worldview paradigm for interdisciplinary climate change science

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Abstract

Available data shows oxygen partial pressures in human blood vessels; vein, bone marrow, lung capillary, as well as atmosphere constitute, approximately, a Fibonacci sequence; 5: 8: 13: 21 % (Common ratio ≈ 1.6…; *phi*). Human life is, therefore, integral to a phi-equilibrium oxygenosphere of Earth. Current Earth climate change crises is, significantly, a phenomenon of oxygen and some of its compounds; oxygen (O_2), ozone (O_3), carbon dioxide (CO_2) and water (H_2O) in dynamic interaction with energy. Climate change crisis is human-made; anthropogenic. Crisis resulted, inadvertently, from the failure of current social system models and their guiding 'Science of Society'. The inability of current paradigm of science to deal with 'holistic complexity', such as biosphere, is suggested to have led to this. Science from African holistic network worldview is argued to be capable of obviating this problem. Some of the critical elements of this world system are naturalism, holism, networking, and synergism. This paradigm is employed to re-interpret, for example, some existing socio-economic data (e.g. income size distribution and un-employment), revealing underlying natural laws. The single most important solution to climate crises in sight is naturalization of human society. Malarial parasite life-cycle is seen as cruise up-and-down the oxygenosphere gradients, and logical treatment as oxygen/ozone. Attention is drawn to the existential risk to humans of perturbing the natural balance of the phi-equilibrium oxygenosphere. Importance of re-greening the Earth through regenerative agriculture, informed by integrated science, is discussed. A focus on oxygen and its relevant compounds, in dynamic interaction with energy, in the restoration of sustainable green biosphere from current risky 'brown humanosphere' is advocated.

Keywords: Biosphere, Holistic complexity, Oxygenosphere, Ozone, Malaria, Regenerative agriculture, Synergism, Webocosmos

4. New irrigation techniques for optimizing water use in new land development in Egypt (The first priority - 1.5 million Feddans)

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Abstract

Egypt has a total land area of approximately 1 million km^2, most of which is desert and only 5.5 % is inhabited. Settlements are concentrated in and around the Nile Delta and its valley. The total cultivated land area is about 8.6 million Feddans, ie.3% of the total land area, and consists mostly of the old and newly reclaimed areas**.** Water resources are the critical factor for all production and service processes and sustainable development in Egypt. The water resources availability for the whole economic and services activities is extremely dependent on the River Nile, its quota of Nile water is still fixed at 55.5 billion m^3/year, and this quota constitutes 90% of the country's water budget, the remaining 10% being minor quantities of renewable and fossil groundwater plus a few showers of rainfall. Agriculture is the major consumer of water (80-85% of the total net demand) , as Egypt lies in the arid zone where nearly all agriculture depends on irrigation. Under the 1st Priority Land Reclamation Projects of the New Land Development in Egypt**,** it is planned to reclaim 1.5 million Feddans of agricultural land in 17 reclamation areas in the Western Desert. Some 1.328 million Feddans will be irrigated with groundwater, and 172,000 Feddans with surface water. The groundwater is being extracted from the large water bearing formations constituted by the extensive Nubian Sandstone Aquifer (NSA) and the overlying Post Nubian Aquifers Systems. One of the main objective of the Sustainable Agriculture Development Strategy 2030 is to improve irrigation water use efficiency while the main goals are: swustainable utilization of natural agricultural resources, improvement of the agricultural productivity for increasing the value of crop production per unit land and water unit, expanding the use of modern and well developed irrigation techniques, promoting land reclamation, developing farming systems, and sustainable development of rain-fed agriculture.The study will cover the selection of suitable irrigation systems based on proposed crop patterns and soil classification of reclamation areas, which will play an important role in the success of the project for optimal use of available water resources.

Keywords: Irrigation systems, Water quantities, Land reclamation, Sustainable agriculture

Introduction

Egypt is north African/ Mediterranean country (Latitudes 22º - 32º North and longitudes of 25º-35º East) with a total area of about 1 million km^2 (Table 1). The country lies in the moderate climatic zone, with hot and dry weather in the summer, and warm and, at some places, rainy in the winter. The main annual rainfall ranges from 0 mm in the desert to 200 mm per year in the north costal region. Extending agriculture to desert lands and maximizing water use efficiency are the two main components of the national agriculture strategy to increase agriculture production in Egypt. Water resources are the critical factor for all production processes and sustainable development in Egypt. Agriculture production of both food and fibers is the main economic activity related to water resources in the Egyptian economy. Agriculture is the major consumer of water, as Egypt lies in the arid zone where nearly all agriculture depends on irrigation. Agriculture accounts for about 80-85% of the total net demand of water in the country, the remaining being for municipal, industry and fishponds requirements. Since 1990, Egypt reached the water poverty line with respect to the per capita share of water of almost 1000 cubic meter per year. In 2014 such share decreased to almost 615 cubic meters per year, and is expected to fall to 500 m^3 per capita before the year 2030 (Table 2).

Table 1. Cultivated and reclaimed agricultural lands in 2014

Land type	**Area in million**	
	Fadden	**Hectare**
Total cultivated area	8.6	3.61
Area of the Nile Valley & Delta (surface irrigated lands)	6.5	2.73
Area of the newly reclaimed land (pressurized irrigated lands – sprinkler & localized systems)	2.1	0.88
Cropped area	15.2	6.39
Expected area of reclaimed land by 2030	2.5	1.05

Table 2. Water resources available and use needs in Egypt, 2016

Resources		**Share with other countries**	**Amount b m^3**	**Uses**	
Traditional	Nile	Yes	55.5	Agriculture	60.00
	Rain fall	-	1.30	Navigation	0.2 0
	Ground water	Yes for 6.3	8.90	Industry	8.50
Non-Traditional	Reuse of drainage water		7.40	Municipal	9.00
	Reuse of treated sewage water		5.00	Forest	2.50
Additional resources	Saline water desalination		0.10		
	Available from development of on-farm irrigation + new varieties and reduction of rice areas		3.61*		
	Virtual water		-**		
Total			78.20		80.2 0
Difference			- 2.0 b m^3 /year		

* increases annually by 0.455 billion cubic meters and depends on the seriousness of implementation

** depends on the import and export of agricultural product

The main constraints facing the on-farm irrigation are:

- Unstable regional policy related to water resources.
- Lack of adequate database for natural resources, rain-fed agriculture, and renewable energy.
- Weak perception of well developed irrigation technologies by farmers.
- Extremely low income of farmers that negatively affects their capability for farming systems development and improving irrigation techniques.
- Harsh environment in the rain-fed agriculture areas.
- Lack of interest of agriculture investors to use renewable energy due to the stability of the conventional energy cost

The potential agricultural area in Egypt is 95% irrigated from the Nile (Table 2). Water management and irrigation technologies are the main wheals for agricultural development projects in Egypt. In such situation, the only available solutions for include to add new water resources, and to improve the water management techniques in order to avoid any waste of water. The second proposed solution is more applicable because the highest percentage of Egyptian water resources is from outside the national boundary.

Land reclamation projects in Egypt

The most important objective of the sustainable Agriculture Strategy 2030 are improving rural livelihoods (social return), and reducing poverty in the rural areas, promoting land reclamation and developing farming systems, sustainable utilization of natural agricultural resources by improving irrigation water use efficiency, expanding the use of modern and well developed irrigation techniques, and improvement of the agricultural productivity for increasing the value of crop production per unit of land and water unit, add more value to the agricultural products through processing (agri-business), and create a more enabling environment for investment in agriculture, thus creating more jobs in the sector. The main objective of land reclamation in Egypt are:

- Providing Food security and increase the food self-sufficiency of agricultural crops by increasing the cultivated land by an area of a million Fadden (first stage).
- Create an opportunity for jobs directly and indirectly to reduce the unemployment rate.
- Establishment of new industrial farming communities depending on low water requirement crops.
- Increase export of agricultural crops and manufactured products.
- Relieve the burden on the balance of payments

First stage of land reclamation project

The planed reclamation area is 4 million Fadden in 4 years (2014-2018). The first phase included reclamation of one million and half Fadden by the year 2015. The location map for the proposed project areas is shown in Figure 1. All of the area will be irrigated by groundwater except Toshka site (143 thousand fed.), which will be irrigated using surface water from the Sheikh Zayed Canal.

The Ministry of Water Resources and Irrigation made an important study to ensure the availability water for irrigation of the proposed areas. It meets the cost of its own national infrastructure (drilling of wells, main canals and drains). The first million and half Fadden will depend on an integrated development based on agricultural industrial clusters in the framework of a comprehensive development. Therefore, the cropping patterns will be according to geo-environmental, soil type and water quality.

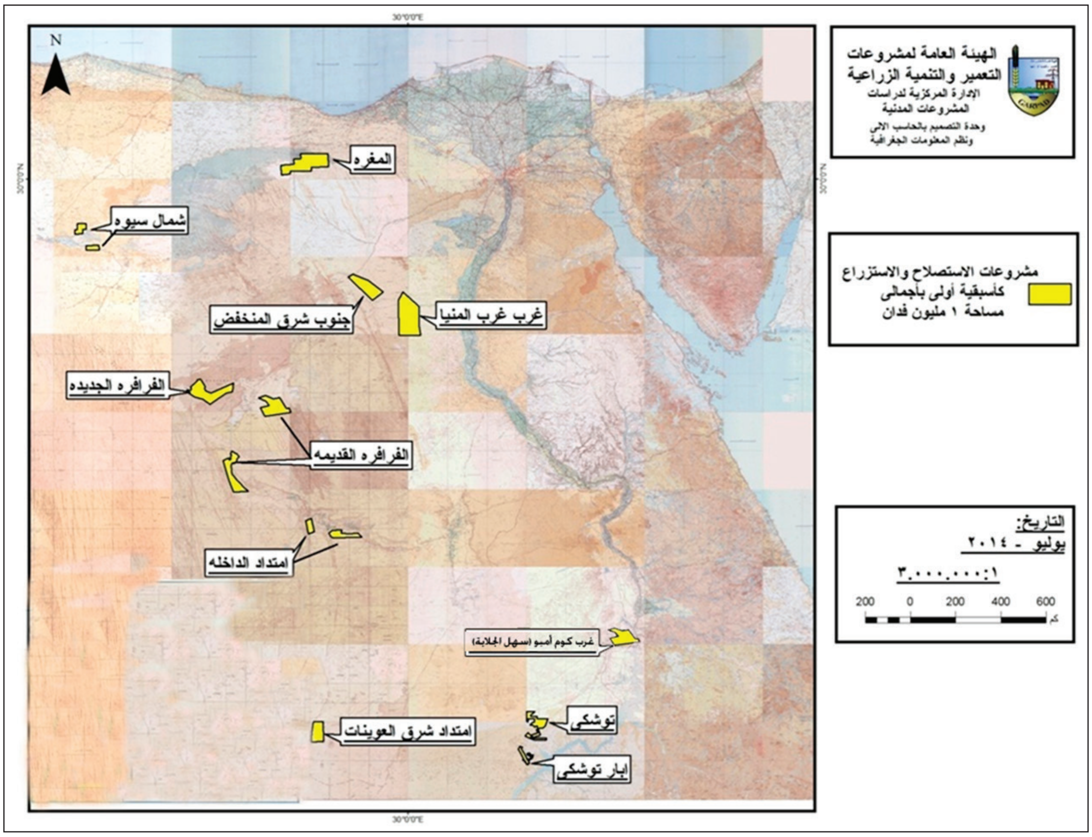

Figure 1. General location map for the proposed project areas.

Proposed irrigation systems

One of the main objectives of the sustainable Agriculture Strategy 2030 is to improve irrigation water use efficiency. The following irrigation methods and systems are selected according to the proposed agricultural models (cropping patterns), and soil and water type of the each area:

• **Center Pivot Irrigation System and Linear-move Sprinkler System** (Figure 2 & 3, Table 5) will be used for irrigating the field crops.Therefore, it may be preferable to leave part of the areas between the central irrigation systems without agricultural exploitation and to be satisfied with residential facilities and service and productive buildings such as workers' houses, engineers and administrative offices and warehouses, staging stations, packaging, greenhouses, water treatment plants, machinery maintenance centers, garages, fuel depots, and animal and poultry production buildings. The discharge of the wells should be considered with the required amount of water for the operation of the center pivot and the linear move sprinkler systems. The required operated flow rate of the center pivot irrigation ranges from 371 m^3 / h to irrigate 150 fed. to 142 m^3 / h for the smallest equipment (Table 5). The minimum required for the linear move sprinkler system is 150 m^3/ hr. Table 7 shows the average cost of irrigation system.

Center Pivot Systems **Linear Move Sprinklers**

Figure 2. Sprinkler irrigation systems.

• **Localized irrigation systems** (Figure 4, Table 6) include surface and sub-surface drip systems drip-bubbler-etc. for irrigating horticultural crops (vegetables, fruits, palm trees, green houses and ornamental plants. The fruit and vegetable crops are mainly harvested fresh. This should be taken in account for the installation of two lines for each row of trees to increase the wet area and avoid the accumulation of salts. Some vegetable crops under trees can be planted in the first years to improve soil properties and cover some cost. Bubblers are mainly used for palm trees and fruit trees. Micro-sprinkler are mainly used for all fruit trees, especially when cultivating some vegetable crops under them or other crops for soil improvement.

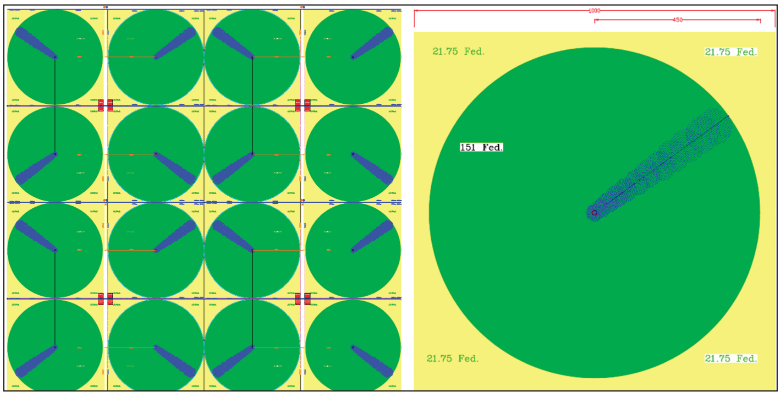

Figure 3. Layout of center pivot system irrigated area.

Table 6 illustrates some of the standard specifications of localized irrigation systems while Table 7 shows the average cost of localized irrigation systems for horticultural crops.

Table 5. Some of the standard specifications of sprinkler irrigation systems

1. Center pivot irrigation system (R =300m, irrigated area 67 fed.) Discharge 95.5-142 m³/h.		**2. Center pivot irrigation system (R =400m, irrigated area 120 fed.) Discharge 168 -252 m³/h.**		**3. Center pivot irrigation system (R =447.5m, irrigated area 150 fed.) Discharge 315 -371 m³/h**	
Application Depth mm-(m3/fed.)	**Speed hr / round**	**Application Depth mm-(m3/fed.)**	**Speed hr / round**	**Application Depth mm-(m3/fed.)**	**Speed hr / round**
3.48 (14.6)	6.9	4.78 (20.1)	9.6	12(50.4)	24
5.08 (21.3)	10.1	5.08 (21.3)	10.2		
7.62 (32)	15.2	7.62 (32)	15.3		
10.16 (42.7)	20.2	10.16 (42.7)	20.4		
12.70 (53.3)	25.3	12.70 (53.3)	25.5		
4. Linear move Sprinkler System					
Discharge 150-400 m³/h.					

Table 6. Some of the standard specifications of localized irrigation systems

Distributer	**Operating pressure (Bar)**	**Vegetable crops**		**Fruit trees.**		**Palm trees**	
		Discharge (Lps)	**No. of distributer**	**Discharge (Lps)**	**No. of distributer**	**Discharge (Lps)**	**No. of distributer**
Surface drip irrigation Systems	0.8	4	2-3 dripper/m	8-12	4 dripper/ tree		
Sub-Surface drip irrigation Systems	0.8	4	2-3 dripper/m	-	-	-	-

Bubblers	1.0-1.2	-	-	100-150	One Bubblers /tree	150-250	1/tree
						100-150	2/tree
Mini- Sprinkler	1.5	-	-	40-70	One Sprinkler/ tree	-	-

Table 7. Average cost of irrigation systems

1. Center Pivot Irrigation System field crops				
Items	**Average cost US$ /fed**		**Average cost US$/ hectare**	
Water Resource	Ground water	Surface water	Ground water	Surface water
well +deep well pump+ pump (shelter	541-1082	-	1287-2574	-
(Centrifugal pump+ pump shelter	-	203	-	483
Center Pivot System	609	609	1449	1449
Main irrigation System network	338	338	804	804
Total	1488-2029	1150	3540-4827	2736

2. Drip Irrigation System for Vegetables				
Items	**Average cost US$/fed**		**US$/hectare**	
Water Resource	Ground water	Surface water	Ground water	Surface water
well +deep well pump+ pump (shelter	541-1082	-	1287-2574	-
(Centrifugal pump+ pump shelter	-	203	-	483
Drip System	811	878	1930	2090
Main irrigation System network	338	338	804	804
Total	1690-2231	1419	4021-5308	3377

3. Drip Irrigation System for fruit trees & bubbler Irrigation System for palm trees				
Items	**Average cost US$/fed**		**Average cost US$/ hectare**	
Water Resource	Ground water	Surface water	Ground water	Surface water
well +deep well pump+ pump (shelter	541-1082	-	1287-2574	-
(Centrifugal pump+ pump shelter	-	203	-	483
Drip Or bubbler System	676	743	1609	1768
Main irrigation System network	338	338	804	804
Total	1555-2096	1284	3700-4987	3055

Reclamation steps

The reclamation steps include the following: a) Constructing national structures: main roads , wells , canals, drainage system, energy sources; b) Constructing internal structures related to each region and the patterns of subtraction and disposition: Country assumes responsibility for internal structure for young graduates and social groups**.** Companies and investors carry out the internal structure and cultivation for each allocated area; **c)**Reclamation: land levelling, irrigation networks, etc. are left to beneficiaries related to the desired pattern of exploitation.

Selected projects for collaboration

Exchange consulting is done in the following areas: A. Training and Human Resources Development programs(HRD) of water resources and on-farm irrigation management; B. Updating the data of natural resources (land, water and climate) using GIS and Satellite images data; C. Studies on integrated agro-climate systems and developing the existing agricultural systems (irrigated agriculture, rain-fed agriculture, and range land; D. Integrated main field crop management; E. Integrated main horticultural crops management; F. Developing an integrated package for mechanical management of different crops; and G. Testing and quality control of irrigation equipment.

The following sub-activities are proposed:

- Harnessing the potential of saline water for sustainable and economical agriculture production systems as well as for non-agriculture options such as concentrating and harvesting salt as byproduct and as a business opportunity.
- Linking with and contributing to the international water and soil quality monitoring and assessment strategies at different scales such as World Water Quality Assessment, led by UNEP.
- Developing small-scale grey water system installation and use guidelines to facilitate expanding the safe use of grey water in rural and urban settings not connected to formal sewerage collection systems; and promoting small scale and inexpensive grey water collection, treatment, and supply systems for landscape and gardening purpose

Investment for the production and manufacturing of agricultural equipment

The local market covers only locally or imported irrigation and mechanization equipment and materials to cover the projects requirement as following:

Irrigation eequipment and materials for irrigation systems

- 50% PVC pipe and PE tube .
- 15 % PVC and PE fittings.
- 15-25 % filtration and chemigation systems.
- 20% sprinkler heads, drippers, bubblers, mini- sprinklers, and aluminum and PVC gated pipes
- 30% Valves.pr. Regulators, flow regulators, air vent, pressure relief valves , water and flow meters
- 40% centrifugal, turbine ,and submersible pumps.
- 20% weather stations.
- 25-35% center pivot systems.

Farm machinery

- 50% Land preparation equipment.

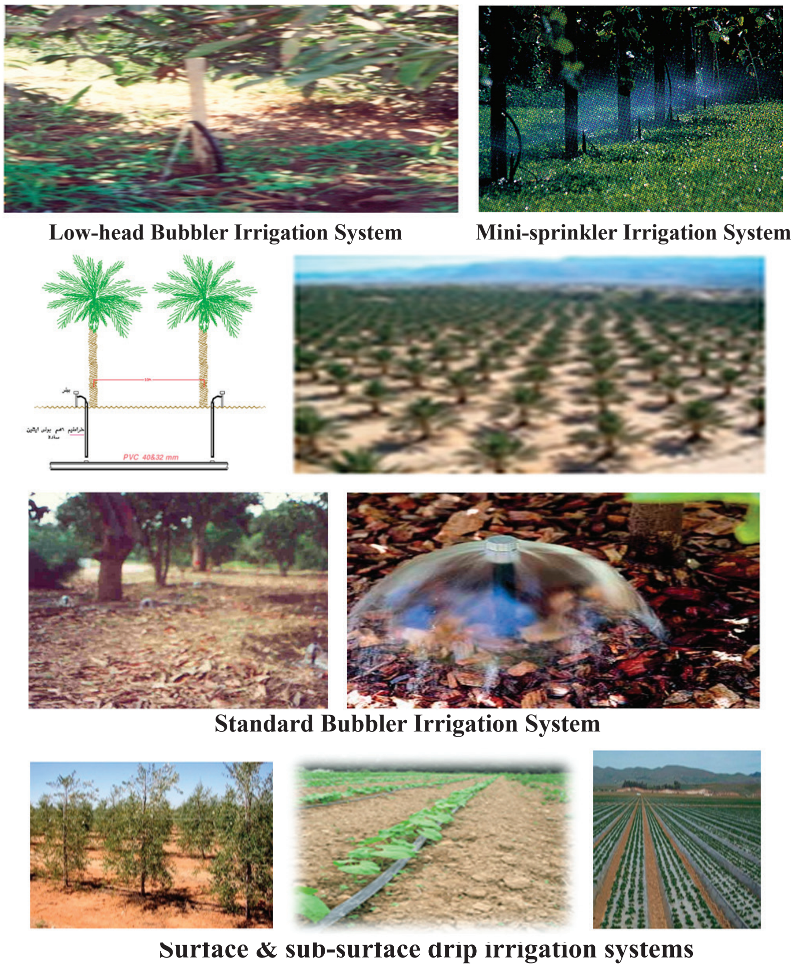

Figure 4. Localized irrigation systems.

- 50% Sprayers, harrows etc….
- 15% post harvesting equipment .
- 20% Deferent sizes tractors.
- 30% Laser equipment.

Opportunities

- Design – Construction
- Material, products, and Equipment Imported.
- Material, products., and Equipment Manufacturing
- Supporting by financing,
- Enter venture partnership on irrigation and mechanization projects.Training and Human Resource Programs (HRD) Of Water Resources and On-Farm Irrigation Management Program would aim to enhance farmer knowledge and uptake of improved irrigation and associated land improvement and crop production technologies

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Presentations in Special Sessions

Special Session 1: Genomics of Stress Tolerance in plants

1. PCD-related genes and transcription factors affect salt tolerance in plant

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Abstract

This speculation was based on a natural exciting phenomenon suggesting that suppression of genes or transcription factors (TFs) inducing programmed cell death (PCD) might confer tolerance against abiotic stresses in plant. First, PCD-related genes were induced in tobacco leaves via the treatment with oxalic acid (OA, 20 mM) for 24 h. RNAs were extracted from cells 0, 2, 6, 12 and 24 h after treatment for deep sequencing and RNA-Seq analysis was done with a special emphasis on PCD-related genes up-regulated after 2 h of OA exposure. A number of PCD-related genes were knocked down via virus-induced gene silencing (VIGS) and results indicated the influence of some of them on inducing or suppressing PCD. Knockout T-DNA insertion mutants of these genes in *Arabidopsis* were tested under salt stress (0, 100, 150 & 200 mM NaCl) and the results indicated that the mutant of an antiapoptotic gene, namely *Bax Inhibitor 1 (BI-1)*, whose virus-induced gene silencing (VIGS) induced PCD in tobacco, was salt sensitive, while a mutant of an apoptotic gene, namely *mildew resistance locus O (Mlo)*, whose VIGS suppressed PCD, was salt tolerant as compared to the WT (Col) control. These data support our hypothesis that retarding PCD-inducing genes can result in higher levels of salt tolerance, while retarding PCD-suppressing genes can result in lower levels of salt tolerance in plant. Then, genes up-regulated after 2 h of OA treatment with known function in PCD were utilized as landmarks to select transcription factors (TFs) with concordant expression. Knockdown mutants of these TFs were generated in tobacco via VIGS in order to detect their roles in PCD. Knockout T-DNA insertion mutant of *Arabidopsis* as well as over-expression lines of one TF, namely ERF109 were tested under salt stress (0, 100, 150 and 200 mM NaCl) and results indicated the involvement of this TF in retarding PCD in tobacco and conferring salt tolerance in *Arabidopsis*.

Keywords: Abiotic stress tolerance, Programmed Cell Death, Arabidopsis

2. Field evaluation of transgenic wheat (*Triticum aestivum* L.) overexpressing barley chitinase gene conferring resistance to wheat rusts and powdery mildew

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Abstract

The study aimed at improving fungal resistance in bread wheat via genetic transgenesis. Transgenic wheat harboring barley chitinase (*chi26*) gene driven by maize *ubi* promoter was obtained using biolistic bombardment. The herbicide resistance gene, *bar,* driven by the *CaMV 35S* promoter was used as a selectable marker. Molecular analyses proved the integration, copy number and level of expression of *chi26* gene in five independent transgenic lines. Chitinase enzyme activity was detected using standard enzymatic assay. Variation in *chi26* gene expression levels of the different transgenic events as compared to their respective controls was proven using qRT-PCR. The transgene was silenced in some transgenic families across generations. Gene silencing in the present study seemed to be random and irreversible. Homozygous transgenic plants of the T4, T5, T6, T8 and T9 generations were tested in the field for five growing seasons to evaluate their resistance against rusts and powdery mildew. The results indicated higher chitinase activity and transgene expression levels that resulted in higher resistance against wheat rusts and powdery mildew in field conditions. Proximate and chemical analyses indicated that the transgenic and non-transgenic lines are substantially equivalent.

Keywords: Bread wheat, Fungal resistance, Transgenic wheat, Chitinase

3. Metabolomic response of *Calotropis procera* growing in the desert to changes in water availability

A. Ramadan[1,2], J.S.M. Sabir[1], S.Y.M. Alakilli[1], A.M. Shokry[1,2], N.O. Gadalla[1,3], Sh. Edris[1,4], M.A. Al-Kordy[1,3], H.S. Al-Zahrani[1], F.M. El-Domyati[1,4], A. Bahieldin[1,4], Neil R. Baker[6], L. Willmitzer[5], and S. Irgang[5]

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Abstract

Water availability is a major limitation for agricultural productivity. Plants growing in severe arid climates such as deserts provide tools for studying plant growth and performance under extreme drought conditions. The perennial species Calotropis procera used in this study is a shrub growing in many arid areas that has an exceptional ability to adapt and be productive in severe arid conditions. We describe the results of studying the metabolomic response of wild C. procera plants growing in the desert to a onetime water supply. Leaves of C. procera plants were taken at three time points before and 1 hour, 6 hours and 12 hours after watering and subjected to a metabolomics and lipidomics analysis. Analysis of the data reveals that within one hour after watering C. procera has already responded on the metabolic level to the sudden water availability as evidenced by major changes such as increased levels of most amino acids, a decrease in sucrose, raffinose and maltitol, a decrease in storage lipids (triacylglycerols) and an increase in membrane lipids including photosynthetic membranes. These changes still prevail at the 6 hour time point after watering however 12 hours after watering the metabolomics data are essentially indistinguishable from the prewatering state thus demonstrating not only a rapid response to water availability but also a rapid response to loss of water. Taken together these data suggest that the ability of C. procera to survive under the very harsh drought conditions prevailing in the desert might be associated with its rapid adjustments to water availability and losses.

Keywords: Water availability, Metabolomic response, *Calotropis*, Desert environment

4. Development of transgenic wheat (*Triticum aestivum* L.) expressing *AtMDAR1* gene conferring salt tolerance

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Abstract

Monodehydroascorbatereductase (MDAR), an important enzyme of the ascorbate–glutathione cycle, is involved in salt tolerance of plants through scavenging of reactive oxygen species (ROS). In this study, a cDNA encoding *AtMDAR1* gene from the *Arabidopsis thaliana* plant was introduced into wheat plants of 'Bobwhite 56' cultivar using biolistic. Copy numbers and expression of *MDAR1* gene were tested in five stable transgenic plants (MD1, MD2, MD3, MD4, MD5) by molecular analysis. Accumulation of ascorbic acid (AsA) in transgenics was greater than the non-transgenic plants. In a greenhouse experiment, transgenic plants showed more vigorous growth than the non-transgenic plants (Bobwhite56) at 200mM NaCl. In a high salt medium, transgenic plants (MD5 and MD6) had higher dry mass, shoot and root length, and higher tolerance index (T_i) in comparison to the non-transgenic plants.

Keywords: Monodehydroascorbatereductase, Salt tolerance, *Arabidopsis thaliana*

5. Optimization of *Agrobacterium*-mediated transformation in *Sorghum bicolor*

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Abstract

Agrobacterium-mediated transformation system was used for the transformation of sorghum. Two different *Agrobacterium tumefaciens* strains, LBA4404 and EHA101 harboring the pTF102 binary vector, carrying both the *GUS* and *Bar* genes, were utilized to transform the immature embryos of seven sorghum genotypes. Transient GUS expression indicated that the seven genotypes are transformable. *Agrobacterium tumefaciens* strain LBA4404 was found superior to the other strain EHA101, in the transformation of the investigated genotypes. Regenerated transgenic plants were obtained from three genotypes, 'LG3', 'LG8' and 'Dorado'. Stable integration of the *bar* and *gus* transgenes in T_0 and T_1 plants was confirmed through PCR and Southern blot analyses. The transformation frequency ranged from 1.2% with sorghum genotype LG3 to 10% with sorghum genotype, LG8.

Keywords *Sorghum bicolor*, immature embryos, *Agrobacterium tumefaciens*, LBA4404, EHA101, gus expression, transgenic sorghum, plant transformation.

Introduction

Sorghum (*Sorghum bicolor* L.) is the fifth most cultivated and consumed grain crop in the world; after maize, rice, wheat and barley (Belton and Taylor, 2004). The crop is very important as a source of food, feed, beverage and starch for industrial purposes. However, the yield and quality of sorghum is constrained by a wide range of biotic and abiotic factor (Reddy *et al.,* 2005; Acquaah, 2007; Kosambo-Ayoo *et al.,* 2011; Mottaleb *et al.,* 2012). Despite its agronomical importance, it has received little attention in the application of genetic engineering and biotechnology. Moreover, it is categorized as one of the most difficult plant species to manipulate for tissue culture and genetic transformation (Zhu *et al.,* 1998).

Like other cereal crops, the first fertile transgenic sorghum plants were obtained *via* particle bombardment (Casas *et al.,* 1993). Seven years later, the first *Agrobacterium*- mediated transformation of sorghum was reported (Zhao *et al*., 2000). Although work on transformation of sorghum has continued (Zhu *et al.,* 1998; Zhao *et al.,* 2000; Gao *et al.,* 2005a and b; Howe *et al*., 2006; Nguyen *et al.,* 2007; Grootboom *et al.,* 2010; Kosambo-Ayoo *et al*., 2011; Wu *et al.,* 2014), much less success has been achieved compared to the other cereal crops. The progress of sorghum transformation has been challenged by difficulties related to recalcitrance to tissue culture, accumulation of phenolic pigments and long period of selection needed for the regeneration of putative transgenic plants (Casas *et al.,* 1993; Zhao *et al.,* 2000; Jeoung *et al.,* 2002; Howe *et al.,* 2006). These difficulties were addressed in several publications by adopting strategies such as adjusting media composition to increase the regeneration frequency and adding Polyvinylpyrrolidone (PVP) to reduce the phenolic pigments (Grootboom *et al.,* 2008; Muhumuza and Okori, 2013; Assem *et al.,* 2014) or shortening the selection period (Lu *et al.,* 2009). However, additional optimization regarding the plant-pathogen nature such as sorghum genotypes and *Agrobacterium* strains combination is desirable to facilitate transformation of a variety of sorghum inbreds. Such optimization is easily accomplished using sensitive and easy to detect marker genes.

In this manuscript, we describe the utilization of *GUS* reporter gene in investigating the transformation of seven regenerable sorghum genotype of commercial importance, with two different *Agrobacterium tumefaciens* strains. The successful implementation of this method with *gus* and *bar* genes allows it to be a useful tool for the transformation of other genes of agronomical importance for this important crop.

Material and methods

Plant materials, *A. tumefaciens* strains and binary vector

Seven *Sorghum bicolor* genotypes, *i.e.* 'LG3', 'LG4', 'LG8', 'TX631', 'SPMD94001', 'Dorado' and 'SPGM94021', obtained from the Department of Sorghum, Field Crops Research Institute, Agricultural Research Center, Egypt, were sown in the field during the sorghum season and plants were self-pollinated. Sorghum panicles were harvested 10-12 days post pollination and immature embryos were excised and used for transformation experiments. Two *A. tumefaciens* strain, LBA4404 and EHA101, containing the standard binary vector pTF102 (Frame *et al.,* 2002) were utilized for sorghum transformation. The vector system, pTF102 in the *A. tumefaciens* strain, was maintained on a yeast extract peptone (YEP) medium containing either 100 mg/l spectinomycin and 25 mg/l rifampicin for LBA4404 or 100 mg/l spectinomycin and 50 mg/l kanamycin with the strain EHA101. Bacteria cultures, for weekly experiments, were initiated from stock plates stored for up to two weeks at 4ºC.

Sorghum transformation

Sorghum panicles were debranched and surface sterilized by soaking the branches for 30 min. in 2.6% sodium hypochlorite (prepared from commercial bleach) containing 0.1% Tween 20. Panicles branches were then washed 2-3 times with autoclaved distilled water under aseptic conditions. The immature seeds were separated aseptically and then re-sterilized for 10 min. with 10% commercial bleach solution containing 0.1% Tween 20. Immature seeds were then washed 3-5 times with autoclaved distilled water under aseptic conditions. Immature embryos ranging in length from 1.0-1.5 mm were aseptically excised from the kernels and prepared for transformation.

Agrobacterium tumefaciens cultures were grown for 2 days at 28 ºC on YEP medium amended with appropriate antibiotics for selection. One loop of the culture was scrapped and suspended in 5 ml of liquid infection medium supplemented with 100 µM acetosyringone. Immature zygotic embryos were washed twice with bacteria-free infection medium, the final wash was discarded and 1-1.5 ml of *A. tumefaciens* suspension (OD_{550} = 0.4-0.5) was added to the embryos. The tubes were incubated in dark for 10 min. at ambient temperature. A number of 50-200 embryos of each genotype were transformed with each *Agrobacterium* strain according to the protocol described by Frame *et al.* (2002). Transformed embryos were transferred to co-cultivation medium (25 embryos/plate) with scutellum side up. Plates were incubated in dark at 22 ºC for ٤ days after which embryos were transferred to resting media and incubated at 28 ºC for one week. The transformation and regeneration processes can be divided into 5 sequential steps: Agro-infection, co-cultivation, resting, selection, and plant regeneration. The compositions of all media utilized in this study are shown in Table 1.

Table 1. Composition of used media

Media	Composition
Infection	4.3 g/l MS salts (Duchefa Biochemie, Prod. No M0221.0050), 0.1 mg/l myo-inositol, 0.5 mg/l nicotinic acid, 0.5mg/l pyridoxine HCl, 10mg/l thiamine HCl, 1.5mg/l 2,4-D, 1g/l vitamin assay casamino acid, 36g/l glucose, 68.5g/l sucrose, pH 5.2. Add 100µM acetosyringone before using.
Co-Cultivation	Infection media with reducing sucrose to 20g/l and glucose to 10g/l, increasing 2,4-D to 2mg/l, adding 0.5mg/l MES, 0.7g/l L-proline, 10mg/l ascorbic acid, pH 5.8, 3g/l phytagel. Adding 100µM acetosyringone after autoclaving.
Resting	Callus Induction Media CI1 (for genotypes LG3, LG4 and Dorado), CI2 (for genotypes LG8, and TX631), CI3 (for genotype SPGM94021) and CI5 (for genotype SPMD94001) as described in Assem et al. (2014) were supplemented with 250 mg/l cefotaxime or 100mg/l carbenicellin (After Autoclaving).
Selection	Resting media with 1.5mg/l bialaphose (After autoclaving).
Shooting	Shoot induction media Ro (for genotypes LG3, LG4, LG8, SPGM9402), STR1M1 (for genotype TX631) and STR1M4 (for genotypes Dorado and SPMD94001) as described in Assem et al. (2014) were supplemented with 100mg/l carbenicillin (After Autoclaving).
Rooting	2.2 g/l MS including vitamins (Duchefa Biochemie, Prod. No M0222.0050), 20 g/l sucrose, 3g/l phytagel, pH 5.8. After autoclaving add 100mg/l carbenicellin.

Histochemical analysis of transient *gus* expression

The histochemical GUS assay (Jefferson, 1987) was used to assess the transient expression of the *GUS* gene in immature zygotic embryos after the co-cultivation (4 or 7 d after infection). Five embryos were selected from each experiment. The level of transient *GUS* expression was assessed by estimating the intensity of expression on the scutellum side of each embryo. Four levels of expression of intensity were scored (+++ strong, ++ moderate, + weak, and - non-expresser). Embryo derived calli and immature inflorescences were also subjected to the histochemical GUS assay.

Selection and regeneration

For stable transformation, selection was carried out towards the expression of the *Bar* gene using selection media containing bialaphos, as a selective agent, at concentration of 1.5 mg/l for 6-8 weeks. For regeneration, embryogenic calli were transferred to shooting media for shoot development. Calli-derived shoots were transferred to rooting media. Cultures of shooting and rooting stages were maintained at 28 ºC under 16 hrs cool white fluorescent light (75 µmol^{-2} s^{-1}) and 8 hrs darkness. Regenerated plantlets were transferred to soil for further development in the greenhouse. Putative transgenic and non-transgenic plants were painted using the commercial herbicide Basta at concentration of 0.1%.

Polymerase chain reaction (PCR)

PCR was conducted to screen the putatively transgenic T_0 and T_1 plants. CTAB protocol (Murray and Thompson, 1980) was used to extract the genomic DNA from putatively transgenic sorghum plants and non-transformed plants. Primers of Gus-1 (5'- CTCGACGGCCTGTGGGCATTCAGTC-3**'**) and GUS-2 (5'-TAGATATCACACTCTGTCTGGCTTTTGG-3**'**) were used to amplify a 750 bp fragment of DNA containing part of the *GUS* transgene. While, primers Bar-1 (5'-TACATCGAGACAAGCACGGTCAACT-3**'**) and Bar-2 (5'-ACGTCATGCCAGTCCCGTG-3') were used to amplify a fragment of 484 bp for the *Bar* gene. PCR reactions were carried out in a total volume of 25 µl containing 10 ng of genomic DNA, 1x PCR buffer, 3 mM $MgCl_2$, 0.2 µM of forward and reverse primers, 0.24 mM dNTP, and 1.5 U of Taq polymerase. Amplification was conducted in a T100 thermocycler (BIO-RAD, Singapore) using the following program for the *Gus* fragment: An initial DNA denaturation for 5 min. at 94 °C followed by 35 amplification cycles (94 °C, 1 min; 62 °C, 1 min, 72 °C, 1 min) and a final extension step at 72 °C for 10 min. For the amplification of *Bar* fragment, only the annealing temperature was changed to 60°C.

Southern blotting

Ten micrograms of genomic DNA from T_0 and T_1 *Agrobacterium*-derived events and control plants were digested with the restriction enzyme *Hin*d III, at 37°C overnight. Digested DNA was separated on a 0.8% (w:v) agarose gel and transferred by alkaline transfer method onto a positively charged nylon membrane and then cross-linked to the membrane by UV irradiation. A fragment (484 bp) of the *bar* gene sequence, generated by PCR, was DIG-labeled and used as the probe. The membrane was hybridized overnight at 68°C with the labeled probe. The hybridization signals were detected by the colorimetric method. The labeling and signal detection were performed using the random priming DNA labeling and detection kit (Roche Cat. No.11093657910) as per manufacturer's instructions.

Results and discussion

Sorghum transformation and regeneration

Sorghum has been considered a recalcitrant crop with regards to transformation (Casas *et al.,* 1993; Zhu *et al.,* 1998; Zhao *et al.,* 2000; Grootboom *et al.,* 2010). Obtaining knowledge about the susceptibility of genotypes and explants to *Agrobacterium*-mediated transformation is extremely helpful in developing strategies for the transformation of recalcitrant crops (Lupotto *et al.,* 1999). A key prerequisite in the development of a genetic transformation protocol for any species is a reliable method of distinguishing transformed from non-transformed tissues. This can be accomplished using a construct containing a reporter gene and a selectable marker gene. In the present study, the transformation potential of seven sorghum genotypes through *Agrobacterium*-mediated method was investigated according to the protocol described by Frame *et al.* (2002). Sorghum lines were transformed with the standard binary vector pTF102 harboring the *Bar* gene as a selectable marker and the *GUS* reporter gene containing a portable intron in its codon region.

In *Agrobacterium*-mediated transformation, the reporter gene can be expressed similarly in the bacterial cells attached to the tested explants, thus leading to false results. Consequently, the use of an intron-contaning β-glucuronidase marker gene is of great advantage. When explants are transformed, transgenic cells containing the *INT-GUS* cassette efficiently splice the intron, thus, giving rise to visibly detectable GUS enzyme activity. Therefore, early phases of transformation of plant tissue can be easily scored with this system (Ohta *et al.,* 1990; Vancanneyt *et al.,* 1990). Also, the use of *Bar* gene as a selectable marker is extremely helpful. This gene confers unique metabolic properties to transgenic tissues, allowing them to grow on media where non-transgenic tissues cannot thrive.

In this study, the effects of different transformation parameters have been tested. These parameters included the *Agrobacterium* strain, the sorghum genotype and the antibiotic used for the elimination of the *Agrobacterium* growth. Two *Agrobacterium* strains, i.e., LBA4404 and EHA101, were used to transform seven sorghum genotypes (LG3, LG4, LG8, TX631, Dorado, SPMD94001 and SPGM94021). Immature zygotic embryos from the seven genotypes were infected with both *Agrobacterium* strains. After co-cultivation, the embryos were subjected to the histochemical GUS assay and the intensity of *gus* expression was scored. Since the *gus* gene in pTF102 construct contains an intron in its coding sequence, blue color was indicative of plant expression of the transgene. Gus expression was detected in *Agrobacterium* treated embryos, callus on selection media and inflorescences from regenerated transformed plants (Figure 1).

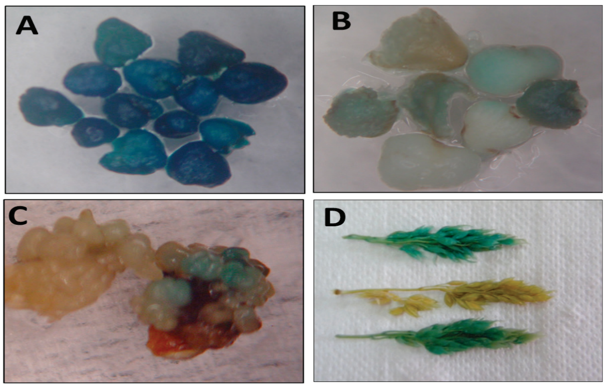

Figure 1. Histochemical Gus assay: **(A)** Immature embryos infected with LBA4404, **(B)** Immature embryos infected with EHA101, **(C)** 6 weeks old embryogenic callus, **(D)** branches from transgenic sorghum inflorescence.

The efficiency of T-DNA transfer is host-pathogen dependent*, i.e.,* depends on an interaction between *Agrobacterium* strains and plant genotypes (Marks *et al.,* 1989; Samac, 1995; Khanna *et al.,* 2004). In the present investigation, the GUS histochemical assay revealed that infected embryos of the different genotypes displayed transient GUS expression (Figure 1 and Table 2). However, immature embryos transformed by *Agrobacterium* strain LBA4404 displayed a stronger expression of *GUS* gene in comparison to immature embryos transformed by strain EHA101. Three degrees of scoring (strong+++, moderate++ and weak+) were given to the *gus* expression of the immature embryos. Gus expression displayed by embryos infected with *Agrobacterium* strain LBA4404 was either strong or moderate. While, the expression shown by embryos infected with strain EHA101 was weak in all the tested sorghum genotypes except SPGM4021, which revealed moderate expression.

Table 2. Transformation frequency for sorghum genotypes transformed with the EHA101 and LBA4404 *Agrobacterium tumefaciens* strains

Genotype	Agro-strain	No. On Co-cultivation	Gus intensity	No. on Resting	No. of plantlets (+PCR)	Transf. Frequency%
LG3	EHA101	126	+	56	0	0
LG3	LBA4404	83	++	42	1	1.2
LG8	EHA101	50	+	19	0	0
LG8	LBA4404	90	+++	85	9	10
Dorado	EHA101	55	+	47	2	3.6
Dorado	LBA4404	50	+++	33	1	2.0

Moreover, putatively transgenic plantlets were recovered mostly from the transformation experiments carried out using *Agrobacterium* strain LBA4404, while, a very few number of plantlets were recovered from experiments carried out using the *Agrobacterium* strain EHA101. Several authors reported on the genotype-strain specificity during *Agrobacterium*-mediated transformation of plants (Owens and Cress, 1985; Byrne *et al.,* 1987; Hobbs *et al.,* 1989; Fillipone and Penza, 1992; Wu *et al.,* 2014). Also, at the same O.D. range (ODs_{550}= 0.4-0.5), embryos infected with *Agrobacterium* strain EHA101 displayed a greater damage (necrosis) than those infected with LBA4404. In this respect, Kuta and Tripathi (2005) speculated that during incompatible plant-*Agrobacterium* interaction, reactive oxygen species are overly produced at the site of *Agrobacterium* infection and may lead to plant cell death and necrosis.

The sorghum lines investigated in this study were found to be regenerable in a previous study (Assem *et al.,* 2014). Here these lines were investigated for transformation potential using the *Agrobacterium tumefaciens* strains LBA4404 and EHA101 containing the binary vector pTF102 containing the *gus* and *bar* genes. The results revealed by the seven sorghum lines using both *Agrobacterium* strains are shown in Table 2. Gus histochemical assay revealed that the seven genotypes are primarily transformable. However, transgenic plants were only recovered from three genotypes, i.e., LG3, LG8 and Dorado. The transformation percentage ranged from 1.2% to 10% for LG3 and LG8, respectively. Dorado was the only genotype that recovered transgenic plants from both *Agrobacterium* strains. In this respect, genotype dependent variations in sorghum in response to *Agrobacterium*-mediated transformation have been reported by many authors (Zhao *et al.,* 2000; Gao *et al.,* 2005a and b; Howe *et al.,* 2006; Gurel *et al.,* 2009; Kosambo-Ayoo *et al.,* 2011). Moreover, the damage imposed by *Agrobacterium* varied among genotypes. After agroinfection, necrosis of callus appeared and the production of pigments increased. Although, PVP was added to the culture media for quenching oxidative burst, the presence of high concentrations of phenolics continued and most calli failed to propagate efficiently. In general, genotypes Dorado and LG8 were the least sensitive to *Agrobacterium* damage, while TX631 was the most sensitive to *Agrobacterium* damage, which presents a major limitation of transforming it with *Agrobacterium*-mediated systems. The damage of plant tissues caused by agroinfection has been previously reported and is considered as one of the major obstacles for *Agrobacterium*-mediated plant transformation (Pu and Goodman, 1992; Hansen, 2000; Zhao *et al.*, 2000; Carvalho *et al.,* 2004). Transgenic shoots obtained by lines LG8 and Dorado were able to regenerate into normal transgenic plants, while the only transgenic event obtained from line LG3 did not survive in the greenhouse.

To eliminate the growth of *Agrobacterium* following co-cultivation, embryos were transferred onto the resting media. Although 250 mg/l of cefotaxime were added to the resting media, some plates contained bacterial overgrowth. Plates with bacterial overgrowth were more frequent with *Agrobacterium* strain EHA101. To get rid of the bacterial overgrowth, carbenicillin was compared to cefotaxime in parallel experiments. Carbenicillin at a concentration of 100 mg/l eliminated the bacterial overgrowth with both *Agrobacterium* strains and was found to be more efficient than cefotaxime at a concentration of 250 mg/l. Similar results were found by Teixeira da Silva and Fukai (2001). They compared the potentiality of three antibiotics, i.e., carbenicillin (CA), cefotaxime (CF) and vancomycine (VA) to control the growth of *Agrobacterium* stains LBA4404 and AGLO. The results revealed that all three antibiotics could effectively control *Agrobacterium* LBA4404 and AGLO growth, with the order of CA>VA>CF in bactericidal effect and that AGLO was more resistant than LBA4404 at any concentration of any antibiotic. Also, Gao *et al.* (2005a) compared the efficiency of the two antibiotics carbenicillin and cefotaxime on controlling the growth of *Agrobacterium*. They found that at high concentration of bacterium inoculum (A_{600} = 0.7), the percentages of cultures showing bacterial growth in the presence of carbenicillin or cefotaxime were 0% and 3%, respectively, suggesting that carbenicillin was more effective in controlling the bacterium under these conditions.

Molecular analyses

Ten bialaphos-resistant regenerated plants and an untransformed control plant were subjected to PCR amplification analysis. Expected *bar* gene and *gus* gene amplification products of 484 bp and 750 bp, respectively, were amplified in the transformed samples. While, the non-transformed control genomic DNA did not show amplification product (Figure 2A and B). Two of the ten putatively transgenic plants analyzed by PCR were found to be negative, giving an escape of 20%. This finding supports the claim that *bar* selection seems to be a leaky system resulting in many escapes (Emani *et al.,* 2002; Gao *et al.,* 2005b; Gurel *et al.,* 2009; Grootboom *et al.,* 2010). Alternative selection like hygromycin, phosphinothricin and mannose selection systems might be recommended for preventing escapes and not interfering with regeneration (Sant, 2011).

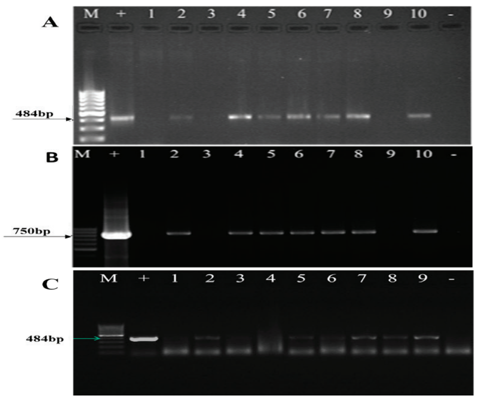

Figure 2. PCR verification of the transgenes in sorghum plants. Verification of *bar* gene **(A)** and *gus* gene **(B)** into putative transgenic T_0 plants. "M" molecular weight size marker 100pb; "-" negative control of un-transformed plant. "+" positive control of the plasmid pTF102; Lanes 1-10 DNA samples from individual events of putative transgenic sorghum plants, genotype LG8. **(C)** PCR verification of the *bar* gene into transgenic T_1 plants. Lanes 1-5 DNA samples from LG8 T_1 plants (T_0 event No. 5); Lane 6-9 DNA samples from LG8 T_1 plants (T_0 event No. 8).

The regular transgene transmission is a main prerequisite in generatively propagated transgenic plants. Here, PCR analyses (Figure 2C) revealed the amplification of the *bar* fragment in the T_1 plantlets (derived from the T_0 plants; LG8 event number 5 and 8).

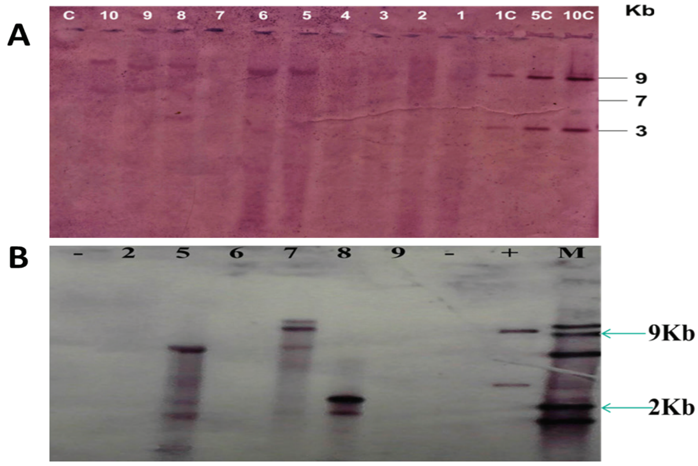

Figure 3. Southern blot analysis of transgenic sorghum plants for the *bar* transgene. **(A)** T_0 plants: "1c", "5c" and "10c" are 1, 5 and 10 copies of the plasmid pTF102; "1-10" DNA sample from individual transgenic T_0 plants, genotype LG8; "c" negative control of untransformed plant. **(B)** T_1 plants: Lanes 2&5 DNA samples from LG8 T_1 plants (T_0 event No. 5); Lane 6-9 DNA samples from LG8 T_1 plants (T_0 event No. 8); "+" positive control of the plasmid pTF102; "-" negative control of untransformed plant.

To confirm the stable integration of the T-DNA in the putatively transgenic plants and the inheritance of the *bar* transgene in the T_1 plants, Southern blotting was conducted. As shown in Figure 3, DNA hybridization revealed the presence of the *Bar* transgene fragment in the genomic DNA of the T_0 and T_1 transgenic events, thus, confirming the genomic integration and the inheritance of the T-DNA in the transgenic sorghum plants. Since the genomic DNA was digested with the restriction enzyme *Hin*d III which cuts twice inside the T-DNA, different bands larger than 2.5 Kb for the *bar* gene were observed (Figure 3). These bands reflect the different T-DNA integration sites in the sorghum genome.

Acknowledgment

The Egypt's Science and Technology Development Fund (STDF) supported this project financially. The binary vector pTF102 was kindly provided by Dr. Kan Wang, Director, Plant Transformation Facility, Iowa State University through a previous US-Egypt Joint Science and Technology Research Fund.

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Special Session 2: Paddy Cultivation in the Dry Areas

1. Developments and prospects of paddy fields in California, USA

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Abstract

Paddy fields (flooded rice fields) were introduced in California long time ago and the state is noted for having the second largest paddy field area in the USA. With an average annual rainfall of approximately 630mm, the state of California gets less rain than the national average (approximately 1000 mm). Several water resources development projects such as Central Valley Project (CVP) and State Water Project (SWP) were constructed and are in operation in California to meet the water deficit particularly during the irrigation period. However, in recent years, the state is facing difficulties to secure water supply for irrigation because of the continuous drought along with the increase in demand of water for other uses. Therefore, the task of increasing substantially the current level of production or increasing the land area of paddy fields has become more difficult than it was a decade ago. Generally, paddy fields require much water than other agricultural lands. However, they give far more benefits than merely that out of rice cultivation. The roles of paddy fields in biodiversity and ecosystem conservation, similar to those of natural wetlands, are well recognized. Furthermore, paddy fields *alleviate* a significant *amount* of the effluent loads of nutrients compared to other agricultural lands. This study focuses on the current status and analyzes the future prospects of paddy fields in California while comparing with the situation in Japan.

Keywords: Paddy fields, Biodiversity, Ecosystem conservation, Natural wetlands

Introduction

Rice was introduced to the American colonies in the mid-17th century and soon became an important crop. The state of California is known for having the second largest rice production in the United States. With an average annual rainfall of approximately 630 mm, the state of California gets less rain than the national average (approximately 1000 mm). Especially, the growing season of rice has limited rainfall because of the Mediterranean climate (Hill *et al*., 2006). Several water-resource-development projects, such as the Central Valley Project (CVP) and the State Water Project (SWP), were constructed and are in operation in California to meet the water deficit in irrigation season. However, in recent years, the state is facing difficulties in securing a water supply for irrigation because of the continuous drought and the increase in demand for water for other uses (California Department of Water Resources, 2014). Therefore, the task of substantially increasing the current level of production or increasing the land area of paddy fields has been more difficult than it was a decade ago. Generally, paddy fields require much more water than other agricultural lands. However, their benefits exceed those of rice cultivation. In this paper, we describe the recent situation with paddy fields in California from the aspect of water quantity and quality, and we also discuss the future prospects of paddy fields in California while examining the paddy field situation in Japan.

Areas and cropping system of paddy fields

The paddy field area in California is approximately 200,000 ha (Hill *et al*., 2006). The Sacramento Valley is California's major rice-production area. Approximately 96% of California rice is grown in this area, and the other 4% is grown in the San Joaquin Valley (Hill *et al.,* 2006). In this paper, we describe mainly the paddy-field area in the Sacramento Valley (Figure 1).

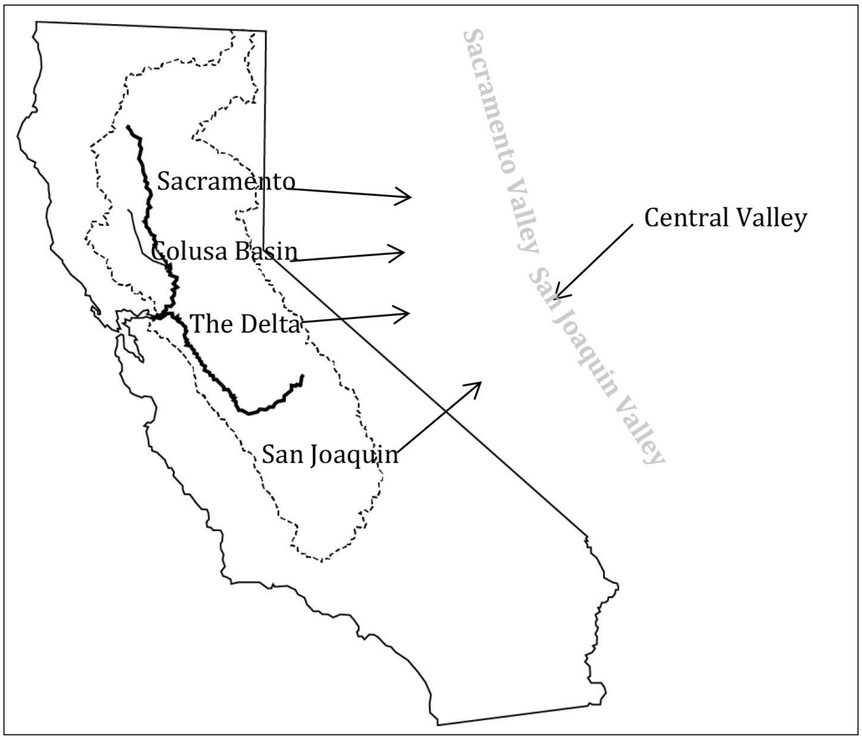


Figure 1. Location of the Sacramento Valley, the San Joaquin Valley, and the Delta.

Paddy fields are usually laser leveled. Rice is aerially seeded on flooded paddies. The season is between 130 to 165 days in length, depending on the rice variety (Hill *et al*., 2006). At the Colusa Basin in the Sacramento Valley, rice is usually sown in late April and harvested in late September (Watanabe and Tanji, 2000). There are many problems in maintaining paddy fields sustainably, such as water quantity, water quality, air quality, and land use.

Water issues (quantity and quality)

Irrigation water for rice is mainly supplied from reservoirs that are located upstream of rivers (Hill *et al.,* 2006). Groundwater is also used for irrigation. Drainage water is often used at the downstream area.

Water quantity

Water demand for urban and environmental use in California is increasing. Hill *et al.* (2006) report that the Central Valley (the Sacramento Valley and San Joaquin Valley) is the fastest growing component of a rapidly growing California population, and that the Sacramento River water was diverted for environmental services, including maintenance of low temperatures for migrating salmon and the habitat of water fowl in 1999. These caused a reduction in the supply of water for agriculture.

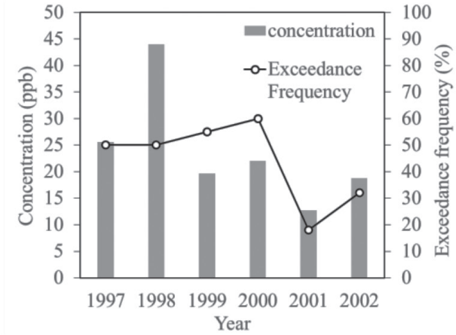
At the Colusa Basin Drain in the Sacramento Valley, the water supply and the use and outflow of drain water were significantly changed because of a water-conservation program. These changes caused water-shortage problems in downstream paddy fields, where recaptured agricultural drain .(water was used (Watanabe and Tanji, 2000

Paddy fields provide habitats for water birds in the Sacramento Valley. Stem *et al.* (2013) compared water bird density and water depth of paddy fields in the Sacramento Valley in different post-harvest management treatments. Densities of water birds were higher in the flooded treatments compared to the non-flooded treatments. One-time flooding provided the most suitable water depth for shore birds and long-legged waders, whereas maintenance flooding provided the most suitable water depths for dabbling ducks. These results confirm that the practice of winter flooding paddy fields provides water bird habitats, but potentially less water use could be achieved using a combination of one-time and maintenance flooding practices.

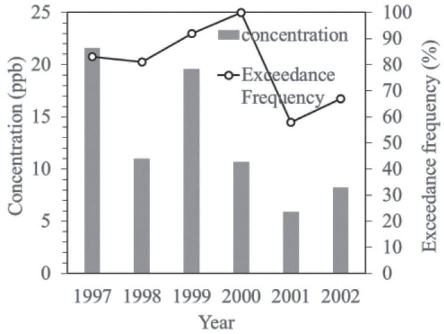
Water quality

In the late 1970s, fish kills from the herbicide molinate were reported, and a metabolite of thiobencarb was later found to be the cause of off-tastes in the drinking water (Hill *et al*., 2006). The California EPA established guidelines for major rice herbicide residues and set performance goals in the Sacramento River and tributary drains (Watanabe and Tanji, 2000). The performance goal was set at 10 ppb for molinate and 1.5 ppb for thiobencarb. To meet these concentrations, flood waters in paddy fields were held in the fields for a certain time period after chemical application. Typical holding periods after application were 30 days for thiobencarb and 28 days for molinate (Hill *et al.,* 2006). As a result of the regulation with water holding, mass flow of pesticides in the Sacramento River were reduced.

Figure 2 shows maximum concentrations and exceedence frequencies of molinate and thiobencarb performance goals from 1997 to 2002 at Colusa Basin Drain (Newhart, 2002). Maximum concentrations exceeded performance goals, but exceedence frequencies gradually decreased. In addition, Watanabe and Tanji (2000) noted that fish kills in the Colusa Basin Drain had been eliminated. However, this water holding had caused another problem, increasing flood water and soil salinity in some paddy fields in the lower Colusa Basin (Watanabe and Tanji, 2000).



(a) Molinate



(b) Thiobencarb

Figure 2. Maximum concentrations and exceedence frequencies of molinate and thiobencarb performance goals (molinate; 10 ppb, thiobencarb; 1.5 ppb) from 1997–2002 at Colusa Basin Drain (Newhart, 2002).

Concentrations of dissolved organic carbon (DOC) are high in the Delta area. The DOC can react with chlorine during drinking-water disinfection and leads to the formation of harmful byproducts, such as trihalomethanes (Ruak *et al*., 2009). DOC exported from rice fields may represent a large allochthonous input into Sacramento Valley surface waters and perhaps the Delta as well (Ruark *et al.,* 2009). Water-quality concerns have arisen in relation to the potential increase in DOC concentration and export caused by the combination of straw incorporation and winter flooding in paddy fields (Ruark *et al.,* 2009).

In the past, rice straw was burned to prevent rice-stem rot disease and for ease of tillage (Watanabe and Tanji, 2000). However, this burning created air-quality problems in downwind populated locations. Regulations enacted in 1991 led to gradually reduced straw burning (Hill *et al.,* 2006). One alternative for straw-residue management is to decompose the straw by soil incorporation and winter flooding. This method of straw decomposition requires post-harvest ponding that also has the beneficial impact of providing wetland habitats for migratory birds (Watanabe and Tanji, 2000). However, there has been criticism regarding the additional use of water during fish migration in the Sacramento River and its tributaries, and potential organic carbon loading of streams from straw decomposition and subsequent drainage.

Ruark *et al.* (2009) monitored two paddy fields with different straw-management practices (incorporation and burning) in the Sacramento Valley for evaluation of the seasonal concentrations of DOC in paddy-field drain water and irrigation canals; quantification of seasonal fluxes and flow-weighted concentrations of DOC; and determination of the main drivers of DOC fluxes. As a result, straw management had a significant interaction effect with the season (growing season and winter season) because the greatest DOC concentrations were observed during winter flooding of straw-incorporated fields. Peak DOC concentrations occurred at the onset of drain flow; therefore, changes in irrigation management may have lowered peak DOC concentrations and, thereby, DOC losses. However, the timing of peak DOC concentrations from paddy fields suggests that paddy-field drainage water is not the cause of peak DOC concentrations in the Sacramento River.

Conclusion

Water management on paddy fields in the Sacramento Valley is complicated when attempting to solve various problems, such as those related to water shortage, migratory fish, water birds, pesticides residues, and DOC. Problems related to water resources in California are important and urgent (CDWR, 2014). The role of paddy fields is most important with respect to agriculture and the environment. Furthermore, paddy fields *can control* the effluent loads of pesticides and DOC by water management. Schlegel and Domagalski (2015) indicated the possibility of controlling nutrient loads from the Sacramento River and the San Joaquin River through water management. This study focused on the current status of paddy fields in California, especially in the Sacramento Valley, where the landscape is dominated by paddy fields. Japan also has a dominant landscape of paddy fields. While, climates and developments are quite different between California and Japan, it is beneficial to compare the case studies of water problems and management regarding paddy fields in the Sacramento Valley with those in Japan.

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2. Impact of climate change towards irrigation operations in Central and Northeast Thailand and its adaptation towards SDG

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Abstract

In the recent years, Thailand had suffered from both floods and drought which caused huge damages to the country's socio economics. Irrigation management in the country has different characteristics by area due to the topographical, meteorological and water demand conditions, i.e., wet area in the central plain (with 6 dams and annual rainfall of 1100-1500 mm) and dry area in the north east area (with 10 dams and annual rainfall of 800-1200 mm), which make each irrigation dam's operation rule different. In future, the climate change will induce more fluctuations to the hydrological parameters, the impacts of climate change to irrigation operation in the changing meteorology were explored comparatively in the area of wet and dry area on both project and farm levels. This study investigated the hydrological change and the impact of climate change towards irrigation dam operations (inflow, release, storage) of the selected irrigation projects in the central and northeast area of the country. Due to the higher temperature and more fluctuated precipitations in the future, the study found that in the central plain, inflow to the main dams will change while in the northeast, inflow will reduce due to rainfall decrease and the irrigation demand will increase due to higher temperature, hence there will be more water shortage in the northeast area than that of the central plain. Hence, at the irrigation project level, the dam release rule modifications with seasonal forecasting tools are essential to determine appropriate cultivation area in each year especially in the northeast area in order to cope with irrigation water shortage in the changing climate environment in the future. The field survey with farmer responses to such a change was conducted and it was found that the responses differed among wet and dry area and irrigated and rainfed areas. At farm level, farmers prepared for adaptation measures, i.e., stop farming with other job creation scheme or do farming with supplementary water from other sources in the dry year such as pumping water from drainage canal, farm ponds, tube well and shallow groundwater or grow less water consuming plants in the rainfed area. Proper adaptation measures are needed to enable farmers to be more resilient to changing climate situations within SDG's framework of the country.

Keywords: Climate change, Irrigation operation, Water shortage, Adaptation

Introduction

Thailand suffered from the big floods in 2011 and has faced with the consecutive droughts from 2014 to 2016. Such events caused huge damages to the socio-economic condition of the country. Irrigation management in the country differs from one area to the other due to the differences in topographical, meteorological and water demand conditions, particularly for rice cultivation. The wet area in the central plain (with 6 dams and annual rainfall of 1100-1500 mm) and the dry area in the northeast area (with 10 dams and annual rainfall of 800-1200 mm), necessitate different rules for irrigation dam operation. Recent meteorological trends show more fluctuations in rainfall pattern and dam storage (Central: Bhumibol and Sirikit, NE: Ubolratana and Lam Pao) as shown in Figure 1. In future, the climate change tends to induce more fluctuations to the hydrological parameters, the impacts of climate change to irrigation operation in the changing meteorology needed to be explored comparatively in the wet and dry area to prepare appropriate adaptive measures of rice cultivation in both project and farm levels.

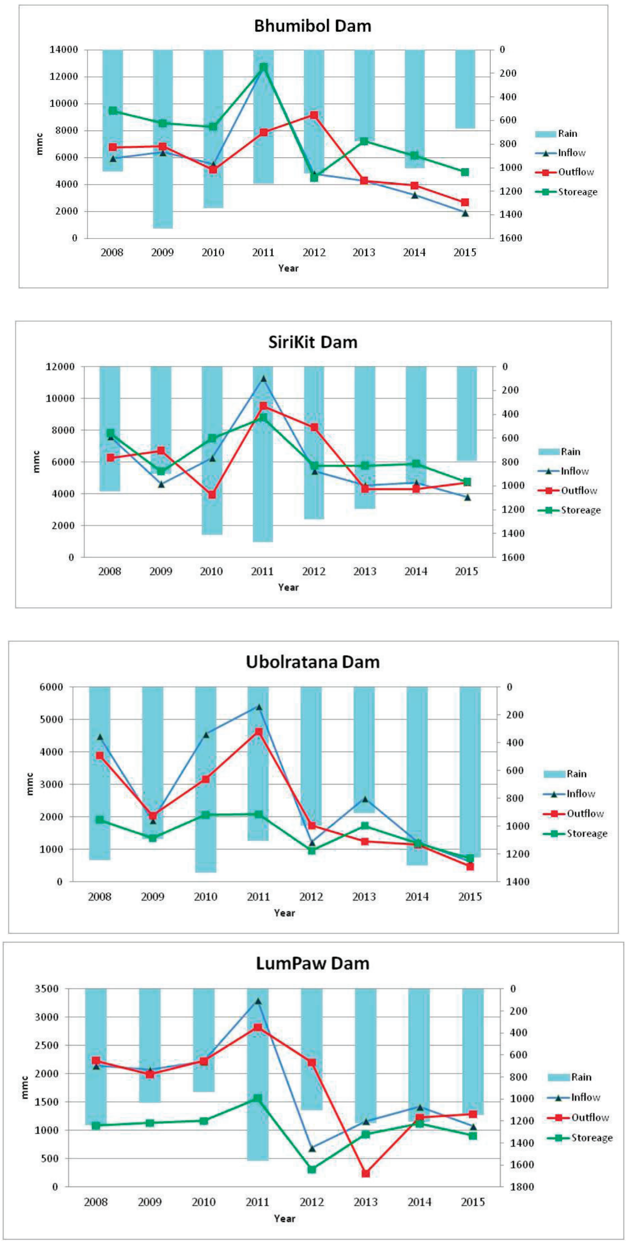

Figure 1. Fluctuations in meteorological conditions and dam operations.

The study of impact of climate change on irrigation system had been conducted in various types of irrigation projects, dam and regional operations (Chulalongkorn University and RID, 2010: Sucharit, 2013) and in the basin planning in the Nan River Basin (Sucharit, 2012). The use of groundwater as supplementary water for irrigation was also explored (Sucharit, 2015). The government had set the water resources management strategic plan (2015-2026) to provide water supply to villages and cities, to reduce water disaster risk, to improve water quality in the natural streams, to foster integrated water management scheme, and to improve water management structure of the central functions and at the community level (Ladawan, 2016). Besides, the country is now committed with UN's SD policy and is on the way to set the SDG including water sector.

Study area

The study selected the central plain area as a wet area and the northeast area as a dry area to compare the irrigation operations and adaptive measures on rice cultivation under the climate change situations. The background information for irrigation in the central and northeast area is described in Table 1. The total area and agricultural area of the northeast is larger than the central area with similar precipitation though the irrigated area, number of dam and total storage in the northeast are less. Figure 2 shows the location of dams selected from each area. The Bhumipol and Sirikit Dams are selected for the central area, and the Ubolratana and Lampao Dams for the northeast area. Two pilot irrigation projects in each region are selected, i.e., Plaichumpol (central and wet area) and Lam Pao (northeast and dry area) Irrigation Projects.

Table 1. General conditions for irrigation management in central and northeast areas

		Central	Northeast
1	Total area (km^2)	91.8	168.9
2	Population (M)	24.4	21.7
3	Precipitation (mm)	1100-1500	800-1200
4	Temperature (Celsius)	33.5	32.7
5	Agricultural area (km^2)	24.4	57.7
6	Irrigated area (M ha)	1.47	0.22
7	Number of dams	6	10
8	Total storage (Mm^3)	26.6	11.8

Objectives and approach

The objectives of the study are set as follows:

1. To investigate the hydrological change due to climate change,

2. To assess the impact of climate change towards irrigation dam operations,

3. To project the water shortage due to climate change in the future,

4. To survey with farmers on the adaptation means for rice cultivation.

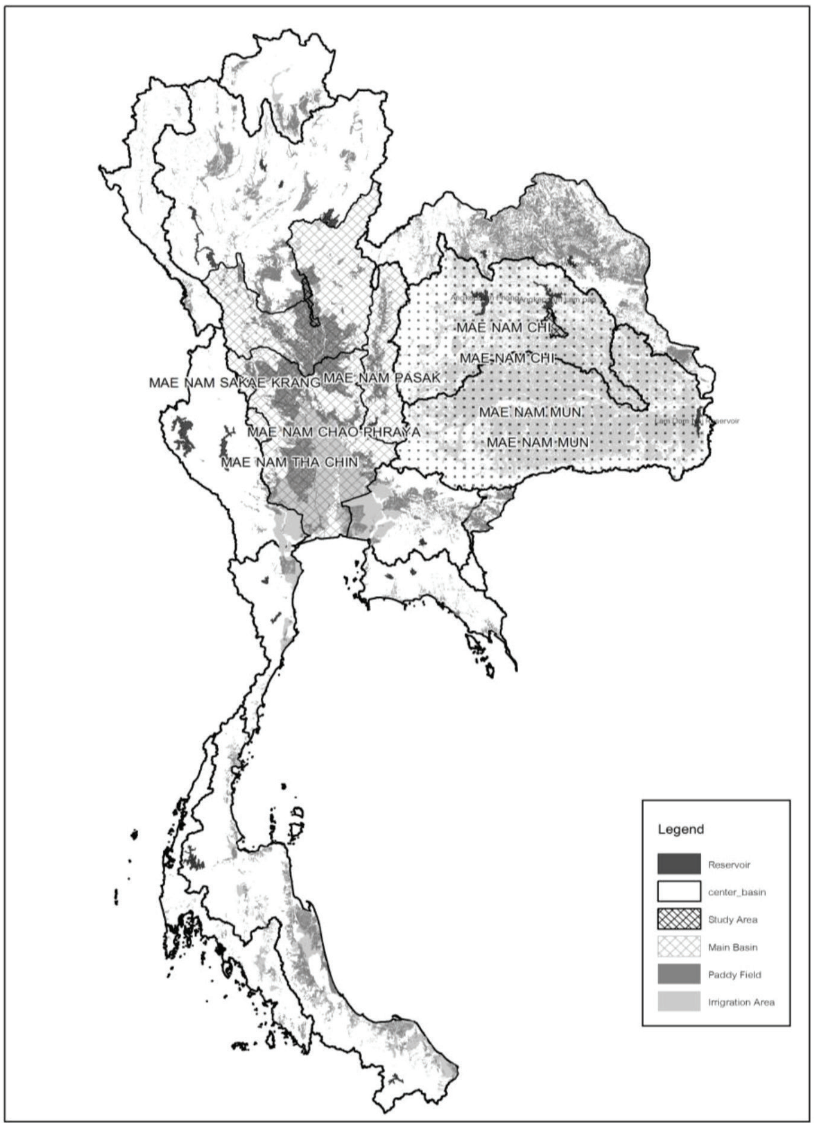

Figure 2. Study area and dam locations.

The study approach started with the review on bias corrected climate data of present (1979-2012), near future (2015-2039) and far future (2075-2099) periods (using MRI-GCM, scenario A1B). The inflows of the four main dams were estimated using the present monthly rainfall-runoff relationships. The dam releases were computed using present monthly inflow-release ratios. The storages of the dam were computed from release and inflow volumes. The irrigation demands were estimated from the future climate and cultivation area which were determined from the water year (dry, moderate, wet) situations in the present. Water shortages were then computed from the dam releases and irrigation demands.

To explore the adaptation for rice cultivation at farm level, field surveys were conducted in the Plaichumpol Irrigation Project (in the central area as a wet case) and the Lam Pao Irrigation Project (in the northeast area as a dry case) during July 2016 which is at the end of critical drought period (Sucharit, 2016). The questionnaires were distributed to 40 farmers in each irrigation project area and in nearby rainfed area for comparison. The interviews of irrigation engineers were also conducted to explore the adaptation scheme at the project level. From the impact study and field survey, the recommendations of future more sustainable management are suggested.

Results

The bias corrected climate data of present, near future and far future of temperature, rainfall of four main dams in the central plain and northeast areas were collected and compared. Water inflows, water release and water storage were computed and shown in Table 2. The overall temperature tends to increase more in the northeast (dry) area. The rainfall in the central (wet) plain will increase while the rainfall in the northeast (dry) area will decrease. The inflows into the dam in the central plain will increase 4.9-5.5 % while in the northeast, inflow will reduce about 1.0-18.4 % due to rainfall changes.

Table 2. Hydrological change towards dam inflows due to climate change

		Central		Northeast	
		Bhumipol	Sirikit	Ubolratana	Lam Pao
1	**Temperature, Celsius**				
	Present	33.54	33.41	32.72	32.11
	Near Future	34.52	34.53	33.84	33.29
	Far Future	36.68	36.95	36.64	35.9
2	**Annual rainfall, mm**				
	Present	1038	1256	1297	1243
	Near Future	1104	1248	1207	1190
	Far Future	1169	1322	1266	1281
3	**Inflow, Mm^3 (dry season)**				
	Present	5187(1078)	5554(798)	2374(288)	2097(129)
	Near Future	5474(1019)	5281(793)	1937(262)	2081(147)
	Far Future	5956(1249)	5609(823)	2089(267)	2357(141)

The impact from climate change was determined from water shortage volume estimated from dam release and irrigation demand. The irrigation demand was determined from the cultivated area (based on the past records for each water year (dry, moderate, wet), then water release and water storage were estimated. The irrigation demand will increase due to higher temperature which will induce more water shortage in the northeast area than that of the central plain. The water shortages in rainy and dry seasons in the main dams are shown in Table 3. In the central plain (wet area), the water shortage will reduce due to more rainfall even with higher temperature. The water shortage in the northeast (dry) area will increase in dry season due to less rainfall and higher temperature.

Table 3. Water shortage estimate due to climate change

	Central		Northeast	
	Bhumipol	**Sirikit**	**Ubolratana**	**Lam Pao**
1 **Area (M ha)**				
total area	1.26	0.11	0.04	0.05
max cultivated (rainy/dry)	1.18/1.14	0.09/0.10	0.04/0.02	0.05/0.04
min cultivated (rainy/dry)	0.88/0.70	0.08/0.08	0.04/0.01	0.05/0.03
2 **Demand, Mm^3 (rainy, dry)**				
Present	5249(2900)	107.4(542)	374(226)	587(373)
Near Future	5896(3089)	851(305)	373(218)	582(304)
Far Future	5429(2923)	782(289)	427(222)	534(368)
3 **Release**				
Present	1915/3311	2275/3097	1825/702	1687/693
Near Future	1678/2991	2272/2921	1696/723	1579/732
Far Future	2329/3864	2269/3233	1806/696	6877/730
4 **Storage, Mm^3 (Rainy/Dry)**				
Present	6778/9176	4982/7414	1659/2207	760/1283
Near Future	7266/9883	4818/7042	1661/2193	696/1352
Far Future	3876/10647	4931/7503	1673/2218	677/1356
5 **Water shortage, Mm^3 (rainy/dry)**				
Present	60.7/168	129/48	0/5.3	0.51/42
Near Future	195/128	88/20	0/6.5	0/26
Far Future	52/12	33/9	0/13.2	0/34

From field questionnaires it became evident that the farmers in the central plain in the irrigation area were impacted from droughts in the year 2015-16. The impacts were from damages to agricultural production and reduction in the quality of produce. Farmers in the rainfed area were impacted from water shortage and production damage. The farmers in the northeast area were mainly affected from water shortage in both irrigated and rainfed areas and the farmers in the rainfed area in the northeast got effect from more insects damage due to the drought.

Farmers in the central plain in the irrigated area adapted themselves by reducing cultivated area, growing less water demanding crops, using shallow groundwater wells and using loan to solve their problems. Farmers in the rainfed area changed to crops that use less water, reduced cultivated area as counter measures. Farmers in the northeast area in the irrigated area adapted themselves by decreasing cultivated area and growing drought tolerant crops. Farmers in the northeast and rainfed area adapted by growing less water consuming crops and reducing cultivated area. Field survey showed that there were a number of farmers in the rainfed area who decided not to grow anything in these drought years due to low paddy price and they had to find other jobs for earning their living.

Irrigation engineers in the field informed that farmers in the central plain seek sources for supplementary water such as shallow groundwater (88.9 %) and pond water (55.6%), while farmers in the northeast used pond water (62%) and shallow groundwater (25 %). Irrigation engineers introduced alternative wet and dry farming methods to farmers in order to save water, and improved irrigation system to reduce water loss. They also had to create additional jobs for farmers who decided not to do farming such as weir construction, etc. It was noticed that dam release rules were also affected by the drought condition. The determination of cultivated area in each dry season will control irrigation demand to match with available water storage. Water release in the rainy season is vital for water storage for the next dry season, especially in the case of Lam Pao Dam (in the dry area) where there are fewer choices of supplementary water sources.

Conclusions

The study found that the overall temperature would tend to increase with higher increase in the northeast (dry) area and the rainfall in the central (wet) plain will increase while the rainfall in the northeast (dry) area will decrease. The inflows into the dam in the central plain will increase 4.9-5.5 %. In the northeast, inflow will reduce about 1.0-18.4 % due to rainfall decrease while the irrigation demand will increase due to higher temperature, which will induce more water shortage than in the central plain (wet area). At farm level, farmers prepared for this scenario by making two choices of adaptation measures, i.e., stop farming and find other jobs or do farming with supplementary water from such sources as drainage canal, farm ponds, and tube well and shallow groundwater using plants that need less water. At the project level, the water release control is important to cope with water shortage in the drought year. The dam release rule in the rainy season with suitable control of cultivated area in the dry season matching to each type of climate (dry/wet) will be vitally affected due to water shortage situations as evident from the Lam Pao Irrigation Project.

Recommendations

The government is planning for the longterm sustainable development. The issues of appropriate rice cultivation area, application of agro-map for suitable agricultural production as new tools are under planning. In the irrigation project area, more integrated, sophisticated and adaptive water management scheme should be adopted to cope with the change. The modification of dam release rule with the consideration of flood risk and introduction of new technology using seasonal forecasting tools are essential to cope with the changing climate in the future. In the rainfed area, more supplementary water sources and other supportive job options should be systematically prepared. Proper adaptation measures are needed to be prepared for farmers in each climate zone to make farming more sustainable with changing climate situations within SDG framework of the country.

Acknowledgements

The authors would like to express sincere thanks to RID staff for the assistance in interviews and farmer questionnaires in the pilot area. We would like to thank RID, JIID, TMD, and MRI for providing data for this study. The study was conducted at the Water Management System Research Unit, Chulalongkorn University, Bangkok, Thailand.

Table 4. Farmers' responses from field survey

	Central (Plaichumpol Project)			Northeast (Lam Pao Project)		
	irrigation area	**rainfed area**	**irrigation officers**	**irrigation area**	**rainfed area**	**irrigation engineers**
1. Impacts from Drought			most drought year			most drought year
(percentage of responses)			preparation works :			preparation works :
1.1 Agr water shortage	68.2	75	a) inform situations to farmers	54.5	66.7	a) warning for appropriate
1.2 Water supply shortage	20.5	13.6	b) repair gates	4.5	16.7	cultivation area
1.3 Agricultural damages	68.2	36.6	c) canal maintenance	18.2	11.1	b) gate repair
1.4 Product downgraded	54.5	22.7	d) prepare water allocations	29.5	22.2	c) canal maintenance
1.5 More insects	25	4.5		25	44.4	
2 Drought counter measures			measures recommended :			measures recommended:
2.1 Agricultural area decrease	54.5	34.1	a) farmers use gw 88.9 %	34.1	33.74	a) farmers used pond water 62.5%
2.2 Use less water crop	38.6	40.9	b) farmers used pond water 55.6%	29.5	44.4	b) farmers used shallow gw 25 %
2.3 Select water tolerance crop	27.3	6.8	c) find other water sources	34.1	11.1	c) recommended suitable crops
2.4 use shallow gw	36.4	15.9	d) recommended suitable crops	6.8	11.1	d) reduce cultivation area
2.5 Dig new wells	27.3	6.8		4.5	0	
2.6 loan to solve problems	50	13.6		13.6	22.2	

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3. Paddy rice irrigation and water requirements with upland crop rotation system in the lower Ili River Basin, Kazakhstan

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Abstract

Large-scale irrigated agriculture had been developed since 1960's in the lower part of the Ili River, where paddy rice and upland crop rotation has been practiced. Continuous irrigation of paddy rice and once or twice irrigation of upland crops have been conducted. Conveyance and distribution efficiency are very low since all irrigation canals are earthen. Seasonal irrigation water requirements (IWR) of paddy rice was about 8,000 mm in 1960s. Later, irrigation requirements were reduced several times and currently set as 2,290 mm/season. there appears no scientific justification for the reduction. We discussed the meaning of paddy rice irrigation in this district and determined the IWR for paddy rice. Seepage from irrigation canals and deep percolation from paddy rice fields raise groundwater table of surrounding upland crop fields. Shallow water table provides upland crop fields with additional water by capillary. This system increases soil salinization. Therefore, after 3 year of upland crops cultivation it is necessary to convert to paddy rice cultivation in order to leach out the accumulated salts. Dividing the irrigation district into 4 blocks: North, East, Central and West, the estimated IWR of the West block was the largest followed by the East, Central and North respectively. Therefore, the IWR for paddy rice should not be uniform over the district. On the other hand, it was found that the IWR can be set uniformly within each block as difference are small. The current IWR is quite low compared with the estimated one. If the current IWR is decreased in the near future, agricultural infrastructure and staff reform will be required to upgrade the efficiency of water delivery and distribution.

Keywords: Upland paddy rice, Irrigation water requirement, Agricultural infrastructure

1. Introduction

The lower Ili River Basin in Kazakhstan is located in an arid region where large-scale irrigated agriculture has been conducted since the late 1960s. The Ili River, which is an exclusive water resource for agriculture in this area, is a transboundary river. Due to hydropower and agricultural requirements as well as water use among riparian countries, the deficit of water for agriculture in the lower part of the river has been of increasing concern. Thus, inappropriate water management within the agricultural fields threatens to create a salinity problem, typical of irrigated agriculture in arid areas. The seasonal irrigation water requirement (IWR) of paddy rice was approximately 8,000 mm/season in the 1960s. However, due to limited water, the irrigation requirement was reduced several times, and is currently set as 2,290 mm/season. There appears to be no scientific justification for the reduction. Therefore, the present paper discusses the water requirement of paddy rice irrigation in this district and determined the IWR for paddy rice.

2. The study area

2.1 The Ili River Basin

The Ili River originates from a branch of the Tian Shan Mountains in China and flows into Lake Balkhash through southeastern Kazakhstan. The annual discharge is approximately 19.6 km^3, 80% of which originates from Chinese territory. Figure 1 shows the Ili River and its environs. The lower Ili River Basin is located in a continental arid zone, with an annual precipitation and average temperature of only 177 mm and 10.7 ºC, respectively. Kapchagai Reservoir is located in the middle part of the river reach and stores water during summer for use in hydropower generation during winter. Therefore, summertime water shortages for agriculture are a concern.

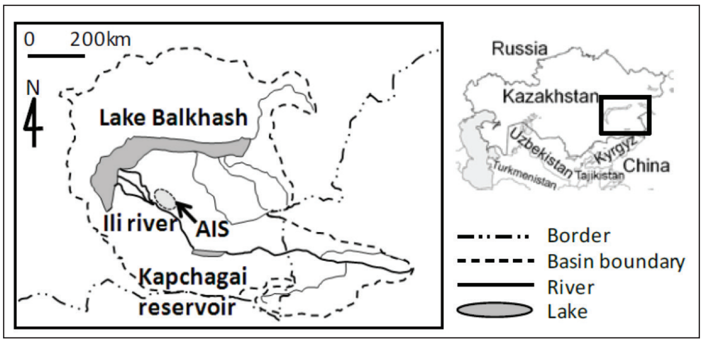

Figure 1. Outline of the study area

2.2 Irrigated agriculture in the lower Ili River Basin

The authors conducted a field survey at the former Bakbakthi State Farm (BSF), a part of the Akdara Irrigation Scheme (AIS) of the lower Ili River Basin. Figure 2 shows the layout of the irrigation and drainage systems of the BSF.

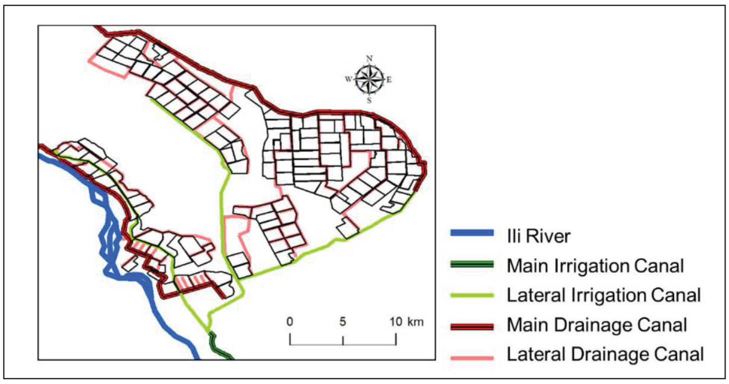

Figure 2. Layout of the irrigation and drainage systems of the Bakbakthi State Farm

The BSF contains 9,500 ha of irrigated area. The farm was established in 1968 during the Soviet era, and the Soviet Union placed great importance on the farm for rice production. During the period of operation of the state farm, required materials and machinery were provided by the government. After Kazakhstan regained independence following the collapse of the USSR, state farms were privatized and became cooperatives between 1993 and 1995. After privatization, the BSF lost all government support. The BSF had been composed of five brigards, which are agricultural production units. These brigards later became five independent agricultural farms, which were subsequently subdivided into small farms. At present, there are 41 individual farms in the AIS.

Due to climatic conditions, the cropping period is limited from early May to late August, with an associated irrigation period of 120 days. The major crops are paddy rice, wheat, and alfalfa. During the Soviet era, six or seven year crop rotations were used, and approximately 40–50% of the cropped area was devoted to paddy rice cultivation. This crop rotation was employed so as to utilize irrigation for paddy rice for leaching out the salts accumulated during upland crop cultivation. Alfalfa is grown not only as a fodder crop, but also for fixing nitrogen since it is a legume. The area of one rotation block is approximately 100 ha, and within this block the same crop is cultivated.

After privatization of the BSF, the privatized farms maintained the crop rotation system. The total cropped area excluding fallow decreased to < 50% of the original irrigated area in 1998 due to disorganization on farms during the transition period. However, the total cropped area has recovered gradually, and has currently reached the 1995 level. The ratio of paddy rice area to cropped area has also increased and the area has reached to approximately 10,000 ha, whereas the upland crop area has not changed much. Although the proportion of the alfalfa area has decreased, the area devoted to other crops, such as industrial crops, has increased.

The rate of application of fertilizer has drastically decreased, as soil fertility management relies on the fixation of nitrogen by alfalfa. In the case of not being able to assure a sufficient rice yield from the second and third years of rice crop cultivation, the farmers convert the paddy rice fields into alfalfa fields. The farm lot size is 1–2 ha (width = 100 m; length = 100–200 m) and the rotation block is approximately 100 ha.

3. Water use and management

3.1 Water balance

Annual water intake to the irrigation area is approximately 700 Mm^3, of which 136 Mm^3 drains into the Ili River. Since the designed value of the conveyance efficiency is 0.75 and the distribution efficiency is 0.60, system efficiency is estimated as 0.45. In other words, only 45% (315 Mm^3) of water extracted from the river (700 Mm^3) reaches the fields. Possible reasons for such low efficiency include the fact that all of the canals are earthen and that the cumulative length of the main and secondary canals can be as long as 270 km. Under such conditions, a large amount of seepage and evaporation occurs through conveyance and distribution system. Figure 3 shows the annual water balance of the irrigated district. Crop evapotranspiration is estimated by the Blaney-Criddle method. The evapotranspiration rates for paddy rice and upland crops are estimated as 644 mm and 450 mm, respectively. When multiplying the aforementioned values by the cropped area, the water requirement is estimated as 162 Mm^3. From the water balance of the paddy fields, seepage from paddy fields is estimated as 254 Mm^3. A large amount of seepage from canals and paddy fields raises the ground water level of the entire farm. The overall irrigation efficiency of the irrigated district is estimated as 0.23. However, considering that seepage from paddy fields effectively leaches salts from the field, 45% (= 315/700) is used effectively (Shimizu *et al.,* 2010).

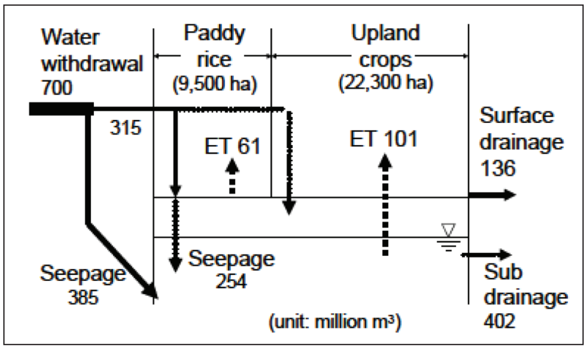

Figure 3. Water balance of the Akdara Irrigation Scheme in 2007 (Shimizu *et al*., 2010).

3.2 Farm water management

Continuous irrigation is practiced within the paddy rice fields, whereas no irrigation is applied to upland crops fields. Soil water moves upward by capillary action from the raised groundwater table as discussed above; therefore, water is supplied to upland crop fields through groundwater.

Due to practical considerations, there are no people tending upland crop fields, except during the seeding and harvest periods, because no irrigation is applied to this type of crop field. In contrast, the average area of a paddy rice field requiring management is 25 ha per person. However, the field workers do not own vehicles with which to travel between fields. Therefore, field workers can only assess the water depth and the inlet and outlet of paddy fields by going on foot. Under the current situation, it can be said that this rotation system saves manpower by indirectly providing a large amount of water to paddy fields.

3.3 Fluctuation of the groundwater table

A large amount of seepage from canals and paddy fields raises the groundwater level during the irrigation period. Figure 4 shows the fluctuation of the groundwater level

within the AIS. The groundwater level is raised by approximately 2 m during the irrigation period, thereby providing upland crops access to water from the groundwater table, since water moves upward due to capillary action in arid areas; however, salinization of the upland crop fields also occurs. Therefore, control of the groundwater level is very important in this area in terms of water supply to upland fields from groundwater and prevention of water logging and salinization by maintaining a high groundwater table.

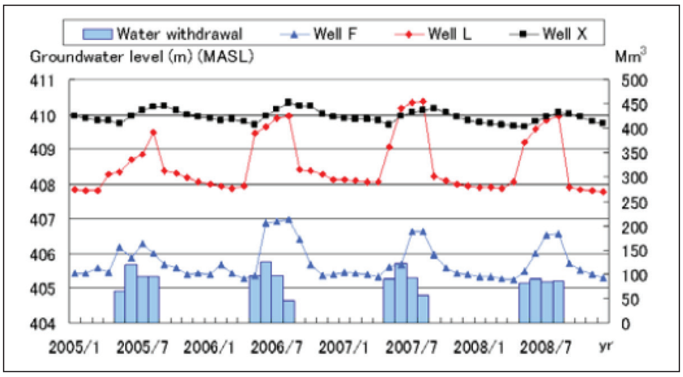

Figure 4. Groundwater fluctuation in the Akdara Irrigation Scheme. Wells F and L are located in the irrigated area, whereas well X is positioned out of the irrigated area.

4. The irrigation water requirement for paddy rice

4.1 Formula used for the calculation of the IWR for paddy rice

The authors reviewed the technical report on "Академия наук казахской ССР Интитут гидрогеологии и гидрофизики им.У.М.Ахмедсафина 1991, Обоснование режима эксплуатации и рекомендации по водопользованию на Акдалинском массиве орошения" for calculating the irrigation water requirement for paddy rice, and verified the current irrigation water requirement. Eleven years of cropping data were used for the calculation, including 1994, 1997, 1999–2002, and 2004–2008. The equation to calculate the IWR for paddy rice is given below and the hydrological components of the water balance of the paddy rice field are shown in Figure 5:

$$Q_{IR} = \frac{Q_{Sat} + Q_{DR} + Q_P \pm Q_S + Q_{ET} - Q_R + Q_L}{10 \cdot A_P}$$

where Q_{IR} is the irrigation requirement (m^3/ha), Q_{Sat} is the requirement for saturation (m^3), Q_{DR} is seepage to drainage canals (m^3), Q_P is deep percolation (m^3), Q_S is seepage to the neighboring field (m^3), Q_{ET} is evapotranspiration (m^3), Q_R is rainfall (m^3), Q_L is the requirement for leaching (m^3), and A_P is the area of paddy rice field (ha).

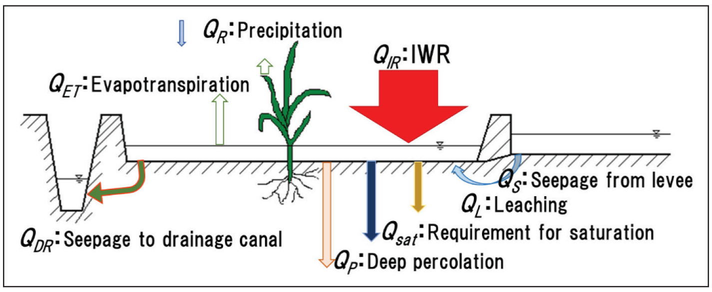

Figure 5. Water balance component for the paddy rice field used in the equation above.

4.2 Data collection

Information on water use within the boundaries of the BSF, such as the cropping pattern, cropped areas, and water withdrawal from the Ili River, was collected by the Balkhash Water Management Office, Almaty Oblast (BWMO), the BSF, and individual farms. Water discharge data such as the amount of water withdrawn from the Ili River, amount of irrigation water conveyed to the AIS, and crop water requirements were collated from a series of annual reports on water use in the Akdara Irrigation Scheme.

Figures 6 and 7 show the spatial distribution of the soil types in the study area and groundwater levels during the non-irrigation period, respectively.

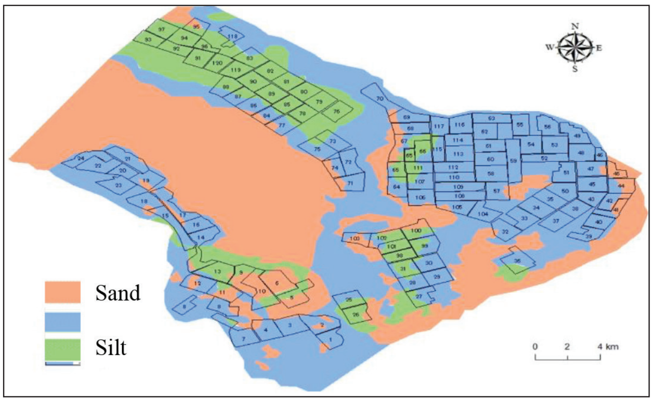

Figure 6. Spatial distribution of soil types in the study area.

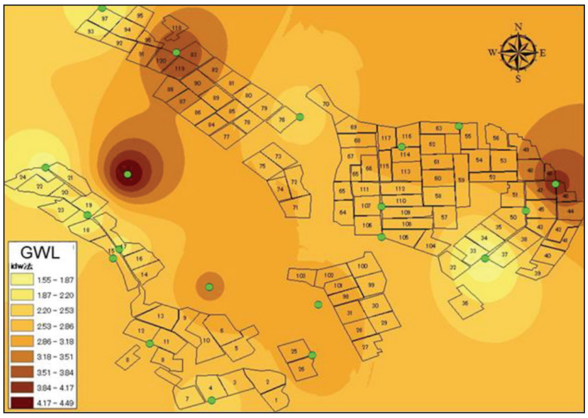

Figure 7. Spatial distribution of groundwater levels during the non-irrigation period. Green points show the location of observation wells.

4.3 Results of the calculation of the IWR for paddy rice and further discussion

Figure8 shows the spatial distribution of the results of the calculated IWR of both farm blocks for 11 years (1994, 1997, 1999–2002, and 2004–2008). The ratios of components of the IWR are summarized in Fig. 8. The results show that the average IWR is approximately 3,000 mm, and that the values of the IWR for farm blocks show spatial heterogeneity. The seepage to the .drainage canal occupies approximately 35% of the IWR, as shown in Figure 9

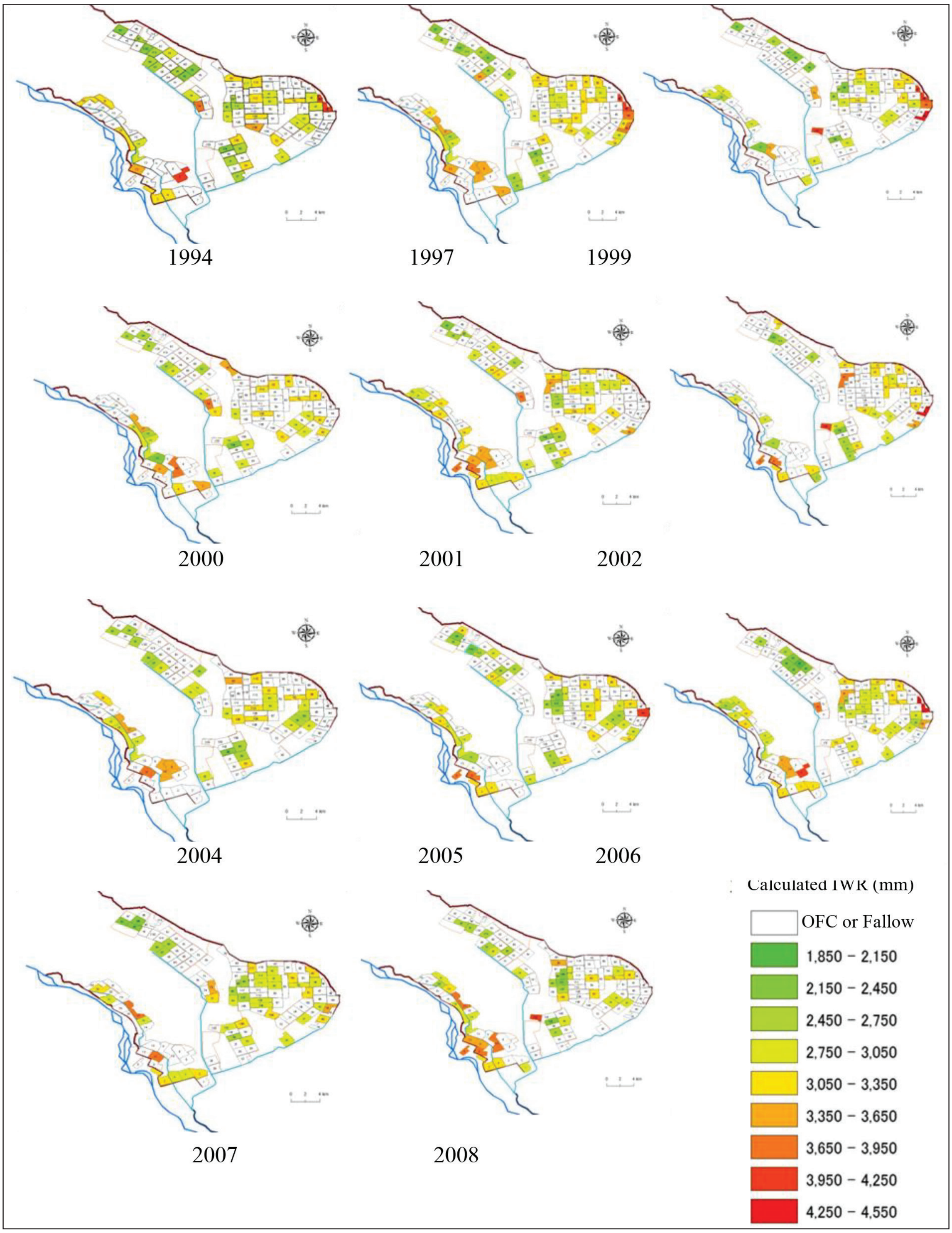

Figure 8. Calculated irrigation water requirement (IWR) values for paddy rice within each farm block.

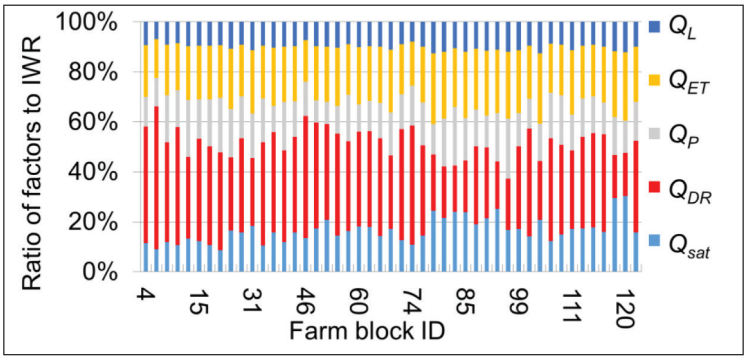

Figure 9. Ratios of factors affecting the irrigation water requirement (IWR).

The IWRs of the eastern and western blocks were compared and the results are shown in Figure 10. The average IWR for the western block was 3,140 mm, whereas that of the eastern block was 2,940 mm; therefore, there is a difference of 250 mm between them. This discrepancy is due to the layout of the drainage system in the BSF, with the ratio of the farm block area adjacent to the main drainage system in the western block higher than that of the eastern block.

Table 1. Ratio of soil types in the western and eastern blocks of the Bakbakthi State Farm (BSF)

Soil type	Sand (%)	Silt (%)	Clay (%)
West	21	63	16
East	7	62	31

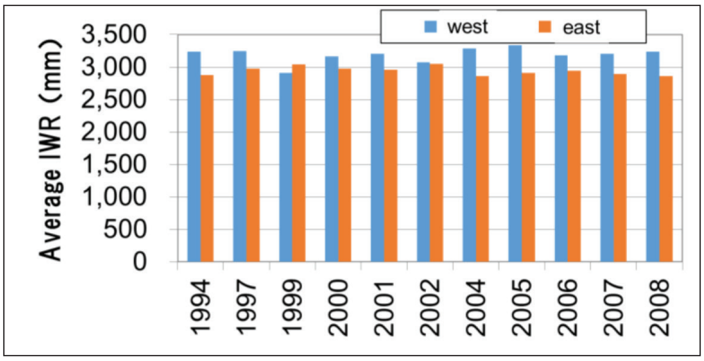

Figure 10. Comparison of irrigation water requirement (IWR) between the western and eastern blocks

5. Conclusions and recommendations

There were no significant differences in the calculated IWR among the two irrigation blocks and among different years. The seepage to the drainage canal affects the IWR. The IWR of the western block is higher than that of the eastern block. The cropping pattern of the adjacent fields does not affect the IWR. The prevailing IWR (2,290 mm) is insufficient to meet the calculated IWR. For a uniform IWR throughout the irrigation district, it is recommended that the applied amount should be 3,000 mm. If different IWR values are applied within the eastern and western blocks, the IWR at the western block should be bigger than that of the eastern block. To improve the farm water delivery performance, a larger amount of water should be delivered to the paddy fields adjacent to the main drainage canals.

Acknowledgements

This study is partially supported by the IPDRE, Tottori University.

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4. Cross-scale hydro-dynamics and effects of paddy cultivation on water management and productivity

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Abstract

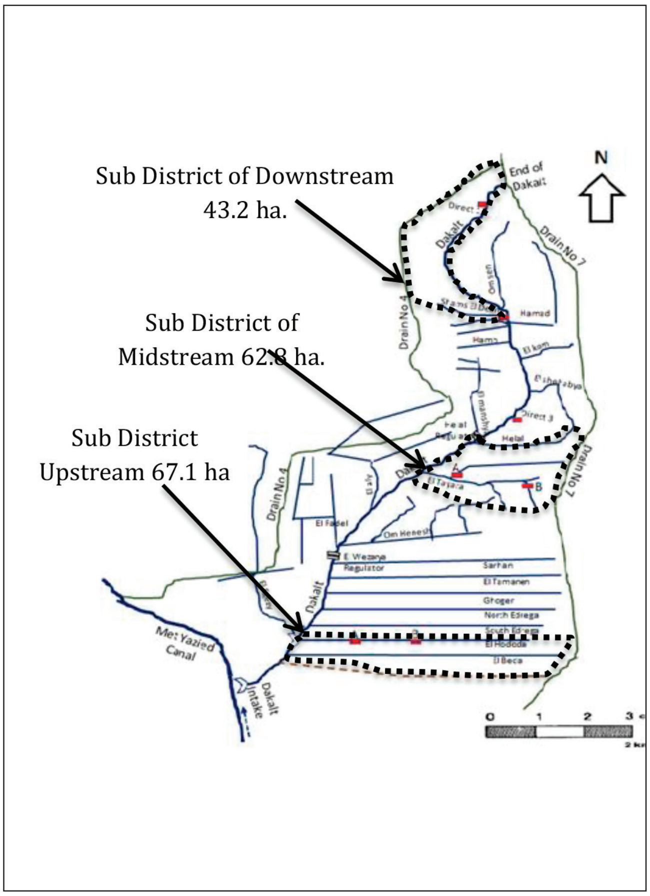
In Egypt, decisions on agriculture and irrigation, such as cultivating periods, crop type and rotation, water allocation and distribution, depend on farmers experience and socio-economic options. Therefore, analysis of cross-scale hydro-dynamics and effects are getting more important in water management, especially under rice cultivation areas as well as at the tail end of irrigation system. The Government of Egypt started implementation of Irrigation Improvement Project (IIP) in 1991 to save water and increase land productivity. The Government has tried to limit rice cultivation because of limited water resources. Unfortunately, in spite of that, rice cultivation has continued to expand due to high profits from rice production. The impacts of increasing rice area have, therefore, got to be analyzed from hydro-dynamics point of view. Many changes have also been taking place in the field conditions because of this increase in rice production, such as water insufficiency, rise in water table and rise in soil salinity, which negatively affect crop production and farm income. This paper assessed the actual relationship between crop yields and field conditions, including water sufficiency, water table properties and salinity in the IIP project area. The study showed that the yields of summer season crops, maize and rice, are negatively affected by un-desirable conditions of water deficiency and salinity, whereby impact on maize is larger than on rice. In the winter season crops, wheat and sugar beet, yields have not been reduced by these field conditions. The crop most seriously affected by salinity at the downstream is maize and the second crop is rice, while sugar beet and wheat are tolerant to salinity and water deficiency. Also, water deficiency affected most the rice crop followed by maize, while sugar beet and wheat were tolerant to water deficiency. In future, it is necessary to check the present policy of contracting agriculture crops and its effect on cross-scale hydro dynamics of irrigation system management.

Keywords: Hydro-dynamics, Water productivity, Water supply, Water-table, Salinity

1. Introduction

Nile River is one of the oldest irrigation systems in the world and many irrigation schemes in the world are as old as the countries they serve. Some of them are showing severe symptoms of ageing which makes their renewal, modernization and rehabilitation essential. However, ageing is not the only problem. Also, fast-growing populations, especially in developing countries, necessitate the improvement of the systems in order to raise efficiency and reduce water losses to a minimum to achieve the required degree of food security.

The best environment for crop production is achieved when the plants root zones are kept adequately moist. Either inadequate or excess water in the root zone causes plant stress and reduces yields. Good irrigation management should maintain optimum root zone moisture conditions without using excessive water to avoid increasing of groundwater table and salinity of soil and groundwater. Poor irrigation management results in waste of water, sometimes wastes plant nutrients, and contributes to potentially harmful high water-table conditions and salinity. Therefore, the Ministry of Water Resources and Irrigation (MWRI) of Egypt started to implement many of the irrigation projects like irrigation improvement projects (IIPs). This is done to improve the irrigation infrastructure, facilitate a more equitable water distribution and improve water management system to avoid rising of groundwater table and salinity. However, there are still some problems regarding the water distributions and groundwater table and soil and groundwater salinity. These affect all crops but the real impacts on different crops is not clear. Therefore, trying to know the extent of impacts of the field dynamics of water sufficiency, groundwater table and salinity on productivity of crops is important as the information is scanty and not well documented.



Outline of the Dakalt district (2011)

Water source	Meet Yazied Canal (Main canal).
Main Canal	Dakalt Branch Canal.
Location of the intake	41 km RMY
Total serve area	2310 ha.
Length of main canal	11.3 km
Irrigation system	Rotation-surface irrigation.
Drainage system	Open and subsurface.
No. of Mesqas (Tertiary canal)	22
Total no of users	4050
Population	21,300
Agriculture associations	EslahDakalt.
Main boundaries	South: Meet Yazied Canal North: El Hamoul – El Ryiad Road East Drain NO 7 + International Road West Dail El Kased canal + Drain NO 4
No of members of representative committees	48 (40 agriculture societies+ 8 housing units)

Figure 1. Case study area: Dakalt district in the Nile Delta.

2. Materials and methods

2.1 Case study area

The command area of Dakalt canal as a part of IIP project in the Nile Delta is chosen. Dakalt command area is located on the right-hand side and fed from Meet Yazid canal (Km 41.07). It is about 12 km long and serves about 2310 ha land. The physical status represents the situation of the middle and northern part of the Nile Delta. Three locations under IIP project along the selected canal were selected: upstream (1.81 Km), midstream (4.86 Km) and downstream (8.260 Km), each location serving an area of 67.1 ha, 62.8 ha and 43.2 ha respectively. The main information, including map of the study area, is shown in Figure 1. EWUP efforts had concentrated at the farm level and the lower portions of the delivery system, starting with the distributary canals. Recently, Japan Society for the Promotion of Science (JSPS) supported a research project with the Water Management Research Institute (WMRI) to develop integrated indices on water management performance in IIPs areas including our study area. The main data are collected at different levels such as secondary canal, tertiary canal (*Mesqa*), on-farm levels and field ditches.

Table 1. Field observations in the Dakalt district (2013)

Items	Methods	Frequency
Crops yield	- Main crops for rice, maize, wheat, sugar beet (data for cotton and alfalfa is not available).	6 plots in each locations
Water requirements	- Modified Penman Montieth equation, based on meteorological data in El Karda, Kafer El Sheikh, Egypt	Monthly
Water supply	- Operation time of intake pumps by Thermo manager - Discharge of pumps by Ultrasonic flow meter	Daily every 10 minutes once summer and once winter
Groundwater table and salinity	- Three observation wells at upstream, midstream and downstream of each Mesqa. - At summer wells installed near rice field	Weekly for summer and winter
Soil salinity	- Samples near observation wells by auger in the depths 0-80 cm.	Once in winter and once in summer

2.2 Field observations

The objectives of this study are to evaluate the field conditions such as water sufficiency, soil salinity and groundwater table and their impacts on yields of main crops as affected by changing paddy areas.

In general, these impacts can only be evaluated by paying attention to internal details. In order to carry out these impacts, the Dakalt command area is selected as the case study area and the field observations are carried out as listed in Table 1. The analysis of variance was carried out according to Gomez et al (1984). Treatment means were compared by Duncan's Multiple Range test (Duncan, 1955). All statistical analysis was performed using analysis of variance technique by means of "SAAS" computer software package.

3. Results and discussion

3.1 Yields

The main outcomes of irrigation improvement projects in Nile Delta is lowering groundwater table, salinity, avoidance of large groundwater fluctuations and supply of irrigation water according to the actual requirements with distribution equity, consequently affecting positively on increases crop yields. To study those impacts on the field dynamics, randomize complete plot design was adopted with one factor (different locations along the canal from upstream to downstream) for productivity of main crops (rice, maize, wheat and sugar beet) of the area, as presented in Table 2. The table explains productivity response of various crops to different field dynamics (water sufficiency, groundwater table and salinity) reflected by location.

Table 2. Crop yield (t/ha) for main crops (2013)

Location	Rice	Maize	Wheat	Sugar beet
Upstream	10.6	9.2	7.7	42.6
Midstream	10.5	8.9	7.1	37.5
Downstream	9.7	6.7	7.0	35.9
F-Test	*	**	NS	NS

*, ** and Ns indicate p <0.05, <0.01 and not significant, respectively.

Highest rice yield was recorded at upstream and midstream with significant difference from downstream. Also, locations and field dynamics affected highly significantly the yield of maize, grown in summer, although there was no significant difference between upstream and midstream. In winter season crops, wheat and sugar beet, there was no significant effect of different field conditions.

3.2 Field conditions

3.2.1 Water requirements and sufficiency

One of the most important issues is how to cope with impacts of the clearly recognized water shortage crisis and its effect on soil salinity, groundwater salinity and yield production, especially, in the areas where irrigated agriculture has been practiced for thousands of years as Egypt. Therefore, many projects have been implemented and new projects are still needed to improve the existing irrigation networks to increase the agricultural productivity and farm income to cope with water shortage crisis. The data of water requirements includes crop water requirements, leaching requirements, and special crop requirements. Water requirement for ET_0 as presented in Table 3 were calculated by Penman Monteith equation. This is to show the difference between applied and required water, the information necessary for the analysis of the shortage or over application.

Comparisons of the water supply indicators in different places along irrigation canal from upstream to the downstream were done by the corresponding values of water supply and requirements for Dakalt areas. The total volumes of external surface irrigation water delivered to the users is presented in Table 4.

Table 3. Water requirements (2013)

Crops		Apr	May	Jun	Jul	Aug	Sep.	Average
Rice	ET0 (mm/day)		5.4	6.2	6.1	5.6	4.5	
	Growth stages		Initial	Mid-season		Late season		
	Kc per gr. St.		0.8	1.3	1.4	1.2	0.8	
	Kc per month		0.9	1.3	1.4	1.2	0.8	
	ET crop(mm/day)		4.8	8.1	7.9	6.7	3.6	6.2
	ET crop (mm/mon)		145.8	241.8	237.9	201.6	109.0	187.2
Maize	ET0 (mm/day)		6.2	6.1	5.6	4.6		
	Growth stages		Initial	Mid- season		Late season		
	Kc per gr. St.		0.6	1.2	1.2	0.6		
	Kc per month		0.6	1.2	1.2	0.6		
	ET crop (mm/day)		3.7	3.7	6.7	2.7		4.2
	ET crop (mm/mon)		111.6	109.8	201.6	82.8		141.0
Cotton	ET0 (mm/day)	4.4	5.4	6.2	6.1	5.6	4.5	
	Growth stages		Initial	Mid- season		Late season		
	Kc per gr. St.	0.3	0.3	1.1	1.1	0.4	0.4	
	Kc per month	0.3	0.3	1.1	1.1	0.4	0.4	
	ET crop (mm/day)	1.3	1.6	6.8	6.7	2.2	1.8	3.8
	ET crop (mm/mon)	39.7	48.6	204.6	201.3	67.2	54.5	115.2

Crops		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Average
Wheat	ET0 (mm/day)		2.4	1.5	1.9	2.2	3.1			
	Growth stages		Initial	Mid-season		Late season				
	Kc per gr. St.		1.3	1.3	1.4	1.3	0.9			
	Kc per month		1.3	1.3	1.4	1.3	0.9			
	ET crop (mm/day)		3.1	2.0	2.7	2.9	2.7			2.7
	ET crop (mm/month)		93.6	58.6	79.8	85.8	83.7			80.3
Alfalfa	ET0 (mm/day)	3.5	2.4	1.5	1.9	2.2	3.1			
	Growth stages	Initial		Mid-season		Late season				
	Kc per gr. St.	1.3	1.2	1.2	1.2	0.9	0.9			
	Kc per month	1.3	1.2	1.2	1.2	0.9	0.9			
	ET crop (mm/day)	4.6	2.9	1.8	2.2	1.9	2.7			2.7
	ET crop (mm/month)	136.5	86.4	54.0	68.4	59.4	84.7			81.4
Sugar beet	ET0 (mm/day)		2.4	1.5	1.9	2.2	3.1	4.4	5.4	
	Growth stages		Initial		Mid-season			Late season		
	Kc per gr. St.		1.0	1.0	0.9	0.9	1.0	0.9	0.9	
	Kc per month		1.0	1.0	0.9	0.9	1.0	0.9	0.9	
	ET crop (mm/day)		2.4	1.0	1.7	1.8	3.1	3.9	4.8	2.7
	ET crop (mm/month)		72.0	30.0	51.3	59.4	93.0	119.1	145.8	81.5

Table 4. Volume of external surface irrigation (2013)

Location	Summer			Winter		
	m³/ha	mm/day	mm/month	m³/ha	mm/day	mm/month
Upstream	10990	6.0	180.2	3602	2.0	59.1
Midstream	9976	5.5	163.5	3762	2.1	61.7
Downstream	8693	4.8	143.0	3849	2.1	63.1

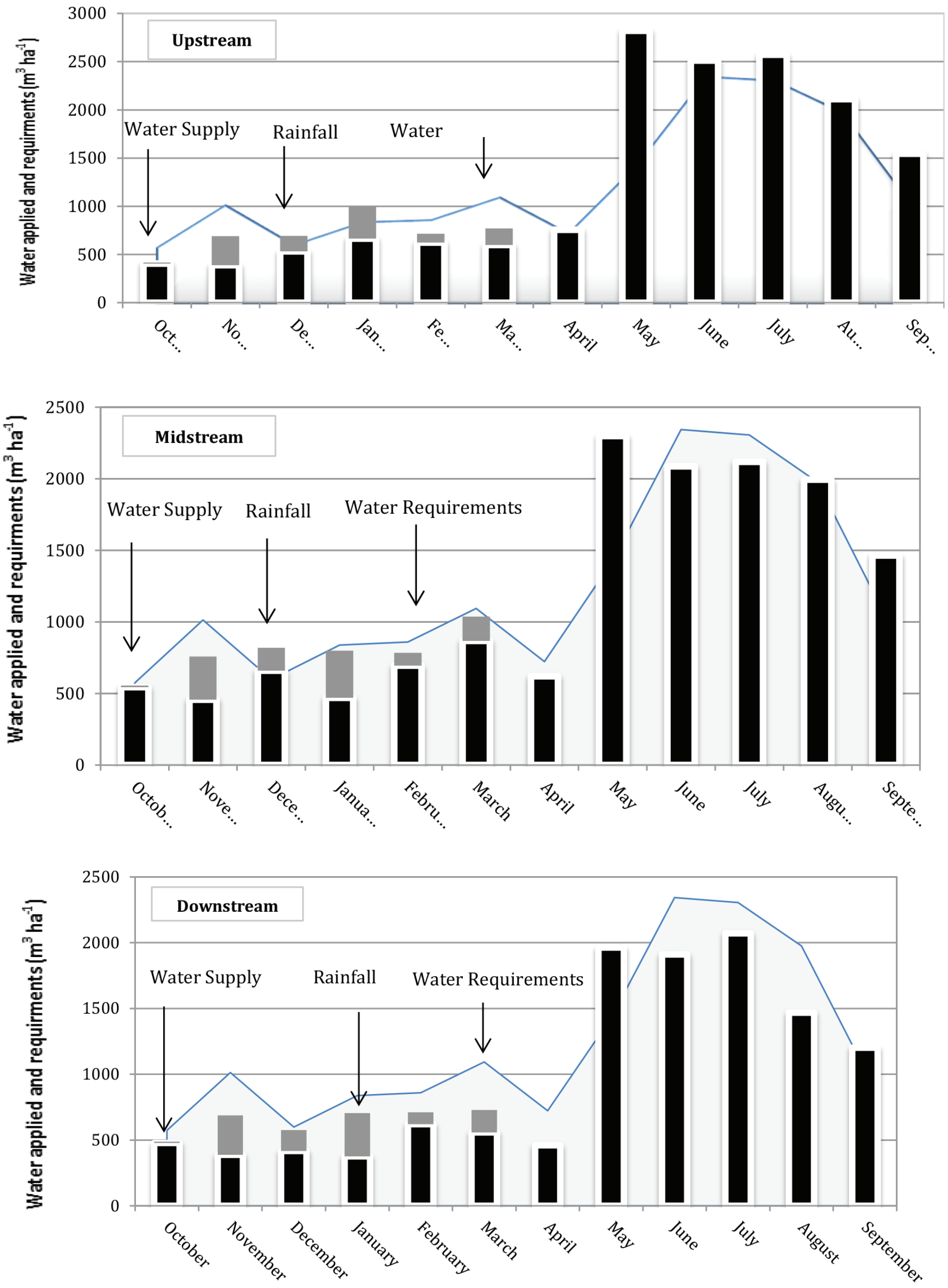


Figure 2. Water requirement and supply in the Dakalt District (2013).

Table 5. Water requirement (R), water supply (S) and water sufficiency (S/R) in 2013

Location	Summer			Winter		
	R (mm /day)	S (mm /day)	S/R	R (mm /day)	S (mm /day)	S/R
Upstream	5.4	6.0	1.1	1.9	1.9	1.0
Midstream	5.0	5.5	1.1	1.8	2.0	1.1
Downstream	5.3	4.8	0.9	2.0	2.1	1.1

Table 4 shows values of water supply at different irrigation locations of Dakalt canal in the summer and winter seasons of 2013. Highest water supply was achieved at upstream in summer season. In winter season the amount of water supply was about half of total water supply in summer. Therefore, there is no problem of water delivery in winter season in Dakalt canal.

As defined by International Program for Technology and Research in Irrigation and Drainage (IPTRID), the RWS is an annual value that compares the total water supply (irrigation water and non-irrigation water) that enters the command area against the net required irrigation water. It can be noted from Figure 2 that in summer season 2013, the stations that are located upstream had not been affected by increasing water requirements in June and July. The water supply was more than water requirements of cultivated crops in all the summer months with no impact of increasing water requirements for cultivated crops in June and July.

3.2.2 Groundwater

An increase in groundwater table and salinity are considered to be an indicator for the negative impact on soil salinity and crops production. Therefore, it is important to study the groundwater table and salinity in Dakalt District command area. It can be observed from Figure 3 that the highest percentage of groundwater salinity occurs in summer season, especially in June and July, at all locations. Also, as mentioned before (Figure 2 and Table 3), the water shortage crisis occurs increasing in these months with increased crop water requirements. The lowest groundwater salinity occurred in October for each location along the canal. The highest level of salinity was found at the downstream end, especially in the summer months when there is an increase in water requirements. It was noted that highest level of salinity in winter season was in November and March when water requirement too was high. The groundwater table was the deepest in winter season. Groundwater table was found shallower in summer with increasing rise in May for downstream, and in June for upstream and midstream. Also, deeper groundwater table was found downstream than midstream and upstream. The shallower groundwater table was in June for upstream and midstream and in May for downstream.

3.2.3 Soil salinity

From Figure 4 it can be noted that salinity in the surface layer of the soil is higher than in the rest at all sites on the canal. It was also noted that the highest level of salinity was at downstream, followed by upstream and then midstream. The salinity increased in the summer season and it was the highest at the downstream, followed by the upstream and the midstream locations.

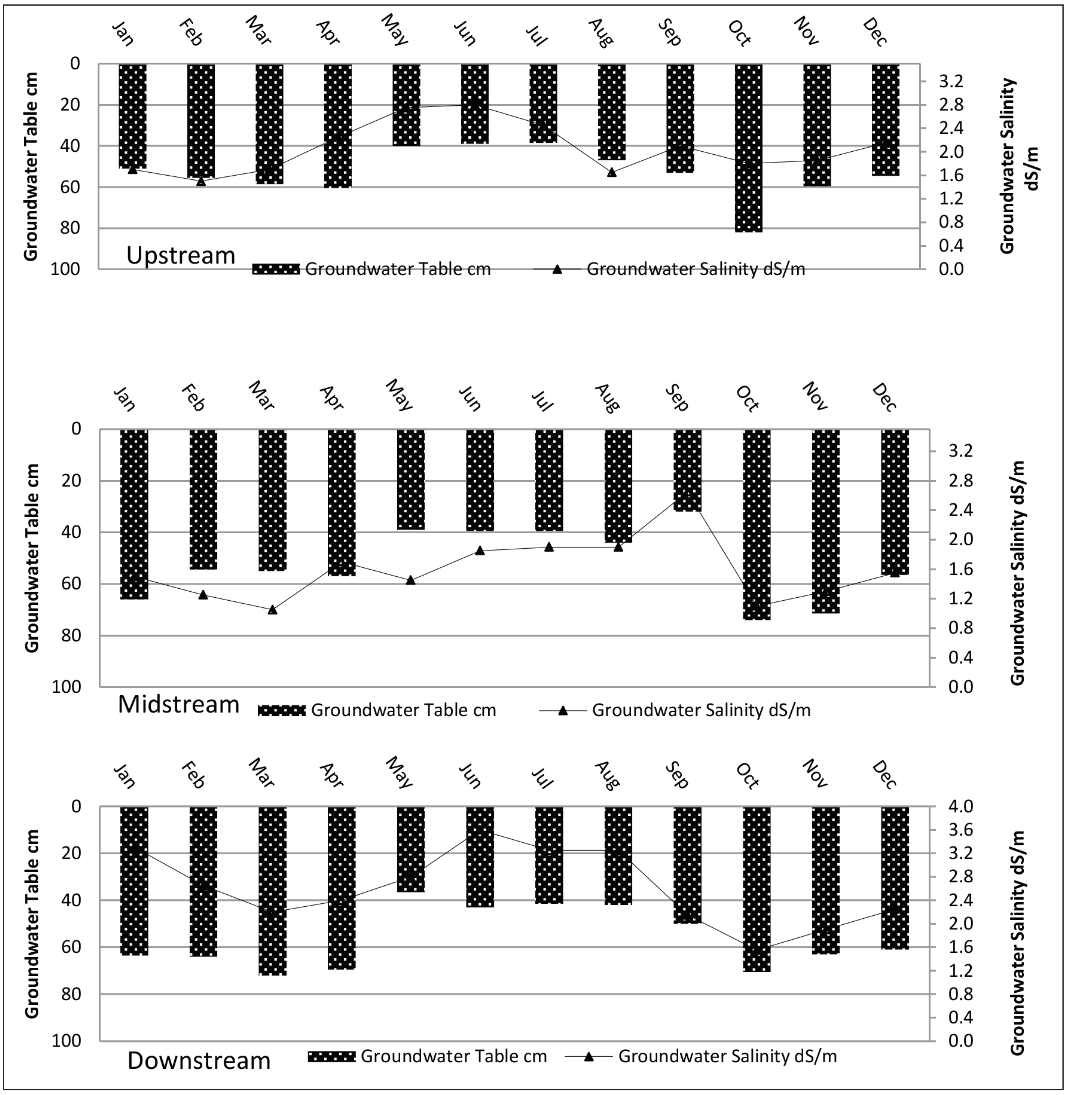


Figure 3. Groundwater table and salinity in Dakalt District (2013).

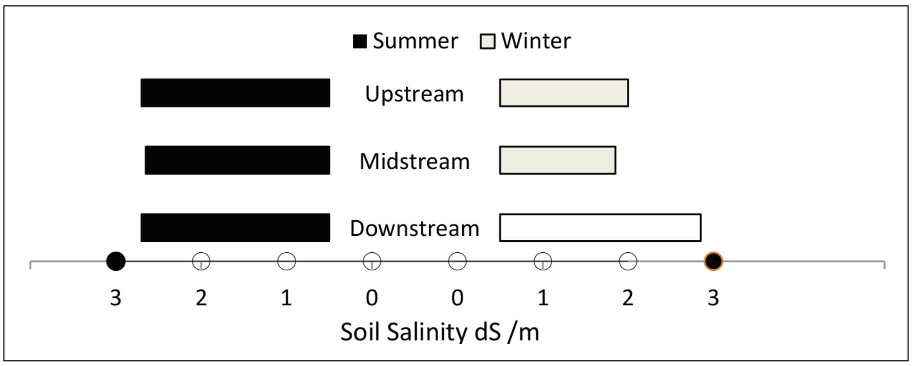


Figure 4. Soil salinity at Dakalt District (2013).

3.3 Discussion

The best environment for crop production is achieved when the plants root zones are kept adequately moist. Either inadequate or excess water in the root zone causes plant stress and reduces yields. Good irrigation management should maintain optimum root zone moisture conditions without using excessive water to avoid increasie in groundwater table and salinity of soil and groundwater. Poor irrigation management wastes water, sometimes wastes plant nutrients, contributes to potentially harmful high groundwater table conditions and salinity. There was a water insufficiency in summer season for downstream where it was lower than 1.0, according to Burt *et al.* (2001). It means there is a problem of water sufficiency at downstream with satisfactory values for upstream and midstream but, in winter season water sufficiency at downstream was more than upstream.

This means problems of water sufficiency appear in summer season only. Also, highest groundwater salinity at downstream was 3.61 dS/m and minimum value was 2.15 dS/m. According to FAO (1985), water salinity higher than 3.0 dS/m causes severe problems.

Winter season groundwater salinity at downstream was lower than 3.0 dS/m. The deepest groundwater table was observed downstream. Seasonally, water table in winter was deeper than summer. Sometimes in summer season, water table becomes deeper than 105 cm. This may be due to increase of water requirements with water shortage crisis in downstream as shown in Figure 3 and Table 5. The highest average soil salinity at downstream locations was 3.17 dS/m in summer with maximum value reaching 4.17 dS/m at the first depth (0-20 cm). According to FAO, soil which has more than 4.0 dS/m salinity is considered as saline. Therefore, soil classification is varying in summer season from saline in the surface layer to sodic in the next layers. It is clear that water sufficiency was affected by groundwater table and salinity. This clearly appears in summer season especially at downstream site. This leads to reduction in yield, especially at downstream for maize and rice. In winter seasons crops such as wheat and sugar beet there was no significant effect.

The impact of water insufficiency on groundwater table and salinity at downstream affected summer crops production where the deepest groundwater table, highest average groundwater salinity and soil salinity were recorded. It can be observed that the maximum effective rooting zone for rice is 0.59m (shallow medium) and maize 2.30m (deep). The range of soil moisture for suitable growth is 28-86% (sensitive) for maize and 60-100% (extremely sensitive) for rice. The maximum critical electrical conductivity of soil saturations extract for production decrease is 3.0 dS/m for rice and 1.7 dS/m for maize. Therefore, decrease in maize production at downstream comes from the effect of water sufficiency on soil salinity (3.17 dS/m) and groundwater salinity (3.61 $\mu S\ cm^{-1}$). Also, the reduction of rice yield comes from water insufficiency (0.9) and soil salinity in downstream.

Table 6. Relations between water sufficiency, groundwater table and salinity

Field conditions			Upstream	Midstream	Downstream
Water sufficiency	Summer		1.1	1.1	0.9
	Winter		1.0	1.1	1.1
Groundwater salinity (dS/m)	Summer	Maximum	3.0	2.9	3.6
		Minimum	1.7	1.2	2.2
		Average	2.5	1.8	3.1
	Winter	Maximum	2.2	1.6	3.4
		Minimum	1.5	1	1.5
		Average	1.8	1.3	2.4
Groundwater table (cm)	Summer	Maximum	-61.0	-43.5	-69.5
		Minimum	-37.0	-31.7	-36.0
		Average	-64.81	-43.0	-38.1
	Winter	Maximum	-82.0	-77.5	-84.5
		Minimum	-51.0	-43.3	-55.0
		Average	-58.0	-61.6	-66.0
Soil salinity (dS/m)	Summer	Maximum	3.3	1.8	3.9
		Minimum	1.1	1.4	1.5
		Average	1.99	2.4	1.7
	Winter	Maximum	2.6	1.1	1.9
		Minimum	0.8	0.9	0.9
		Average	1.5	1	1.3

In winter season, the impact of water sufficiency on groundwater table and salinity did affect yield of sugar beet and wheat. There was water sufficiency for all locations with higher water sufficiency at downstream than upstream. However, range of soil moisture for suitable growth for wheat and sugar beet is moderate (35-80%). Therefore, there is no effect on winter crops from the point of water sufficiency in Dakalt area. Regarding the critical electrical conductivity of soil saturation paste, wheat is moderately sensitive to salinity (6.0 dS/m) and sugar beet is tolerant to salinity (7.0 dS/m). The average measured soil salinity was 1.24, 1.05 and 1.34 dS/m for upstream, midstream and downstream, respectively. Thus, there was no effect of water sufficiency on soil salinity and yield in winter season.

4. Conclusion

Rice-based cropping system has been practiced in Egypt. The rate of salt accumulation during the upland cropping phase is rather rapid with the raise in the groundwater level in neighboring upland fields. It has affected the productivity of upland crops which can, therefore, guide the strategy of supplying water to the upland fields. The effectiveness of this indirect method of water supply appears to be affected by the spatial distribution of paddy fields in the district. It is, therefore, indispensable to maintain an adequate supply of irrigation water and an appropriate drainage system during paddy cropping phase in order to maintain a good conditions for the irrigated agriculture.

Acknowledgment

This research was supported by the Grant-in-Aid for Scientific Research of JSPS, No.24248041.

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Special Session 3: Restoration of Degraded Dry Ecosystems: beyond conventional approaches

1. Aeolian desertification and its control in Northern China

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Abstract

Aeolian desertification is land degradation through wind erosion, mainly caused by excessive human activities. In the arid, semiarid and part of sub-humid regions in Northern China, Aeolian desertification has rapidly expanded in last 100 year and this is particularly true for last 60 year. The expansion of the desertified land has accelerated since 1950 as the annual expansion rate was 1560 km^2 between 1950 and 1975, 2100 km^2 between 1975 and 1988, 3600 km^2 from 1988 to 2000 and the recovery has been only -1375 km^2 from 2000 to 2010. Thus the whole situation of aeolian desertification was deteriorating before 2000 and it has improved only after 2000. According to our studies, we believe that the human interventions can reverse the aeolian desertification based on the reasonable landuse and adopting varied prevention and curative measures. China has made much progress in understanding and combating aeolian desertification through many research and development efforts and projects for decades. The biggest project, based on a new state policy, is the National Project of 'Grain for Green Program', which started in 1997 and is covering 1060 counties in 22 provinces. The Program has adopted many approaches for combating the aeolian desertification to achieve its objectives: reclaim 3.67 million ha of farming land and degraded steppe, and rehabilitate 5.13 million ha of aeolian desertified land suited for reforestation and vegetation. There are about 8 million ha of land under the threats of aeolian desertification that will be brought under control in the next ten years and about 26.67 million ha of windbreaks will be planted. This paper is intended to analyze the process of aeolian desertification and to introduce the idea and approaches for combating aeolian desertification in Northern China.

Keywords: Aeolian desertification, Landuse, National project GGP, Policy and approach, Northern China

2. From degradation to sustainable management: policies for ground water use in dry ecosystems

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Abstract

The increasing population and food demand necessitates accelerated efforts to increase food production. This requires more land and water. Water scarcity has already been a reality in dry areas and particularly in the MENA region, which, with an annual per capita availability of 1,200 m^3, is one of the most water-scarce regions in the world. All available water resources are being utilized and the ground water is being over exploited leading to its irreversible depletion. Further, climate change is expected to make things worse. Agriculture is the largest user of water but its economic value added to water consumed is much lower than other sectors. On the other hand, farmers often over-irrigate with low farm water use efficiency. Therefore, policy makers and water resources mangers are considering water reallocation options where agricultural share may be reduced. However, water pricing or valuation is a sensitive issue in that there is prevailing perception that Islamic Law guarantees free access to water as an essential element of life. The policy-makers are concerned about the negative effects of water pricing on farm income and the social stability. There is also the perception that water pricing will reduce food security. We analyzed the effects of structured and progressively increasing water tariffs on water saving, farm income and food production using two cases: Jordan and Syria. The findings indicate that it is possible to design specific tariffs that meet the challenges indicated above. First, farmers are given, without charge or at a low tariff, volume of water equivalent to the technical crop water requirement or profit maximizing water level. Then the tariffs are progressively increased for higher ground water withdrawals. In the case of Jordan we tested the application of 0.01 JD/m^3 at abstraction rate of 15,000-200,000 m^3/well/year, and 0.1 JD/m^3 for abstractions exceeding 200,000 m^3/well/year. In Syria, we tested the terrify of US$1 for every 1 m^3 of irrigation water applied to the wheat crop in excess of 1,800 m^3 (the upper limit of the recommended application range). In all cases, the analysis indicates that these tariffs can change farmers' behavior towards ground water use by persuading them to adopt water conserving practices. These changes will have no or small negative effect if any on farm income, and in some cases even small positive effect, as a result of cost reduction and increased efficiency. In all cases, there is no significant reduction in food production due to reduced water application. This provides policy makers starting point to address the problem of water pricing in agriculture and increase the overall efficiency of water use across the whole economy as water scarcity will continue to worsen in the future.

Keywords: Water scarcity, Ground water, Water pricing, Policy options, Farm income, Food production, MENA region

3. Dry ecosystem services: Approaches for valuation and ensuring public support

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Abstract

Humans derive a wide range of services from the natural capital, called ecosystem services, which make human life possible. Changes to ecosystems and degradation of ecosystem services, especially in the dry areas, are increasing at an alarming rate. Payments for Ecosystem Services (PES) is a novel conservation approach that internalizes environmental externalities through the creation of markets and quasi-markets. Private actors are assumed to put in practice the Coase theorem, meaning that the problem of externalities can best be overcome through private negotiations between affected parties. Dry ecosystems are home to some of the most charismatic species, support high species endemism and comprise many unique ecosystems and biomes, including savannahs, dry forest, coastal areas and deserts. However, currently dry ecosystems are neglected, under-valued and increasingly degraded. In order to restore the degrading dry ecosystems and to maintain the levels of ecosystem services derived from them, their true market value needs to be estimated so an action plan, which links the restoration to the beneficiaries, can be developed, funded and implemented. Two case studies, one from Mexico and the other from Kazakhstan, are presented to show how PES plans can be developed with the participation of stakeholders. This involves identification of the ES, estimation of its value, mapping of beneficiaries of the ES and development of mechanisms that link the ES with the beneficiaries for its sustainable management. Decision- and policy-makers in dry areas can take cues from PES studies to better target taxes, penalties and subsidies, and create enabling policies, institutions and environment for saving and rehabilitating degrading ecosystems.

Keywords: Dry ecosystems, Degradation, Ecosystem services, Market value, Stakeholder participation, Enabling policies

4. Dust storms from degraded drylands of Asia: dynamics and health impacts

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Abstract

Asian dust is an atmospheric phenomenon where huge amount of fine soil particles are blown up by strong wind accompanied by a passage of cold front (i.e. dust storm). Dust initiated in the Chinese and Mongolian deserts often travels to downwind regions such as Korea and Japan, and is observed there as dust haze. Dust particles are often contaminated with air pollutants derived from human activities as they transport over densely populated regions. The frequency of dust events has increased in 2000s due to land degradations in emission regions. With the increase of dust event, concerns have been expressed over health hazards associated with dust. The main damages resulting from dust differ between emission region and downwind region. In emission region, it is a disaster that may cause death to people and animals. Also, highly dense dust there is an air pollution causing respiratory diseases and severe subjective symptoms. In downwind region, although the dust density is lower than in emission region, recent epidemiological studies have shown that Asian dust events coincided with increases in daily admissions and clinical visits for allergic diseases such as asthma, allergic rhinitis, and conjunctivitis. Moreover, it is pointed out that Asian dust leads to the development in healthy subjects of such symptoms as itchy eye and skin, nasal congestion, and sore throat.

Keywords: Asian dust, Air pollution, Health impacts, Epidemiological studies

Introduction

Dust storms originate in many places of the drylands all over the world. In general, Estimates of the relative strength of dust emissions for different parts of the world demonstrate the importance, firstly of the Sahara (with over half of the global total), secondly of China and Central Asia (with about 20%) (Goudie, 2014). Dust events often effect not only on human life and health in the drylands but also in downwind regions. Although the Sahara is the most significant global source of dust, approximately 60% of the Saharan dust moves southwards to the Gulf of Guiana where nobody lives (Karanasiou *et al.,* 2012). Asian dust is the long-range transport of atmospheric pollutants originating in drylands and carried by westerly winds into northeast Asia (Figure 1). It affects large number people because East Asia is one of the most heavily populated areas in the world. Recently, the frequency and severity of atmospheric dust have been increasing steadily. Concerns have been expressed over health hazards in affected areas. The principal damage by Asian dust differs in emission region (sandstorm) from that of downwind region (air pollution) (Goudie, 2014). Here we describe the health effects in each region.

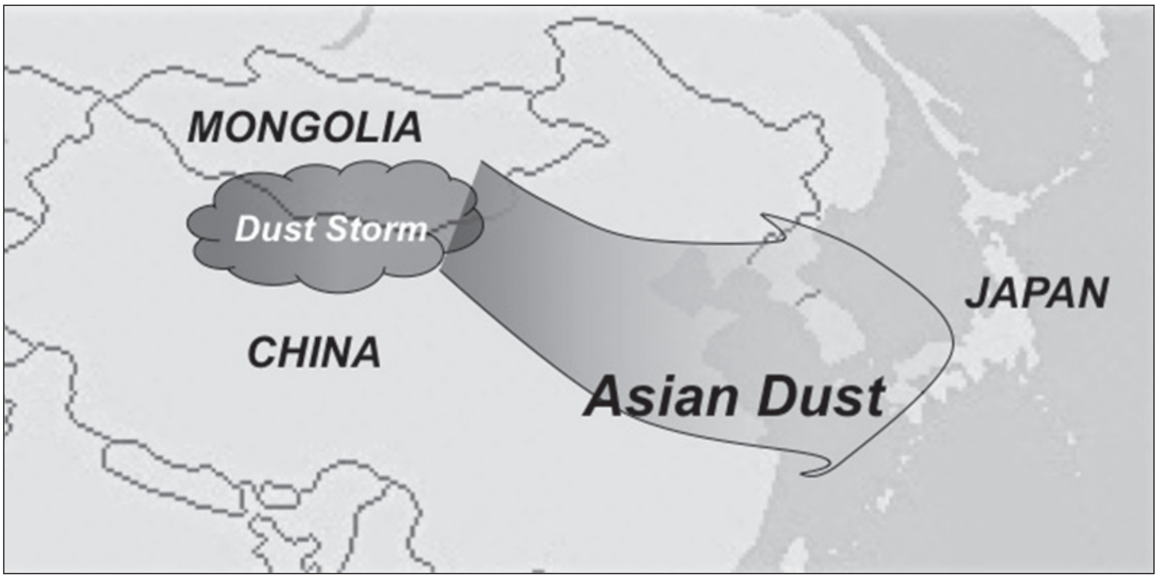

Figure 1. Positional relation of the Asian dust emission area and downwind regions.

Health impacts of Asian dust on emission regions

In Mongolia, during April 17–20, 1980, and May 5–6, 1993, between 9 and 16 people and 100,000–675,000 head of livestock died due to severe snow and dust storms (Dulam, 2005). Most recently, an intense dust storm occurred May 26–27, 2008, in a broad area of Mongolia. Some 52 people lost their lives and 320,000 animals were killed. In emission region such as Mongolia, severe dust storm events are great disaster. We investigated subjective symptoms of the eyes and respiratory system as reported by inhabitants in the urban and desert areas of Mongolia immediately after this latest dust storm. The prevalence of eye symptoms was higher among the desert area subjects than among the urban area subjects. We suggest that the health effects of dust storms may be associated with a high prevalence of eye symptoms in Mongolia (Mu *et al.,* 2011).

We also performed a cross-sectional survey on Health Related Quality of Life (HRQOL) and the livestock loss one year after this dust storm. Our results provide preliminary evidence that livestock loss has long-term effects on HRQOL: some of HRQOL markers (general health and vitality) were lower among people who lost livestock than among those who did not. Therefore, saving lives, animal husbandry and medical health support after disasters (e.g., medical care patrols, psychological consultations, etc.) are necessary. At the same time, developing an early warning system to ameliorate damage is also needed (Mu *et al.,* 2013).

Exposure to dust particulates irritates the respiratory tract and is associated with respiratory disorders, such as asthma, pneumonia, and nonindustrial silicosis. Actually, diseases of the respiratory system morbidity in provinces located in Gobi Desert have been stably high (Figure 2). It is said that populations particularly vulnerable to airborne and respiratory diseases are children and the elderly, and people with pre-existing heart and lung diseases.

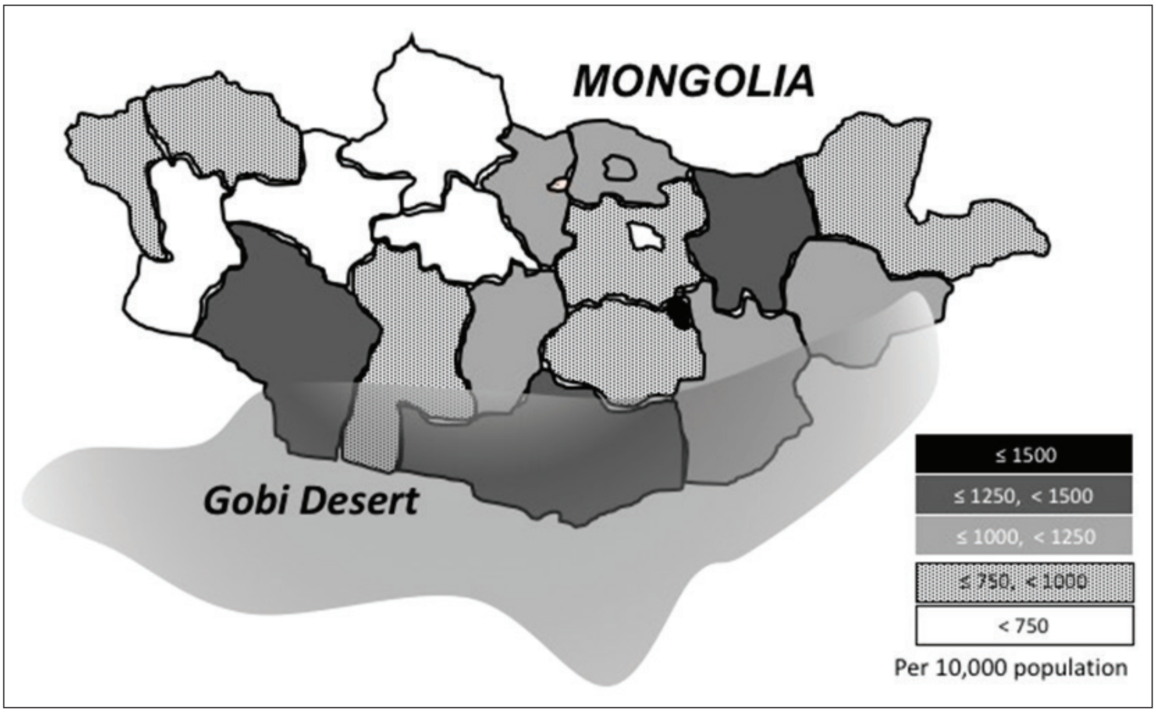

Figure 2. Diseases of the respiratory system morbidity in each province in Mongolia.

Health impacts of Asian dust on downwind regions

In downwind regions such as Japan, South Korea, and Taiwan, recent epidemiological studies have shown that Asian dust events coincided with increases in daily hospital admissions and clinical visits for allergic diseases such as asthma, allergic rhinitis, and conjunctivitis. Children are particularly vulnerable. Their exposure to dust particles transported globally from desert storms is associated with increased hospital admissions for childhood asthma (Kanatani *et al.,* 2010). Worsening asthma symptoms caused by Asian dust may be attributed to combined particulate matter and air pollutants (Watanabe *et al.,* 2011). In cardiovascular diseases, it is suggested that Asian dust is a potential trigger of acute myocardial infarction (Matsukawa *et al.,* 2014). Moreover, it is pointed out that Asian dust influences the symptoms such as itchy eye and skin, nasal congestion, and sore throat in healthy subjects (Otani *et al.,* 2011).

What is causing the health problem related to Asian dust on downwind region?

We previously reported an association between skin symptoms and Asian dust events (Otani *et al.,* 2012). Analysis of Asian dust particles in Japan has shown the presence of ammonium ions, sulfate ions, nitrate ions, and heavy metal compounds that are not considered to originate from the soil. Asian dust particles have been thought to adsorb anthropogenic atmospheric pollutants during transport. Skin symptoms during Asian dust events may be allergic reactions (type 4 hypersensitivity) to Asian dust particle-bound metals.

Recent studies have shown that microbes, such as bacteria and fungi, migrate vast distances during Asian dust events by attaching themselves to dust particles. In Korea, springtime air contains a large variety of fungi and potentially high levels of fungal allergens including Penicillium (Oh *et al.,* 2014). In Japan, the possibility of bacterial attachment to aeolian dust particles is pointed out. Our study also demonstrates a significant association between Immunoglobulin E levels of microbial allergens and nasal symptom scores. Asian dust events may trigger type 1 hypersensitivity to fungal allergens (Otani *et al.,* 2014).

Asian dust outbreaks mostly affect East Asian countries. An implication for public policy in East Asia is that to protect public health, anthropogenic sources of particulate pollution need to be more rigorously controlled in areas highly impacted by Asian dust.

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5. Role of rainwater harvesting in the restoration of the Badia of Jordan and Syria

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Abstract

The agro-pastoral systems in eastern Mediterranean region (Jordan and Syria), called locally *badia*, is a typical degraded dry ecosystem. The *badia* forms over 70% of Jordanian and 60% of Syrian territories and is a home to several million inhabitants depending mainly on raising sheep and goat. It receives an annual rainfall of 100-250 mm in winter, from December to March, of which about 90% is usually lost to evaporation or quality deterioration in salt sinks. Summers are hot and dry with temperatures exceeding 40^{o}C. Due to overgrazing, wood cutting, drought and rainfall characteristics, together with human interventions, vegetation has been degraded and soil erosion, by both water and wind, has continued over years. As a result, the dust storms have become frequent and there is continuous migration of people to cities. Now the badia is severely degraded providing only about 1-2 months of animal feed, depending on the annual rainfall, for the sheep and goats whose number exceeds the carrying capacity of the ecosystem. ICARDA, with national and international partners, has conducted a research program for the rehabilitation of the badia in Syria and Jordan based on integrating water harvesting in the system revegetation. An 8-year 'Badia Water Benchmarks Project' led to the development of an integrated mechanized micro catchments water-harvesting package, along with the soil-water-plant and management components, suitable for this environment. Community based integrated watershed management approach with focus on water harvesting was used in the development. The 'Vallerani' machine was adapted to the badia environment and a laser guiding system was added for more precision and lower cost. The package was adopted by the national institutions in Jordan and development efforts are underway implementing it in the badia on a large scale. This presentation will highlight the main research outputs and the lessons learned in the out scaling and subsequent dissemination.

Keywords: Agro-pastoral systems, Badia of Jordan & Syria, Water harvesting, 'Vallerani' machine, Integrated watershed management

6. Revegetation of a degraded ecosystem in dry environments: Experiences from China

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Abstract

Dry ecosystems occupy over 40% of the earth's land surface and are subject to continuous degradation. Revegetation is difficult, if possible at all, due to poor natural resources and management of fragile ecosystems. It is, therefore, vital that revegetation included the introduction of improved plants species and enhanced soil microbiology. In China, 2,636,200 km^2 (27.5% of China's land area) is degraded and the most important cause is wind erosion. Kubuqi desert is a sandy ecosystem located in Inner Mongolia, China. In this ecosystem, sand fixation through vegetation is practiced where trees enhancement is the key issue. To improve the establishment, selection of tree species may be conducted based on ecophysiological features of plants. Mycorrhizal fungi were tested for their effectiveness. Mycorrhizal fungi form mycorrhizas in plant roots and have a mutualistic relationship with host plants known to enhance plant water and nutrient uptake, drought and salt tolerance, disease resistance, and soil aggregation. Because of these functions, the use of mycorrhizal fungi appears to be effective for restoration of degraded drylands. But, its application for the revegetation in drylands is still limited. As a result of our research on tree species selection, *Populus simonii* and *Salix psammophila* showed higher tolerance to drought and sand cover than other species. Inoculation of soil with mycorrhizal fungi enhanced the growth of *Pinus tabulaeformis*. In this paper, a case study on the revegetation of a dry sandy ecosystem in China is introduced and the recommended procedure learnt from the research are discussed.

Keywords: Revegetation, Land degradation, Kabuqi desert, Mycorrhizaal fungi, Sand and drought tolerant trees.

Introduction

Dry ecosystems occupy over 40% of the earth's land surface (MA, 2005). Due to extreme temperature, intense sun, high winds, limited water and nutrient of dryland soil, the ecosystem is easily damaged and is subject to continuous degradation. In addition to the effects by global warming, human activity such as overgrazing by domestic animals (34.5%), deforestation (29.5%), and over cultivation for agriculture (28.1%) are the main causes of the land degradation in drylands (UNEP, 1997). Following the destruction, surface soil loss by water erosion, wind erosion, and salinization proceed. Percentages of dominant degradation type are water erosion (45.1%), wind erosion (41.8%), and chemical deterioration (9.7%), and physical deterioration (3.4%) (UNEP, 1997). Once the surface soil is lost, it is difficult for the land to recover by itself because most of the limited resources such as nutrient, seeds, and microorganisms exist in surface soil (Charley and West, 1975; Bainbridge 2007). Loss of microorganisms leads to the reduction of soil function such as nitrogen and carbon cycling. Therefore, an active addition of plants and microorganisms is needed for the restoration of the degraded ecosystems.

Restoration with trees can be achieved at low cost and with high efficiency, so many trials for restoration via revegetation have been conducted in the world. The most severe problem of revegetation is the establishment of seedlings. So, stress tolerant monoculture of such trees as poplar and black locust was selected in drylands of China from the viewpoint of growth rate, drought tolerance and availability of seedlings. Regarding the establishment, the tree selection was successful. But problems arose regarding damage by diseases and insects and lowering of water table. Also, the introduced species like mesquite (*Prosopis* spp.) may expand to the unexpected regions and cause the problem of invasion (Shackleton *et al*., 2014).

Desertification and restoration in China

In China, 2,636,200 km^2 (27.5% of China's land area) is degraded (State Forestry Administration, P. R. China, 2009). The degree of desertification was estimated as light (23.9%), moderately (37.4%), severe (16.4%), and extremely severe (22.2%). The most severe cause of the land degradation was wind erosion (69.8%), and it was followed by the freeze-thaw process (13.8%), water erosion (9.8%), and salinization (6.6%) (State Forestry Administration, P. R. China, 2009). The factors causing the land degradation are overgrazing by domestic animals, over cultivation for agriculture, and deforestation like in the other drylands. To improve the situation, revegetation has been encouraged in China since 1970's, and the forest area in China has increased from 8.6% in 1949 to 18.2% in 2005. Nowadays, the yearly revegetated area has become more than the degraded area, and degraded land is decreasing year by year in most provinces. However, 2,636,200 km^2 (27.5% of China's land area) of degraded land and needs further revegetation.

Tree selection for sustainable revegetation

Revegetation is one of the effective options to recover the degraded ecosystems. So revegetation is conducted in many countries to combat desertification. The revegetation has consequences concerning improvement of environments and usage for human life. Preventions of water erosion, soil erosion, and salt accumulation, developing wind control forests, and the creation of shading lead to improvement of environments. And the use of wood, charcoal, fruits and seeds are the examples of usage. To clarify the purpose for revegetation is very important to realize the successful and sustainable restoration. Also, it is important to select trees that are suitable for the target environments. The most important point for the tree selection is to consider the available water in the region. The choice of shrubs and grass species is also to be considered when the available water is not enough for the plantation of tree species. Soil factors are also important to be considered and sandy soil may have the problem of drought and moving sand, and salt accumulation sites have the problem of high salinity stress for plants. Therefore, use of stress tolerant species in the target region is necessary. In addition, one perspective of tree selection is the use of native tree species in the target sites. This will also promote conservation of biodiversity and native ecosystems. In China, policy for forest management has changed from wood production to ecosystem conservation in 2002, and the knowledge on the selection of suitable tree selection appears to be important.

Use of mycorrhizal fungi for revegetation

Mycorrhizal fungi are the fungi that form mycorrhiza with plant roots. Mycorrhizas were classified into seven types, namely, arbuscular mycorrhiza, ectomycorrhiza, ectendomycorrhiza, arbutoid mycorrhiza, monotropoid mycorrhiza, ericoid mycorrhiza, orchid mycorrhizal fungi (Smith and Read, 2008). In the seven types of mycorrhizal fungi, arbuscular mycorrhiza and ectomycorrhiza are the dominant mycorrhizal types in arid and semi-arid ecosystems. Both types collect nutrient such as nitrogen and phosphorus from soil and supply them to host plants. On the other hands, host plant supplies the 10-30% of net photosynthates to the fungi. So the relationship between mycorrhizal fungi and host plants is symbiotic. By mycorrhizal symbiosis, not only nutrient uptake but also plant growth, disease resistance, drought tolerance, and salinity tolerance has been reported to be enhanced (Smith and Read, 2008). Also, the soil aggregation is enhanced by the supply of polysaccharides and glomalin-related soil protein (Rillig and Mummey, 2006).

Based on its function, mycorrhizal fungi has been reported to be used for revegetation (Herrea *et al*., 1993; Castellano 1996; Caravaca 2002). Representative inoculum sources of mycorrhizal fungi are commercial products, soil containing mycorrhizal fungi, and spore from sporocarps. Commercial products are easily used by addition to the soil around roots or nursery soil. But it is expensive to use on a large scale, and the use is still limited to developed countries in Europe and North America (Parent and Moutoglis, 2009). More reasonable methods are the inoculation with spore or soil. For inoculation with soil, it is recommended to collect surface soils from the good forests consisting of the target tree species (Lamhamedi *et al*., 2009). Then, it is reported that the addition of 10-20% of soil to the original soil will be effective. When the inoculation is successful, mycorrhizal colonization is observed in around one month. However, the soil method does not assure whether the effective mycorrhizal fungal species colonize the target plants or not. In addition, some pathogens may also come with the soil inoculation. Therefore, the more promised method is to use spores from sporocarps. This method is just available for ectomycorrhizal fungal species because arbuscular mycorrhizal fungi do not form mushrooms. As ectomycorrhizal fungal species, high functional and high spore productive species such as *Pisolithus* spp. and *Rhizopogon* spp. are frequently selected and used.

Revegetation trial in Kubuqi desert

Kubuqi desert is the seventh largest desert in China located in northern part of Ordos Plateau, Inner Mongolia (Figure 1). The desert extends 262 km from east to west, and the total area is 18,600 km^2. The desert is in temperate continental climate, and the average temperature is 24ºC in June and -11ºC in January. Annual precipitation is 150-400 mm, and the most of the rainfall is in summer. More detail of the site environments is described in Miyazaki *et al*. (2014a) and Izumi *et al.* (2015). Kubuqi desert consists of a series of moving sand dunes and is expanding year by year. The desert is one of the source regions of Asian dust and revegetation for the prevention of desertification is needed. Revegetation in Kubuqi desert started in 1998 and the area has reached 200 km^2.

Figure 1. Location of Kubuqi desert in China.

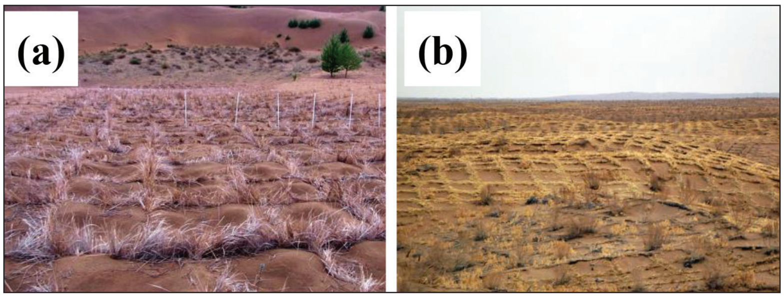

Figure 2. (a) Straw checkerboard established in Kubuqi desert, (b) Revegetation with straw checkerboard in Minchin, Lanzhou

In the desert, we conducted the revegetation trial to evaluate the adequate tree species for the revegetation and effectiveness of mycorrhizal fungi in this site. Before planting, straw checkerboard was established to stabilize the moving sand (Figure 2). This method is known as developed by Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Science in 1950's. It's a kind of sand prevention fence and developed to preserve the road and railway from blown sand. Briefly, straw, the branch of trees, or stem of grasses are buried into sand in a line and make 1 x 1 or 2 x 2 m^2 quadrats with aboveground stump height of 20-30 cm. By the straw checkerboard, wind speed at the height of 50 cm decreased by 20-40%. The amount of sand shifted in straw checkerboard was estimated as approximately 1% (Zhu *et al*., 1988). After the establishment of the straw checkerboard, six tree species frequently used for revegetation (two *Pinus* species (*P. sylvestris*, *P. tabulaeformis*), two *Salix* species (*S. babylonica*, *S. psammophila*), and two *Populus* species (*P. alba*, *P. simonii*)) were planted. *Pinus* species were planted as seedlings. *S. babylonica* and *Populus* species were planted as cuttings with roots. *S. psammophila* was planted immediately after preparing the cutting from the branch of matured trees. To evaluate the effectiveness of mycorrhizal fungi, soil containing ectomycorrhizal fungi was collected from plantation site and added to the soil around *P. tabulaeformis* roots.

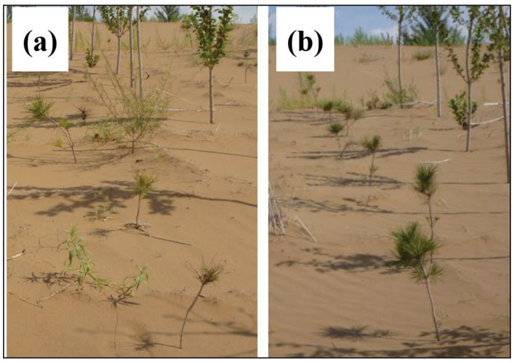

Figure 3. (a) Pine seedlings with no additional soil, (b) Pine seedlings with additional soil including ectomycorrhizal fungi

After 2 years, survival rates were higher than 50% except for *P. sylvestris*. This is because the rainfall of the year of planting was higher compared to usual years. Tree growth was higher in *S. babylonica*, *S. psammophila*, and *P. simonii*. Interestingly, the growth of *P. simonii* was enhanced by sand burial (Miyazaki *et al.* 2014b). The fast plant growth is a very important character to avoid sand burial in the moving sand dune. As osmolyte, betaines and sugars, and sugar alcohol were examined. *P. alba*, *S. babylionica*, and *S. psammophila* accumulated high amounts of beta-alanine betaines compared to the other tree species (Izumi *et al*., 2015). The contents of total sugar and total sugar alcohol were higher in *P. simonii* and *S. babylionica*. The results indicated that drought stress tolerance via osmoregulation seems to be controlled by these chemicals, and the dependency of each tree species to each osmolyte was different. For mycorrhizal inoculation test, mycorrhizal colonization and growth of *P. tabulaeformis* were enhanced by addition of soil including mycorrhizal fungi (Figure 3). As the conclusion of our revegetation trial, *P. simonii*, *S. babylonica*, *S. psammophila* are suitable for the revegetation in Kubuqi desert. In addition, the combination with mycorrhizal fungi was effective in such moving sand dune.

Conclusions

In our revegetation experiments in Kubuqi desert, China, *P. simonii*, *S. babylonica*, *S. psammophila* were found as suitable tree species. The growth rate of these tree species was very fast and the ecological character appears to be adaptive to establish in moving sand dune. Also, soil inoculation containing mycorrhizal fungi was effective for the mycorrhizal colonization and growth of pine species. The use of adequate tree species with mycorrhizal fungi may enhance the establishment and revegetation effectiveness.

Acknowledgement

We especially thank Prof. Theib Oweis for valuable comments on the constitution of the manuscript.

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Presentations in Concurrent Sessions

Theme 1. Application of new technologies for the improvement of stress (drought, heat, cold and salinity) resistance of crops for dry areas

1. Wheat breeding for multiple stress tolerance at ICARDA: Achievements and prospects

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Abstract

Wheat is the principal food crop in Central and West Asia and North Africa (CWANA) region with an average consumption of 200 kg/capita/year. The productivity of wheat in the region is very low (2.5 t/ha) principally because of t drought, heat and stripe rust among others. In the year 2050, the CWANA population is expected to increase from the current 0.9 billion to 1.4 billion, and the demand for wheat will rise from the present 164 million tons to 268 million tons. Fulfilling this demand is challenging especially in the face of climate change where its effects are predicted to be more pronounced in the CWANA region. The wheat breeding program at ICARDA has developed high yielding wheat genotypes with increased water-use efficiency, heat tolerance and resistance to major diseases and pests following inter-country shuttle breeding and key location testing approaches. Some of the elite genotypes yielded up to 2.5 and 11 t/ha under drought (250-300 mm) and irrigated/optimum rainfall (550 mm) conditions, respectively. Major genes for resistance to stem rust and yellow rust have been deployed. Most of the elite genotypes have protein levels of 12 to 16% with the 5+10 (Glu-D1), 7+8 (Glu-B1) and 2* (Glu-A1) alleles. Molecular markers linked to heat tolerance and yellow rust resistances have been identified. Pedigree analysis showed that resistance sources for heat and drought in such elite germplasm were introgressed from synthetic wheats and wild relatives mainly *T. dicoccoides*. These genotypes have been distributed to the NARS for potential direct release and/or parentage purposes. Rapid deployment of such wheat varieties with improved crop management technologies will help to increase and enhance sustainable wheat production across the CWANA region.

Keywords: Wheat productivity, Drought, Heat stress, Stem rust, Yellow rust

1. Introduction

Wheat is the most favoured staple food crop in the Central and West Asia and North Africa (CWANA) region. The CWANA region is a vast geographic area extending west to east from the Atlas Mountains in Morocco to the fertile irrigated Indus valley in Pakistan, and from the highland, high-rainfall areas of Ethiopia in the south to the temperate and dry northern Kazakhstan. As expected, this vast geographic area is characterized by large variations in agro-ecology, farming systems, moisture, temperature, soil types and cultural practices. In addition, the region harbors all kinds of wild and cultivated wheat types of different growth habits. Based on moisture availability, cropping systems and temperature regimes, the wheat production area in the CWANA region can be classified under five distinct mega-environments (E) namely: (E1) Favorable Irrigated and High Rainfall Spring Wheat Environment of CWANA that covers over 13.0 million hectares; (E2) Semi-arid (Mediterranean Rain-fed) Spring Wheat Environment with about 11.0 million hectares; (E3) Favorable Irrigated Winter/Facultative Wheat Environment that covers an area of 5.4 million hectares.; (E4) Semi-arid Rainfed Winter/Facultative Wheat Environment has an area of Approximately 12.7 million hectares; and (E5) the High Latitude (Spring Planted) Spring Wheat Environment with approximately 8.0 million hectares, all in Northern Kazakhstan (Tadesse *et al.,* 2012a, 2016).

During the period 1961-2013, wheat production area has increased from 26.9 to 54 million ha, while total production and yield (t/ha) have increased from 22 to 122 million tons and from 1.1 to 2.6 t/ha, respectively (Figure 1) (FAO, 2015).

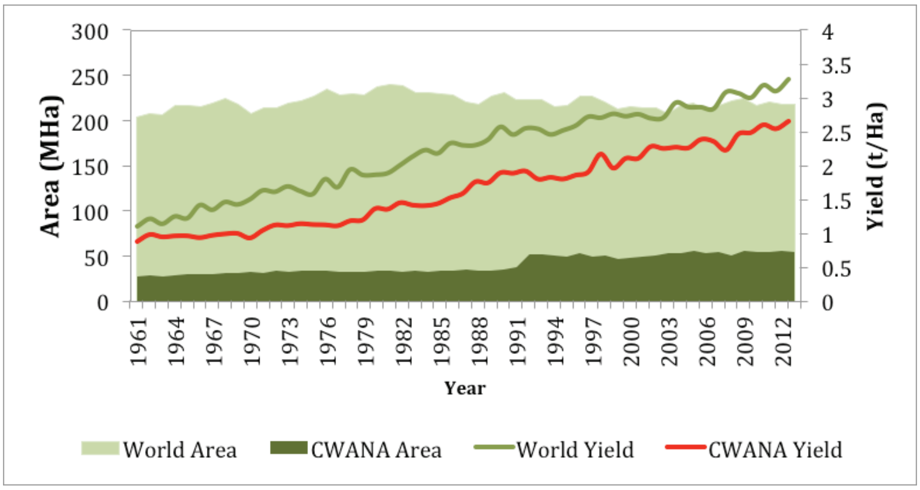


Figure 1. Trends in wheat area and yield at global and CWANA level, 1961-2013 (FAO, 2015).

The increase in production is mainly due to the adoption of improved wheat cultivars originating from the International Maize and Wheat Improvement Center (CIMMYT) and the International Center for Agricultural Research in the Dry Areas (ICARDA), utilization of inputs, better agronomic practices, increased area of production, and favorable policies (Braun *et al*., 2010). The most important wheat growing countries in the region include Kazakhstan (13.7 Mha), Pakistan (8.9 Mha), Turkey (7.9 Mha), Iran (6.8Mha), Morocco (3.0 Mha), Afghanistan (2.4 Mha), Algeria (1.8 Mha), Ethiopia (1.6 Mha), Syria (1.5 Mha), Uzbekistan (1.4 Mha) and Egypt (1.3 Mha). The difference between wheat production and consumption is big in the region through out the years (Figure 2).

Most of the countries in the CWANA region except Kazakhstan, Syria, Pakistan and Turkey are not self-sufficient in wheat production, and accordingly, wheat is their single most important imported commodity. Among North African countries, Egypt is the largest importer with 9 million tons of wheat imported every year. According to Shiferaw *et al.* (2013), demand for wheat is growing at 5.6 % and 2.2 % per year in Central Asia and North Africa, respectively. In the year 2050, the population in CWANA is expected to increase from the current 0.9 billion to 1.4 billion, and the demand for wheat will rise from the present 164 million tons to 268 million tons, calling for more research and development efforts to increase wheat productivity at the regional and global levels (Shiferaw *et al*., 2013).

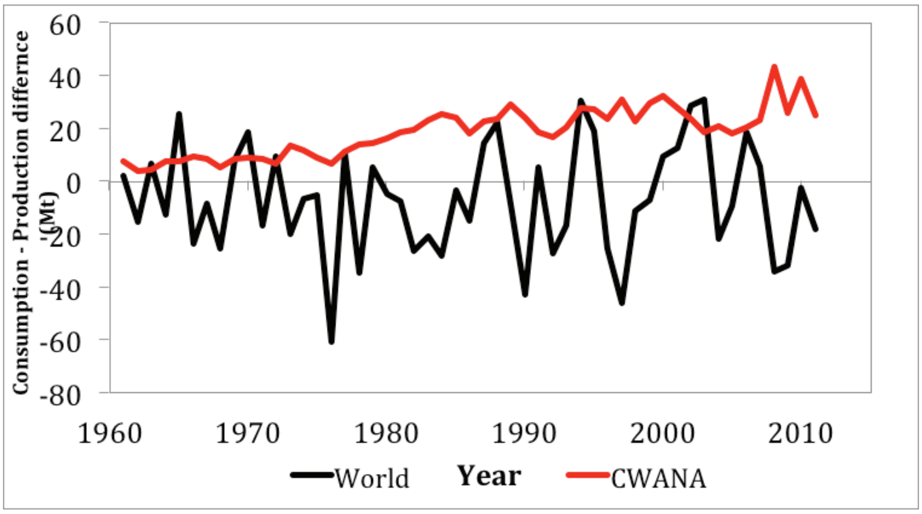


Figure 2. Wheat consumption and production difference at global and CWANA levels, 1961-2011; FAO, 2015.

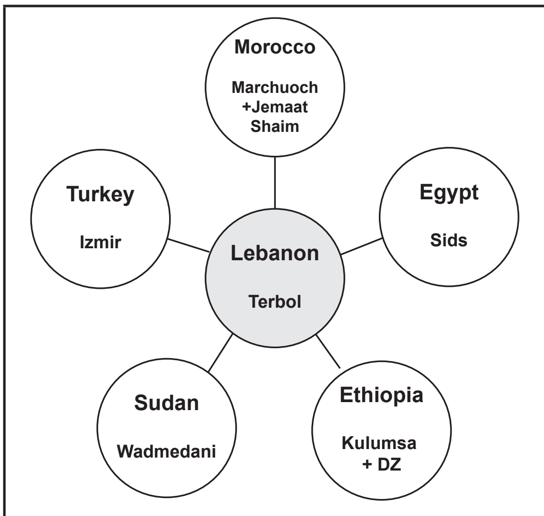
CWANA also hosts some of the most damaging and virulent races of diseases and pests affecting wheat productivity. Farmers are typically required to apply fungicides and pesticides multiple times during the cropping season to avoid near complete losses. These chemical products are often at a premium in the small rural markets of CWANA and their availability far from certain. Furthermore, farmers are rarely trained in the deployment of integrated pest management (IPM) practices; the results of IPM malpractices can be the rapid development of novel races with acquired resistance to the pesticides.

The area under wheat cultivation in North Africa, West Asia, Central Asia and the Caucasus, and the Nile Valley sub-regions is characterized by large variation in agro-ecology, farming systems, moisture, temperature, soil types, races of pests, and cultural practices. In these sub-regions most of rainfed wheat farmers, whose livelihoods solely depend on income from wheat grain, fodder and straw production, live in areas with less than 350 mm of rainfall per annum. Hence, the adverse effects of the harsh climate, poor soil conditions, crop diseases and insects result generally in low and highly variable wheat production. Because of these complexities, it is prudent that international breeding programs take the mega-environment approach and use the shuttle breeding and multi-location yield trial strategy to develop high-yielding genotypes with wide or known specific adaptation. However, biotic and abiotic stresses exacerbated by the impacts of climate change are posing a big threat to the wheat productivity in the region. The effects of climate change are also evident on the quality of wheat as increased heat results in early ageing with shriveled wheat grain and protein degradation.

2. Approaches and strategies of germplasm development at ICARDA

The wheat breeding program at ICARDA applies both conventional and molecular breeding approaches and techniques in order to develop high yielding and widely adapted germplasm with resistance/tolerance to the major biotic and abiotic constraints prevailing in the developing world (Tadesse *et al.,* 2012b; Tadesse *et al*., 2016). Some of these strategies and techniques include classification of Mega-Environments (ME) and assembling of targeted crossing blocks, shuttle breeding, utilization of doubled haploids (DH) and marker assisted selection (MAS), key location yield trials, distribution of germplasm to NARS through international nurseries, and partnership and capacity building of NARS (Tadesse *et al.,* 2016). The spring bread wheat breeding program at ICARDA makes more than 3000 crosses every year. Germplasm generations are segregated and shuttled between Terbol station in Lebanon (F1), Sids station in Egypt (F2), Kulumsa station in Ethiopia (F3) and Merchouch station in Morocco and Terbol station in Lebanon (F4) following the selected bulk selection method.

This is followed by key location yield testing for preliminary and advanced yield trials at Terbol and Kheferdan (Lebanon), Marchouch and Jammatshaim (Morocco), Sids (Egypt), Wadmedani (Sudan) and Izmir (Turkey) and Kulumsa (Ethiopia). This enables to combine yield potential and wide adaptation with resistance to biotic and abiotic stresses.



Marchouch + Jemaat Shaim: Yellow rust, Septoria, drought tolerance, HF resistance

Sids: Yield potential

Izmir: Screening for rusts (Lab +field)

Kulumsa /DZ: Stem rust, yellow rust, septoria, fusarium

Wadmedani: Heat tolerance

Terbol: CB, adaptation, yield potential, rusts, cold, drought (at Kheferdan)

Figure 3. Shuttle breeding strategy adopted by ICARDA to develop improved wheat lines combining high yield, wide adaption, pest and disease resistance and high quality.

Every year, the spring bread wheat program composes and distributes more than 450 elite sets of genotypes in the form of the following international nurseries and yield trials from Terbol station in Lebanon to more than 30 countries in the CWANA and SSA regions and beyond on request from the NARS:

- Spring bread wheat observation nursery for CWANA (CWANA SBWON)
- Spring bread wheat observation nursery for heat tolerance (HT-SBWON)
- Spring bread wheat yield trial for HT(ESBWYT-HT)
- Elite spring bread wheat yield trial (ESBWYT).
- Spring bread wheat yield trial for dry-land environments (CWANA DSBWYT)

3. Variety release by the national programs

The International Wheat Improvement Network (IWIN), an alliance of NARS, CIMMYT, ICARDA, and advanced research institutes (ARIs) have continuously supplied improved wheat germplasm to the national research programs for the last 4 decades which has led to the release and adoption of many wheat varieties by most of the national programs in the developing world. These varieties have enabled developing countries to have a sustained increase of wheat production and productivity, and thereby improved food security and farmers' livelihoods (Dixon *et al.,* 2009;Bayerlee and Dublin, 2010; Payne, 2004). Predominantly, the agricultural research institutes and agricultural universities of the respective countries carry out wheat breeding in the CWANA region. Some of the strong research institutes and universities have reasonable number of research centers, sub centers and testing sites addressing the major agro-ecologies of the country. However, even in these institutes and centers, the research facilities and manpower are limited, posing a major problem across the region. In spite of these challenges and constraints, the national breeding programs have been operating diligently to develop high yielding wheat cultivars with resistance/tolerance to the major biotic and abiotic constraints prevailing in the different agro-ecologies of each country.

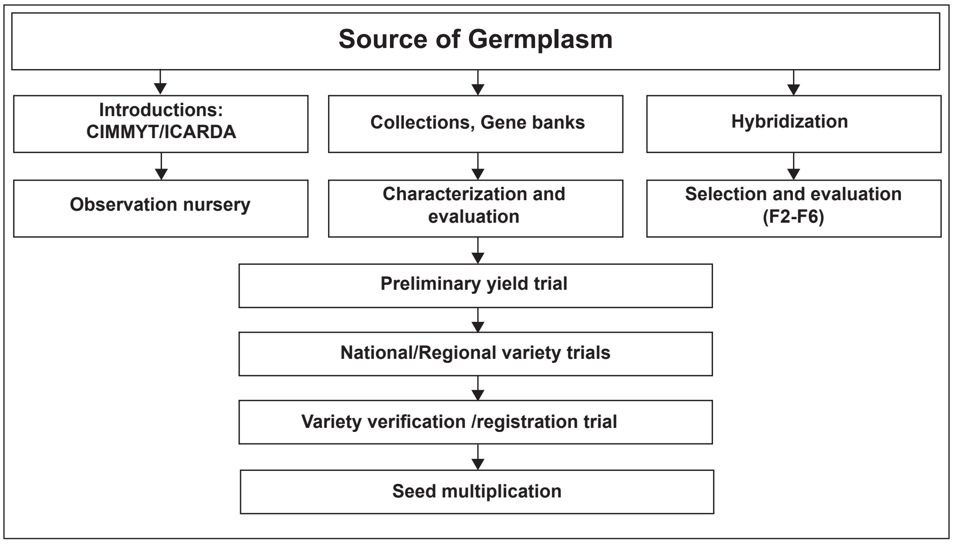


Figure 4. Germplasm acquisition and evaluation scheme in the national breeding programmes.

The general procedure of germplasm acquisition, development, evaluation and release is outlined in Figure 4, with slight modification at country levels. The national wheat research coordinating center of each country requests international wheat nurseries from ICARDA and CIMMYT, and grows the nurseries for further evaluation and selection either for direct release or parental purposes. Fixed germplasm obtained from the international centers or from the national programs is evaluated across locations in preliminary yield trial (PYT) for 1 year followed by national/regional variety trials (NVT/RVT) across locations for 2 years. Breeders need to apply for variety registration/release by submitting 2 years of the NVT/RVT data across locations along with the candidates and check cultivars performance. After submission confirmation, the best 2-3 candidate cultivars along with local and recent check cultivars are promoted into variety verification/

registration trial (VVT) in which each variety is planted on 10m x 10m non replicated plots for 1 year both on station and on farm. A technical committee evaluates the material at grain filling stage for resistance to diseases, maturity, yield potential and farmers preference. The committee reports its assessment to the National Variety Release Committee, which makes decision to release or reject or repeat the variety verification trial. Upon acceptance/release, 50-100 kg of breeder seed should be submitted to the national/regional seed enterprises for multiplication of pre-basic, basic and certified seed. Following these procedures, national programs have released many cultivars in the last 5 years (Table 1).

Table 1. List of ICARDA-origin bread wheat varieties released by the national programs of the CWANA and SSA regions from 2011-2016

Variety Name	Cross/Pedigree	Selection History	Year of Release	Country
HOGGANA	PYN/BAU//MILAN (= ETBW 5780)	CMSW94WM00188S-0300M-0100Y-0100M-15Y-8M-0Y-0IAP-0QTAP-0YT	2011	Ethiopia
SHORIMA	UTQE96/3/PYN/BAU//MILAN	ICW02-00330-4AP/0TS-0AP-030AP-10KUL-030KUL-0AP/0KUL-0DZ/0AP	2011	Ethiopia
KARIM	T.AEST/SPRW//CA8055/3/BACANORA86	ICW92-0477-1AP-1AP-4AP-1AP-0AP	2011	Iran
GOUMRIA-3	VEE#7/KAUZ	ICW94-0029-0L-1AP-1AP-7AP-0APS-0AP-0SD	2013	Sudan
NORMAN	OR F1.158/FDL//BLO/3/SHI4414/CROW	ICWH860291-3AP-1AP-0AP-1AP-0AP	2007	Tajikistan
GIZIL BUGDA	SAULESKU41/SADOVO1	TCI950295-3AP-0AP-0E-1YE-0YE-1YM-0YM	2009	Azerbaijan
NARC-2011	OASIS/SKAUZ//4*BACANORA-88/3/2*PASTOR	CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S	2011	Pakistan
MUQAWIM 09	OASIS/SUPER-KAUZ//4*BACANORA-88/3/2*PASTOR	CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S	2009	Afghanistan
SUPER 152	PFAU/SERI.1B//AMAD/3/WAXWING	CGSS02Y00153S-099M-099Y-099M-46Y-0B	2011	India
MISR 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	CMSS00Y01881T-050M- 030Y-030M-030WGY-33M-0Y- 0S	2010	Egypt
Sandal-4	CLEMENT/ALD'S'//ZARZOUR/5/AU//KAL/BB/3/BON/4/KVZ//CNO/PJ62	ICW99-0181-2AP-0AP-0AP-22AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP	2015/16	Eritrea
Quafza-3	SHA5//CARC/AUK/3/VEE#5//DOBUC'S'	CMSS93Y00621S-0AP-4AP-1AP-3AP-0AP	2015/16	Eritrea
Sidraa-1	GV/ALD'S'/5/ALD'S'/4/BB/G11//CNO67/7C/3/KVZ/TI/6/2*TOWPE	ICW00-0629-1AP-0AP-0AP-16AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP	2015/16	Eritrea

Variety Name	Cross/Pedigree	Selection History	Year of Release	Country
Jawahir-3	SHUHA-4//NS732/HER	ICW97-0410-4AP-0APS-0AP-3AP-18AP-0AP	2015/16	Eritrea
GOUMRIA-3	VEE#7/KAUZ'S'	ICW94-0029-0L-1AP-1AP-7AP-0APS-0AP	2015/16	Eritrea
Obora	UTIQUE96/FLAG-1	ICW02-00330-4AP/0TS-0AP-030AP-9KUL-030KUL-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP-0SIN-0ET	2015/16	Ethiopia
Dambal	AGUILAL/3/PYN/BAU//MILAN	ICW02-00295-22AP/0TS-0AP-030AP-3KUL-030KUL-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP-0SIN-0ET	2015/16	Ethiopia
Fentale	FERROUG-2/FOW-2	ICW98-0031-3AP-0APS-030AP-21AP-5AP-0AP-0SDN-0WR-0ET	2015/16	Ethiopia
Amibara	SHUHA-8/DUCULA	ICW99-0386-22AP-0AP-0AP-20AP-0AP-0SDN-0WR-0ET	2015/16	Ethiopia
LACRIWHIT-7	CROW'S'/BOW'S'-3-1994/95//TEVEE'S'/TADINIA	ICW01-00260-0AP-6AP-0AP/0TS-0AP-8AP-12AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP-0SDN/0SD -0NGA	2015/16	Nigeria
LACRIWHIT-8	REYNA-15 = CHAM4/SHUHA'S'/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S"	ICW00-0634-6AP-0AP-0AP-10AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP-0SDN/0SD -0NGA	2015/16	Nigeria
Shalkot-14*	Babagha-10=TRACHA'S'//CMH76-252/PVN'S'	ICW93-0065-6AP-0L-3AP-0L-1AP-0AP-0PAK	2015/16	Pakistan
Reyna 28	CHAM-4/SHUHA'S'/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S'	ICW00-0634-6AP-0AP-0AP-7AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP	2015/16	Mali
Reyna 28	CHAM-4/SHUHA'S'/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S'	ICW00-0634-6AP-0AP-0AP-7AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP	2015/16	Niger
Reyna 28	CHAM-4/SHUHA'S'/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S'	ICW00-0634-6AP-0AP-0AP-7AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP	2015/16	Mauritania

4. Current performance of ICARDA's elite spring bread wheat genotypes under multiple stresses

Identification and development of wheat cultivars combining high yield potential with better water use efficiency and heat tolerance can help stabilize yield gains in the face of drought, heat stress and climate change. The development of wheat cultivars with high early vigour and cold tolerance has been a major target of wheat breeders in dry land areas, as early and complete canopy establishment shades the soil surface and reduces evaporative loss from the soil, thereby significantly improving water productivity of wheat. High yielding and drought tolerant spring wheat genotypes with resistance to rusts, including the UG99 race, have been identified from ICARDA's breeding program after evaluation across key locations (Table 2). Pedigree analysis showed that most of them contain synthetic hexaploid wheats (SHWs) while others possess *T. dicoccoides* in their background. Some of these genotypes have deep green leaves with early vigour and 'stay green' characters.

Table 2. Performance of elite bread wheat genotypes across key locations in Egypt, Sudan and Morocco, 2013/14

Variety	Marchouch (Morocco) (t/ha)	Sids (Egypt) (t/ha)	Wad Medani (Sudan) (t/ha)	Average (t/ha)	% of the check (Attila-7)
IBW-IMAR	7.11	11.62	3.23	7.32	119%
IBW-AMAL	6.49	12.72	2.50	7.24	118%
IBW-HAMID	7.13	9.56	3.77	6.82	111%
IBW-WAHID	7.31	10.16	2.92	6.80	111%
IBW-BRIVAN	8.98	7.81	3.05	6.61	108%
IBW-FARID	6.39	10.23	3.03	6.55	106%
IBW-OMAR	6.96	9.72	2.65	6.45	105%
IBW-AKID	6.50	9.87	2.94	6.44	105%
IBW-WIDAD	6.51	8.46	3.87	6.28	102%
IBW-TARTUS	5.89	9.39	3.40	6.23	101%
Sids-1 (Check)	5.36	10.88	2.35	6.20	101%
Attila-7 (Check)	6.19	8.40	3.86	6.15	100%
Pastor-2 (Check)	6.24	7.49	3.42	5.72	93%

In most developing countries, apart from grain yield, disease resistance and drought/heat tolerance, and grain quality have not been a strong criterion in variety selection. However, some NARS are beginning to critically look for high-quality cultivars suited for the preparation of a range of products. Cultivars such as Anza, Bezostaya, HD1220 and Pavon-76 are known for their excellent bread-making quality. These cultivars are still predominant in some countries not only because of their wide adaptation, high yield potential and stability, but also because of their high protein content and bread-making quality. With this understanding, the wheat breeding programs at ICARDA and CIMMYT routinely undertake evaluation of germplasm for quality traits using international standard grain quality procedures. The quality of most of the currently available elite genotypes for both irrigated and rain-fed environments ranges from acceptable to excellent, with protein levels of 12 to 16%. Most of these genotypes have the 5+10 (Glu-D1), 7+8 (Glu-B1) and 2* (Glu-A1) glutenin subunit alleles, which are known to be highly correlated with superior protein quality.

5. Looking forward

Exploring adaptive genes from genetic resources: Genetic resources remain a major source of genes to overcome the major biotic and abiotic stresses and for improving further the quality and nutritional attributes of wheat. It is important to continue mining and utilization of these resources using improved tools such as the Focused Identification of Germplasm Strategy (FIGS) and genotype by sequencing (GBS) approaches.

Rapid development and deployment of high-yielding varieties that are heat and drought tolerant, along with improved crop management technologies, such as conservation agriculture, water harvesting, drip irrigation, and site-specific nutrient management will help enhance sustainable wheat production across the CWANA region. To make the wheat genetic improvement efforts sustainable, it is vital to have well-trained young scientists in the National Agricultural Research Systems (NARS). ICARDA has established an annual wheat improvement course in which junior and mid-career NARS scientists undergo a hands-on training/experience and a comprehensive hands-on course on breeding for durable disease resistance, high yield potential and stability, drought and heat tolerance, end-use quality, and seed health issues, using conventional and molecular tools.

Integrated Pest Management (IPM) is a sustainable approach to managing pests such as weeds, diseases and insects by combining cultural, physical, chemical and biological tools in a way that minimizes economic, health and environmental risks. This diverse approach has the potential to substantially reduce the use of chemicals, while providing a high level of effective pest management. However, IPM programs require a higher degree of awareness creation among the policy makers and extension agents and commitment from them in order to implement and promote IPM packages at farm level.

Efficient and effective seed delivery systems are critical for new crop varieties to reach farmers and bring meaningful impact. Many national seed systems in the developing countries are weak and operate under heterogeneous agro-ecological farming systems and market environments. They also face a broad range of constraints such as poor policy and regulatory frameworks; inadequate institutional and organizational arrangements; deficiencies in production, processing, and quality assurance infrastructure; poorly trained personnel, and limiting technical and managerial capacities, compounded by farmers' difficult socio-economic circumstances. It is therefore crucial to assist and strengthen NARS in managing a strong seed system through capacity development, establishing fast-track variety release systems, participatory demonstrations and accelerated seed multiplication of newly released wheat varieties to ensure fast replacement of existing vulnerable commercial varieties.

With increasing incomes of many global consumers, the demand for specific wheat quality attributes and products is increasing. This creates a differentiation of wheat products in markets, based on visible or non-visible characteristics and opens the possibility of adding value to the wheat industry, creating extra employment along value chains, and increasing farm gate prices. The willingness to pay premium price for high quality wheat encourages farmers to grow wheat varieties with known quality profiles and reasonably good yield potential. In this regard, it is noteworthy that it is possible to improve the nutritional value of wheat by introgressing genes for high quality proteins and micronutrients such as iron and zinc. This effort, however, requires investment in research, institution capacity building for varietal classification, grading into different wheat classes, and raising public awareness.

For sustainable wheat production, favorable and conducive government policies play an important role. Government subsidies to agricultural inputs such as improved seed, irrigation water, and chemicals encourage farmers to adopt improved technologies and increase production. Furthermore, creation of adequate infrastructures and marketing systems is of paramount importance for having a successful and competent wheat industry at national and regional levels. The International Wheat Improvement Network (IWIN) has been a successful and efficient network for distributing globally new wheat genotypes. Such a network could be strengthened by widening partnerships and collaboration, in order to develop, disseminate, and market more productive, stress tolerant, and nutritive wheat varieties, and to perfect and promote production practices, based on the principles of conservation agriculture, which boost yields while conserving or enhancing critical resources like soil and water.

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2. Genome-wide association study of adaptive traits under high temperature environments

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Abstract

Heat stress has become a major threat to international food security in bread wheat (*Triticum aestivum* L.). Genetic variation for heat tolerance-adaptive traits is limited in the elite wheat germplasm, whereas in the secondary gene pool, considerable genetic variability for heat tolerance has been found in both *Aegilops tauschii* and *T. turgidum*. Recently Multiple Synthetic Derivatives (MSD) population possessing large variation of *Ae. tauschii* has been developed. This study aimed to identify QTLs/genes associated with heat stress-adaptive traits. We conducted a genome-wide association study (GWAS) using 15,616 DArT-seq and SNPs markers across 400 MSD population lines. Phenotyping was carried out under heat stress in Sudan at three locations. The 400 lines showed considerable genetic variation in most of the traits studied. Several lines were earlier than the check cultivar 'Norin 61' and others showed low canopy temperature. Three QTLs were identified for days to heading on chromosomes 2A, 2B and 2D. Two QTLs were detected for growth habit on chromosomes 2D and 5D. Two QTLs were identified for canopy temperature at heading stage on chromosomes 2A and 2D. In heading trait, the associated genes might be the photoperiod alleles *Ppd-A1, Ppd-B1* and *Ppd-D1*. The variation observed and QTLs detected in this population could be useful for wheat breeding and improvement for heat stress tolerance. This population could be evaluated for other abiotic stresses such as salinity and drought.

Keywords: Wheat, Heat stress, QTLs, Multiple Synthetic Derivatives (MSD)

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important food crops in the world. Its productivity is often reduced by both biotic and a biotic stresses, and heat stress is one of the major constraints. However, genetic variation for heat stress tolerance is limited in the elite wheat germplasm. Because wild species in the secondary gene pool *(Aegilops tauschii* and *T. turgidum*) have considerable genetic variability for potentially adaptive traits, increased biomass, total photosynthesis and thousand-kernel weight, those should be exploited in wheat breeding (Gill *et al.,* 2008; Halloran *et al.,* 2008; Lopes *et al*., 2015).

Many scientists are using a few wild relatives and synthetic wheats (SW) in breeding program; this limits the diversity of germplasm or, in others words, there will be few good genes coming from few lines. Tsujimoto *et al*. (2011) produced Multiple Synthetic Derivative (MSD) populations by crossing 43 synthetic wheat (SW) with ‘Norin 61’ (Japanese spring wheat variety). Synthetic wheat is the amphidiploid between *T. turgidum* var. *durum* cv. ‘Langdon’ and 43 accessions of *Ae. tauschii* collected from whole distribution of this species. Paliwal *et al.* (2012) reported that plant biomass, harvest index, thousand kernel weight, grain filling duration, grains per m^2, spikes per m^2 and canopy temperature can be used as selection criteria for heat stress.

QTL mapping is a key approach for understanding the genetic architecture of complex traits in plants (Holland, 2007). In wheat, classical QTL mapping locates genomic regions of the QTLs that originated from both parents crossed to produce the segregation population (Navakode *et al*. 2014) and hence this study. As a complement to this QTL mapping, genome wide association studies (GWAS) provide a powerful approach for identifying genetic markers associated with complex traits of interest (Lopes *et al*., 2014; Risch and Merikangas, 1996). However, GWAS for spring wheat are limited and represent a challenge due to the large genome, incomplete genome sequence, and hexaploidy, which make it difficult to assign the markers to individual (A, B and D) genomes (Sukumaran and Yu, 2014).

In this study, we used 400 MSD lines genotyped with 68,516 silico-DArT and SNPs markers to identify new source of germplasm for heat tolerance and to identify markers associated with heat tolerance-related traits using GWAS. We identified several promising lines and QTLs, which can be used to breed well adapted heat tolerant wheat cultivars.

Materials and methods

Plant material and phenotyping

We used 400 plants selected randomly from MSD population (Tsujimoto *et al.,* 2011) developed from crosses between ‘Norin 61’ (N61, Japanese spring wheat variety) and 43 SW lines (Matsuoka *et al.,* 2013). These lines in addition to their parent N61, two Sudanese varieties (‘Imam’ and ‘Gomeria’) and an Afghanistan landrace ‘Safedak Ishkashim’, were evaluated in three different environments in Sudan using Augmented Randomized Complete Block Design. The three environments represent gradient temperatures from low or optimum in Dongola (DON, 19°08′N, 30°27′E, 239 masl) in Northern State, Hudeiba (HUD, 14°40′N, 33°50′E, 409 masl) in River Nile State, and to high temperature in Wad Medani (MED, 14°24′N, 29°33′E, 407 masl) in Gezira State. In MED we used two planting dates, optimum and late planting (4th week of November and 2nd week of December, respectively).

The seeds were treated with imidacloprid (35% WP) at 1g/kg seeds to control pests, mainly termites and aphids. The seeds were sown manually at 120 kg ha^{-1}. Each line was sown in a plot of four rows, 0.5 m long and 0.2 m apart. Superphosphate as a source of phosphorus was applied by furrow placement before sowing at 18.8 kg P/ha. Urea as the nitrogen source was split-applied at the three-leaf stage (second irrigation) and the tillering stage (fourth irrigation) at 86 kg N/ha. Irrigation was applied every 10–12 days. The fields were hand-weeded at least twice.

We evaluated three phenotypic traits including growth habit, days to heading and canopy temperature at heading stage. Metrological data, in particular, the weekly maximum, minimum and mean temperatures, during the cropping season were obtained from metrological stations located at the three experimental sites (Figure 1A, 1B, 1C). Analysis of variance was carried out using Plant Breeding Tools software (PBTools, version 1.4. 2014).

Genotyping

DNA extraction was carried out according to CTAB procedure Saghai-Maroof *et al.* (1984). Two µg of total genomic DNA in 20 µl from each sample was sent to Diversity Arrays Technology Pyt. Ltd, Australia (http://www.diversityarrays.com/) as a commercial service provider for whole genome scan using DArT-seq markers. Totally, 68,516 DArT markers were used to genotype the 6 synthetic wheat derivatives with their recurrent parents N61 and their synthetic wheats.

Results

Phenotypic evaluation

Weekly maximum, minimum and mean temperatures during the cropping season at the three sites are given in (Figure 1A, 1B, 1C). Temperature in the second planting date was higher than in the first planting date at MED. The temperature at MED was higher than DON and HUD (Fig. 1A, 1B, 1C). The high temperature of the second planting date in MED reduced the mean of all traits studied (Table 1).

The genotypic effect was significant for all traits studied at the three sites except tillers number per plant at DON (Table 1). The frequency distribution of MSD population for growth habit 14.7 %, 18.4%, 21.7%, 22.2 and 23.0% were erect, semi erect, intermediate, semi prostrate and prostrate, respectively. The days to heading (DH) of N61 were 63 and 62 under optimum planting and late planting at MED, respectively (Table 1). The DH of MSD population ranged from 53 days to 126 days under optimum planting and from 50 days to 111 days under late planting (Table 1). We observed 93 genotypes were earlier than N61 under optimum planting, whereas under late planting we found 90 and 228 genotypes earlier than N61 and Imam, respectively. DH of the MSD lines ranged from 62 to 104 days and from 54 to 119 days at DON and HUD, respectively (Table 1). At DON we observed 83 genotypes were earlier than N61, the 157 genotypes earlier than the other checks and 21 genotypes later than the latest check. DH of the MSD lines ranged from 54 to 119 days at HUD, furthermore 72 genotypes had earlier heading than N61 (Table 1).

The canopy temperature at heading stage (CTdh) was cooler in optimum planting (12.4−29.6 °C) than in late planting (10.5−34.9 °C) at MED (Table ١) and under late planting, 25.5% of the MSD population had a cooler canopy than the cooler check N61.

The tiller number per m^2 (TN) ranged from 175 to 995 and from 125 to 860 under optimum and late planting at MED, respectively (Table 1). A total of 145 and 140 MSD genotypes had more TN than N61 under optimum and late planting, respectively. The TN at DON ranged from 187 to 797; furthermore, we observed 86 genotypes had the higher TN than N61. On the other hand the TN ranged from 100 to 487 at HUD, and, furthermore, we found 50 genotypes had higher TN than N61 (Table 1).

Table 1. Growth habit (GH), days to heading (DH), canopy temperature at heading stage (CTdh) and tiller number per m^2 (TN) of the MSD population and their parent N61 plus three checks for heat stress tolerance at optimum planting (OP) and late planting (LP) at Gezira Research Farm, Wad Medani (MED), Dongola Research Farm, Dongola (DON) and Hudeiba Research Farm, Hudeiba (HUD), Sudan season (2015/2016)

Check	GH	DH				CTdh		TN			
		MED OP	MED LP	DON	HUD	MED OP	MED LP	MED OP	MED LP	DON	HUD
Norin 61	1	63	62	72	61	15.1	18.3	488	398	464	252
Gomeria	3	63	65	75	68	15.3	18.1	393	426	445	212
Imam	2	72	70	78	73	16.7	19.0	386	448	470	252
Safedak	2	100	100	95	96	28.1	31.7	465	514	508	320
Range	1–5	53–126	50–111	62–104	54–119	12.4–29.6	10.5–34.9	70–995	125–860	187–797	100–487
Mean	3.0	76.0	72.0	79	71	18.9	20.9	463.0	379.0	448	209
G	*	***	***	***	***	***	***	***	*	NS	***
SE	1.3	4.0	3.7	5.3	1.8	4.4	3.6	119.8	224.8	115.1	59.4

G, genotypes. NS, not significant. *, *** Significant at the 0.05 and 0.001 probability levels, respectively.

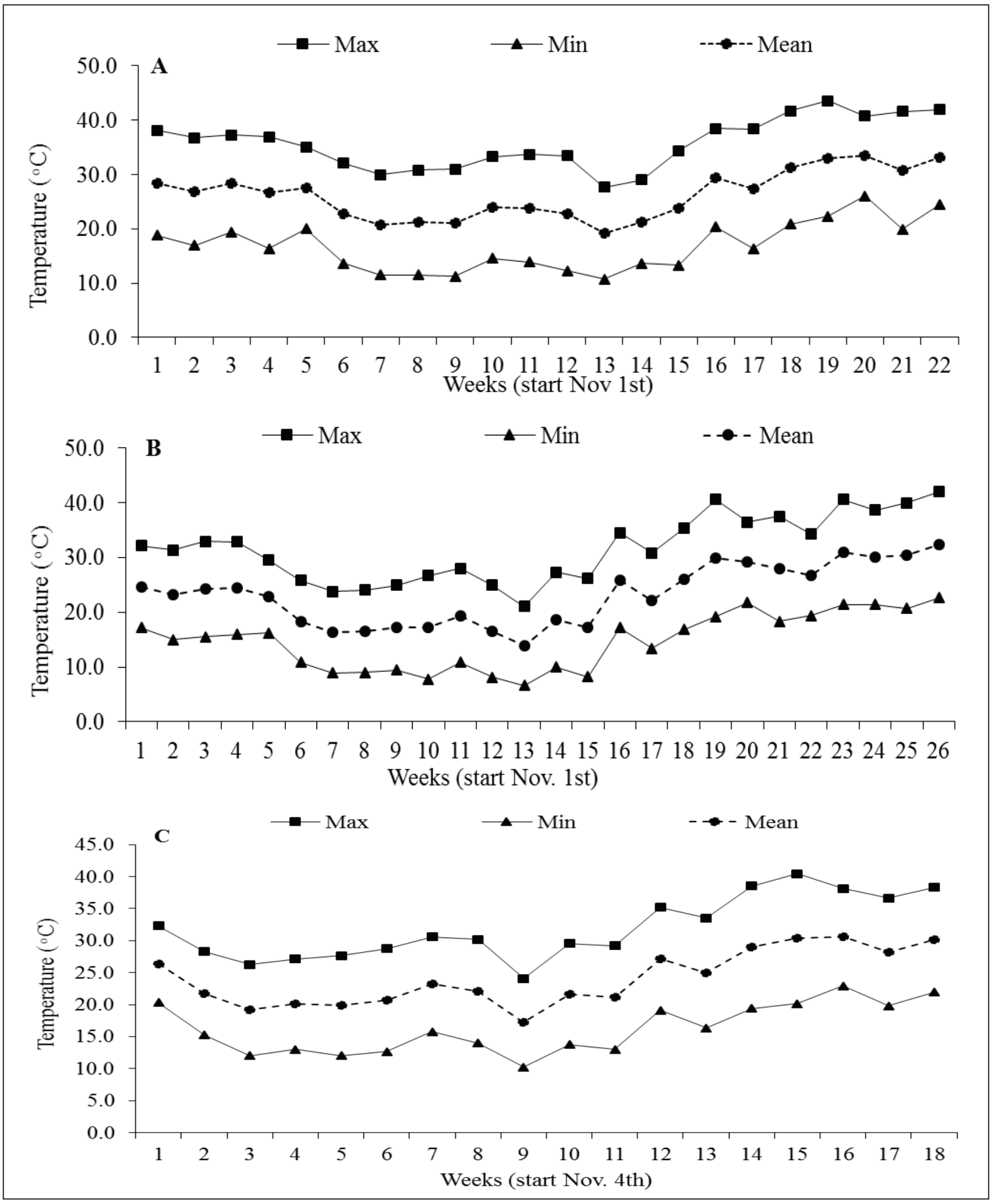

Figure 1. Weekly, maximum, minimum and average temperatures at Gezira Research Station, Wad Medani (A) Farm, Dongola Research Farm, Dongola (B) and Hudeiba Research Farm, Hudeiba (C), respectively during the 2015/2016 cropping season.

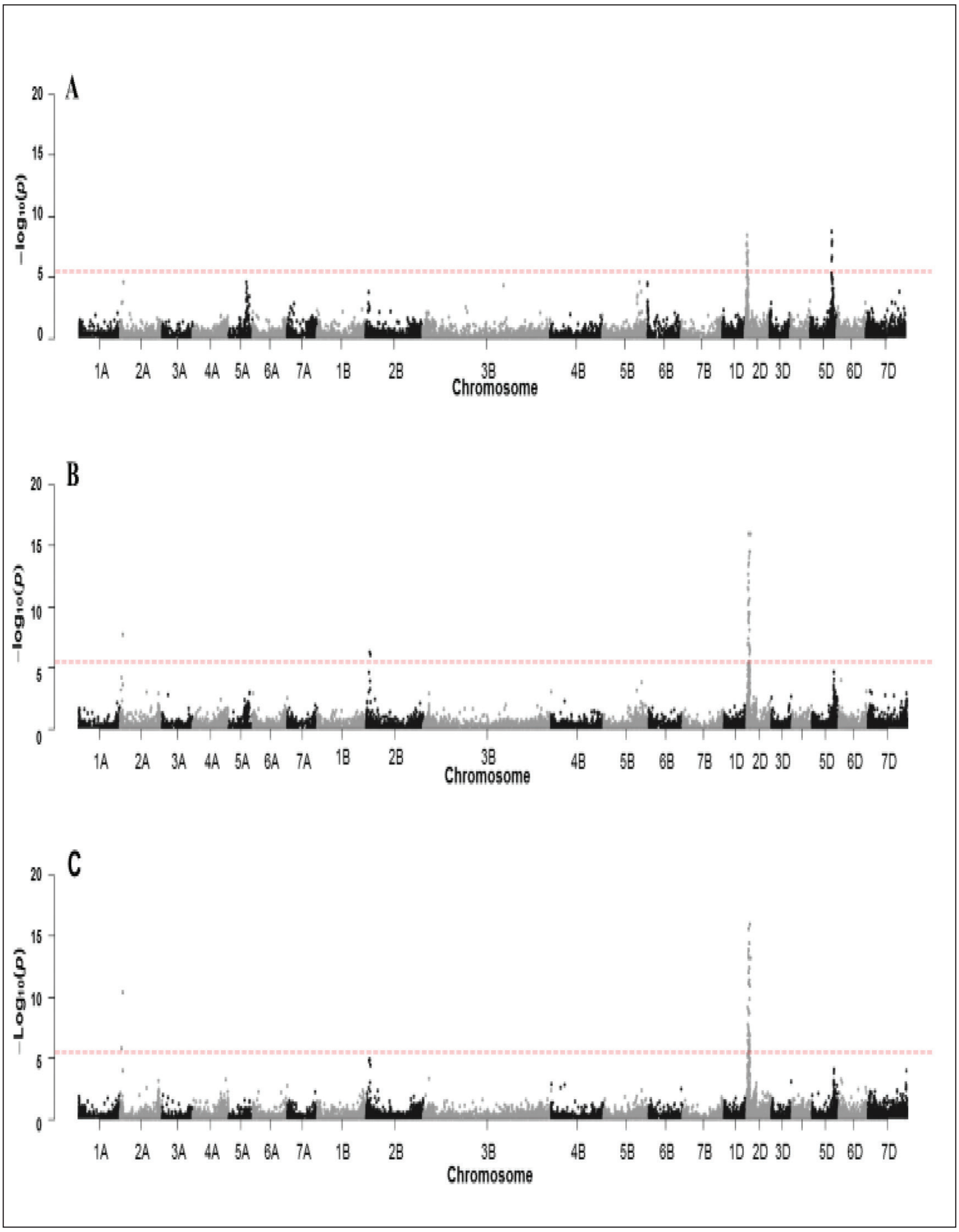

Figure 2. GWAS results using 14,300 SNPs markers in MSD population for growth habit (A), day to heading (B) and canopy temperature at heading stage (C) at Gezira Research Farm, Wad Medani, season 2015/16.

Marker-trait associations

For this analysis we used only the phenotypic data of the late planting date at MED as it represents the most stressed environment (Figure 1A). After the markers filtration, we used 14,300 SNP markers with a minor allele frequency (MAF) greater than 0.05 for maker traits associations (MTAs). Two QTLs were detected for GH on chromosomes 2D and 5D with 19 significant markers (Figure 2A). For DH we detected three QTLs on chromosomes 2A, 2B and 2D with 41 significant SNP markers (Figure 2B). Two QTLs were identified for CTdh on chromosomes 2A and 2D with 52 significant SNP markers (Figure 2C).

Discussion

Our results indicated that all traits are highly affected by heat stress. The MSD population showed wide genetic variation under heat stress–irrigated conditions of Sudan. Previous study reported the canopy temperature, days to heading, and spikes per m^2 are indirect selection criteria for increasing grain yield under heat and drought stresses (Serious *et al*., 2014; Khan *et al*., 2007).

Of seven QTL identified in this study, four QTLs (2A, 2B, 2D and 5D) were significantly associated with traits related to heat tolerance (Figure 2A, 2B, 2C). Many authors have reported that days to heading and canopy temperature were genetically controlled by quantitative trait loci. Heidari *et al*. (2012) identified two QTLs on chromosomes 2D and 2B made the largest contribution to the expression of days to heading. Lopes *et al.* (2013) identified QTLs for canopy temperature in the Seri/Babax bread wheat population on chromosomes 2B, 5D-b, 7D-b under drought, hot irrigated and non-stress conditions.

Conclusion

Our results showed the presence of ample genetic variability in growth habit, days to heading, canopy temperature at heading stage and tiller number per m^2. This variation can be used and utilized for breeding heat tolerant and adapted genotypes. Through GWAS we identified several QTLs, which might have an impact on wheat improvement and lead to higher yield. In addition, the combining of GWAS and phenotypic analysis was a powerful approach to describe genetic variation for heat stress tolerance. The identified QTL can be used for marker-assisted selection in breeding wheat for improved heat tolerance. The MSD population can be a good source of genes for improving wheat varieties under high temperature stress and with any wheat breeding objectives.

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3. Flowering and fruiting of some new Valencia orange cultivars budded on sour orange and Volkamer lemon rootstocks

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Abstract

A field experiment was carried out in a private orchard at Wady El-mollak, El Sharqia Governorate, Egypt during two successive seasons (2012 and 2013) to evaluate flowering, fruit set, yield, fruit quality and develop relationship of temperature and humidity with fruit drop for some newly introduced Valencia orange cultivars. The experiment comprised five Valencia orange cultivars (‘Frost’, ‘Olinda’, ‘Delta’, ‘Campbell’ and ‘26’) budded on sour orange (SO) and Volkamer lemon (VL) rootstocks, laid out in a randomized complete block design. Regarding the effect of cultivars, results showed that 26, Campbell and Frost gave the highest yield per tree. Whereas, TSS/acid ratio and Vitamin C content were not affected significantly by cultivars except that Frost gave the lowest values of Vitamin C. Regarding the effect of rootstocks, VL rootstock gave the highest significant values of yield per tree, TSS/acid ratio and Vitamin C. Whereas the combination of cultivars 26, Delta and Olinda on VL rootstock gave the highest values of yield per tree with the highest values of fruit physical properties. Concerning the relationship between meteorological conditions (temperature and humidity) with fruit drop it was found to be a positive and strong with temperature. The relationship between humidity and fruit drop was negative and strong.

Keywords: Fruit quality**,** New Valencia orange cultivars, Sour orange, Volkamer Lemon, Yield

Introduction

Oranges are the most extensively grown citrus fruit in Egypt. The production has reached about 2.85 million tons (Agricultural Statistics Institute, 2013) because of the expansion in the area triggered by conducive environmental conditions, great demand for local consumption, and high economic value as a main export crop to the European countries and Gulf States (Barakat *et al.*, 2012). The volume of Egyptian exports of orange has reached about 1.10 million tons representing 38.6 % of the total production (UPECH, 2013). Generally, Egypt has excellent opportunities for further expanding its exports due to its favorable climate and strategic geographic location. However, the yield decline in the middle Egypt is a cause of concern. The main cause for poor yield is the great flower and fruit drop, perhaps because of nutritional imbalance as well as unsuitable environmental conditions (Ahmed *et al.*, 2013). Therefore, the present study was conducted with an objective to evaluate flowering, fruit set, yield, and fruit quality of some newly introduced Valencia orange cultivars, grafted on two commercial rootstocks, and develop a relationship between temperature and humidity conditions of the growing environment with flower and fruit drop of these cultivars. The information so generated might help in improving the productivity of Valencia oranges in Egypt.

Materials and methods

A field experiment was carried out in a private orchard at Wady El-Mollak, El-Sharqia Governorate, Egypt during two successive seasons (2012 and 2013) on five newly introduced Valencia orange cultivars (‘Frost’, ‘Olinda’, ‘Delta’, ‘Campbell’ and ‘26’) budded on two citrus rootstocks, Sour Orange (*Citrus aurantium* L.) (SO) and Volkamer lemon (*Citrus Volkameriana* L.) (VL). Thus, the experiment, comprising five scions and two rootstocks, was laid out in a randomized complete block design with five replicates and each replicate was represented by one tree. The orange trees were selected on the basis of similarity in age (about seven years old), normal growth vigor, health, and flowering and fruiting behavior. All trees were planted 4 x 6 meter apart on a sandy soil under drip irrigation system and received the same cultural practices.

Number of flowers at full bloom was counted for both leafy and woody inflorescences to determine the fruit set. Fruits were counted after two weeks of full bloom and fruit setting was calculated. After 15days from full bloom, the number of dropped fruits was counted every 15 day till the end of June when drop stopped. Then the percentage of dropped fruit at the different intervals period was calculated.

The meteorological data for Wady El-mollak, El Sharqia were obtained from the central meteorological laboratory, Dokki, Giza, Ministry of Agriculture, for developing relationship between temperature, humidity and fruit drop. The scion canopy volume was calculated using the equation: canopy volume = 0.5238 x scion height x diameter square, according to Morse and Robertson (1987) for developing relationship between canopy volume and fruit drop.

At maturity, the average number of fruits /tree was counted in mid December of each season. Ten fruits from each tree were weighed, and the yield per tree was theoretically calculated from the fruit count.

A sample of five fruit / tree was randomly selected and used for the determination of various physical and chemical properties: fruit shape, fruit firmness, peels thickness and juice volume. The ascorbic acid content was determined by using 2,6- dichlorophenolindophenol dye and 3% oxalic acid as substrate. The titratable acidity was determined by titrating 5 ml of juice against sodium hydroxide (0.1 N) using phenolphthalein indicator. The acidity percentage was calculated as mg anhydrous citric acid per 100 ml of juice according to the A.O.A.C. (1995). The total soluble solids (TSS) were determined as % in juice by means of hand refractometer. The TSS / Acid ratio was calculated.

The data were subjected to statistical analysis of variance according to Snedecor and Cochran (1980). Duncan test was used to compare means.

Results and discussion

The percentage of flowering, fruit set and fruit drop

Results in Table 1 show the effect of cultivars, rootstocks and their interaction on flowering and fruit set during the 2012 and 2013 seasons. All main effects and interactions were significant. ‘Frost’ cultivar had the lowest flowering %, followed closely by ‘Olinda’. VL rootstock gave significantly higher values than SO. The highest significant values were obtained with ‘Delta’, ‘Campbell’ and ‘26’ on VL rootstock followed closely by ‘Olinda’ on VL, especially in the second season. Concerning the percentage of fruit set, the significant lowest values were obtained by ‘Olinda’ in both the seasons. VL gave the significantly higher values of fruit set as compared to SO. Highest values were obtained by ‘26’ on VL while the lowest values were obtained with ‘26’ budded on SO. These results are in agreement with those reported by Zayan *et al*. (2004) and Ibrahim (2005).

Table 1. Effect of some Valencia orange cultivars and two rootstocks on flowering% and fruit set% during the 2012 and 2013 seasons

Cultivars	Rootstocks					
	VL*	**SO****	**Means**	**VL***	**SO****	**Means**
	flowering%			**fruit set %**		
	2012 season					
Frost	32.10bc	29.33d	30.71C\	40.91b	36.98c	38.95AB\
Olinda	33.01b	28.65d	30.83C\	40.22b	35.32c-f	37.77B\
Delta	36.05a	31.18c	33.62AB \	40.33b	35.98c-e	38.16AB\
Campbell	35.98a	32.32bc	34.15A\	41.54b	36.88cd	39.21AB\
26	35.21a	31.21c	33.21B\	44.32a	34.98f	39.65A\
Means	34.47A	30.54B		41.46A	36.03B	
	2013 season					
Frost	39.05bc	35.65d	37.35B\	41.87bc	36.98d	39.43AB\
Olinda	40.21ab	36.99cd	38.80AB\	41.10bc	36.32de	38.71B\
Delta	40.87ab	36.94cd	38.93A\	40.99bc	36.55de	38.77B\
Campbell	41.21ab	37.32cd	39.26A\	42.21ab	37.21d	39.71A\
26	42.32a	36.95cd	39.64A\	43.98a	35.98f	39.98A\
Means	40.73A	36.78B		42.03A	36.61B	

In each season, means of each of rootstocks and cultivars or their interactions having the same letter (s) are not significantly different at 5% level.

*VL = Volkamer lemon, ** SO = Sour orange

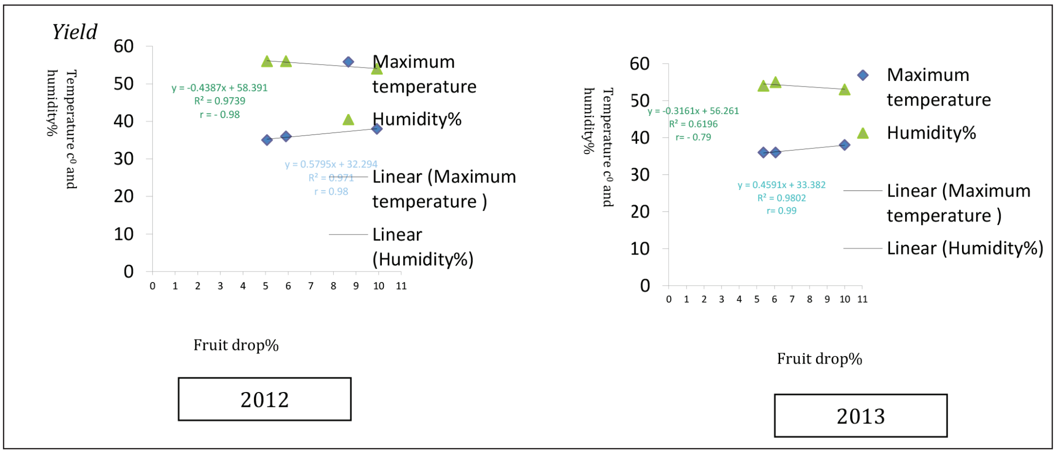

Figure 1. Relationship between temperature, humidity and fruit drop for Valencia orange cultivars budded on two rootstocks during the 2012 – 2013 seasons.

Significantly lowest values of fruit drop were obtained with '26' on both rootstocks and 'Campbell' on SO in both seasons. The highest fruit drop was obtained on the first date (3-May) followed by the fourth date (14-June), while the drop was least on the fifth date (28-June).

Figure 1 shows the relationship of temperature and humidity with fruit drop. There was a strong positive correlation between temperature and fruit drop and a negative relationship of fruit drop with humidity. About 98% of the variability observed in fruit drop can be explained by assessed values of temperature. While, 97% of the variability observed in fruit drop can be explained by assessed values of humidity in the first and 67% in the second seasons.

Figure 2 shows the relationship between canopy volume and fruit drop. The relationship was strong and negative. It could be concluded that cultivars that gave large canopy volume showed the lowest fruit drop. 'Campbell' and '26' gave large canopy volume, which increased the ability of trees to tolerate unsuitable environmental conditions (temperature and humidity) in June resulting in decreased fruit drop. These results are in agreement with those reported by Zayan *et al.* (2004) and Ibrahim (2005).

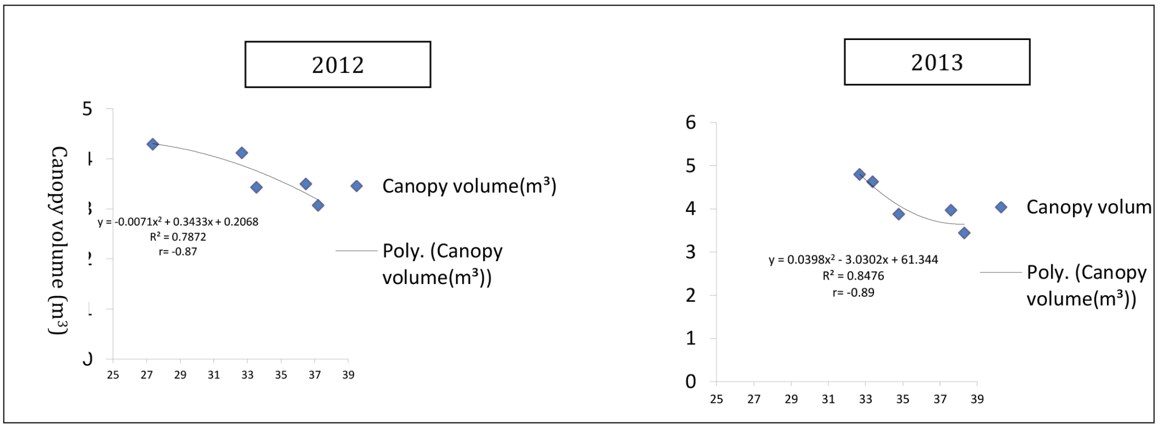

Figure 2. Relationship between canopy volume and fruit drop for Valencia orange cultivars budded on two rootstocks in the 2012-2013 seasons.

Fruit yield

Data in Table 2 show the effect of Valencia orange cultivars, rootstocks and their interaction on fruit number, fruit weight and yield/tree during 2012 and 2013 seasons. Fruit number, in the first season was not significantly affected by Valencia orange cultivars. However, in the second season the significant lowest values of fruit number were obtained by 'Delta'. VL rootstock gave significantly higher values for fruit number in the two seasons. The lowest values of fruit weight and yield were obtained by 'Frost' in the two seasons. VL rootstock gave the highest values of fruit weight and yield in the two seasons. Ibrahim *et al.* (2004), Shafieizargar *et al.* (2012) and Barakat *et al.* (2013) also reported that with Navel and Valencia orange cultivars VL rootstock gave higher fruit weight and yield as compared to SO rootstock.

Table 2. Effect of some Valencia orange cultivars and two rootstocks on fruit number, fruit weight and yield per tree during the 2012 and 2013 seasons

Cultivars	Rootstocks								
	VL*	SO**	Means	VL*	SO**	Means	VL*	SO**	Means
	Fruit NO./ tree			Fruit weight (g.)			Yield kg/tree		
2012 season									
Frost	95.33a-c	92.33b-d	93.83A\	338.67d	344.67d	341.67B\	63.52bc	61.00c	62.26B\
Olinda	100.00a	87.67d	93.83A\	375.33ab	351.67cd	363.50A\	67.53a	60.83c	64.18A\
Delta	97.00ab	90.00cd	93.50A\	383.33a	352.67b-d	368.00A\	67.18a	61.74c	64.46A\
Campbell	95.33a-c	90.33cd	92.83A\	375.67ab	349.33cd	362.50A\	65.81ab	61.55c	63.68AB\
26	99.00a	90.00cd	94.50A\	372.33a-c	349.00d	360.67A\	65.50ab	62.23c	63.87AB\
Means	97.33A	90.07B		369.07A	349.47B		65.91A	61.47B	
2013 season									
Frost	99.67a	91.33cd	95.50AB\	345.33d	354.67b-d	350.00C\	64.42bc	62.40cd	63.41B\
Olinda	100.00a	89.00d	94.50AB\	374.00ab	349.33cd	361.67BC\	67.40ab	61.10d	64.25AB\
Delta	97.33ab	90.33cd	93.83B\	379.00a	368.00a-c	373.50A\	66.89ab	63.24cd	65.07AB\
Campbell	98.67a	92.33b-d	95.50AB\	367.33a	353.33cd	364.80AB\	67.13ab	62.63cd	64.88AB\
26	100.33a	95.00a-c	97.67A\	376.67a	353.33cd	365.00AB\	67.79a	63.57cd	65.68A\
Means	99.20A	91.60B		370.27A	355.73B		66.73A	62.59B	

In each season, means of each of rootstocks and cultivars or their interactions having the same letter (s) are not significantly different at 5% level.

*VL= Volkamer lemon, **SO= Sour orange

Fruit quality

'Campbell' got lowest score for fruit shape. Fruit shape was not affected significantly by rootstocks in the two seasons. Fruit firmness was not affected significantly by cultivars in the first season but in the second season 'Delta' gave the significantly lowest values. With respect to the specific effect of rootstocks, data showed that SO gave significantly higher values than VL in the two growing seasons.

The significantly highest values of peel thickness were obtained by 'Frost' cultivar while 'Campbell' gave the lowest values during the two seasons. VL rootstocks gave significantly higher values than SO in both seasons. The significantly lowest values of juice volume were in 'Campbell' cultivar during the two seasons. R VL rootstocks gave significantly higher values in the two seasons. The interaction was significant in the two seasons. whereas the effect varied from season to another. The highest values were obtained by '26' on each rootstock. In this respect, Zayan *et al*. (2004) working on Valencia orange and Shafieizargar *et al*. (2012) on 'Queen' orange pointed out that trees grafted on VL produced the largest fruits as compared with SO. Also, Ibrahim et al. (2004) reported that the significant highest values of peel thickness were obtained with Volkamer Lemon. Whereas sour orange gave lowest values of peel thickness.

Table 3. Effect of some Valencia orange cultivars budded on two rootstocks on vitamin C, TSS and acidity during the 2012 and 2013 seasons

Cultivars	Rootstocks								
	VL*	SO**	Means	VL*	SO**	Means	VL*	SO**	Means
	Vitamin C			TSS			Acidity		
	2012 season								
Frost	39.10d	44.40a	41.75B\	10.45a	10.28a	10.37A\	0.90a	0.91a	0.91A\
Olinda	41.21cd	43.88a-c	42.55AB\	10.25a	10.66a	10.16A\	0.98a	0.97a	0.98A\
Delta	41.03cd	45.32a	43.18AB\	10.28a	10.00a	10.14A\	0.97a	0.98a	0.98A\
Campbell	43.55a-c	44.65a	44.10A\	10.15a	9.96a	10.06A\	0.96a	0.98a	0.97A\
26	41.32b-d	44.32ab	42.82AB\	10.40a	10.19a	10.30A\	0.97a	0.98a	0.98A\
Means	44.51A	41.24B		10.09A	10.31A		0.97A	0.96A	
	2013 season								
Frost	38.87b	44.07a	41.47B\	10.44a	10.24a	10.34A\	0.91a	0.92a	0.92A\
Olinda	42.65a	44.22a	43.43AB\	10.24a	10.08a	10.16A\	0.99a	0.99a	0.99A\
Delta	42.32a	44.98a	43.65A\	10.36a	10.69a	10.23A\	0.99a	0.99a	0.99A\
Campbell	44.22a	44.98a	44.60A\	10.28a	10.07a	10.18A\	0.96a	0.99a	0.98A\
26	42.98a	44.98a	43.98A\	10.42a	10.24a	10.33A\	0.99a	1.01a	1.00A\
Means	44.65A	42.21B		10.15A	10.35A		0.98A	0.97A	

In each season, means of each of rootstocks and cultivars or their interactions having the same letter (s) are not significantly different at 5% level.

*VL = Volkamer lemon, **SO = Sour orange

Fruit chemical properties

Data in Table 3 show the effect of different Valencia orange cultivars, rootstocks and their interaction on vitamin C, TSS% and acidity during the two seasons. Results showed that values of vitamin C were significantly affected by Valencia orange cultivars, rootstocks and their interaction in the two seasons. Significantly lowest values of vitamin C were obtained in 'Frost' cultivar during the two seasons. Regarding the effect of rootstocks it was noticed that VL gave the highest values in the two seasons. TSS and acidity were not affected significantly by Valencia orange cultivars, rootstocks and their interaction. However, values of TSS/acid ratio were significantly affected by Valencia orange cultivars budded on two rootstocks and the harvest date in the two seasons. Significantly highest values were obtained by 'Frost' grafted on VL. Finally it could be concluded that, VL rootstock gave higher values of yield/tree and fruit quality especially for physical properties and Vitamin C than sour orange. Fruit from trees on SO tend to have higher ascorbic acid content than the other rootstock Harding *et al.* (1940) reported that fruits on SO rootstock were smooth, thin skinned, juicy, excellent in quality, and can be held up well without appreciable deterioration after maturity.

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4. Effect of nano-calcium and nano-silicon compounds on salinity tolerance for green bean plants

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Abstract

Salinity is a major limiting factor for crop growth and productivity, especially in arid and semi-arid lands. Therefore, this study was conducted to find out the effect of applying nano-silicon and nano-calcium on mitigating the negative effects of salinity on green bean (*Phaseolus vulgaris* var. Polista). Seeds were planted in September 2013 and 2014 in pots containing sandy soil, and irrigated with saline water with a salt content of 500, 1000 and 1500 ppm. Nano-silicon was supplied at the concentrations of 1 cm^3/l and 2 cm^3/l and nano-calcium at 0.5 g / l and 1 g / l. Application took place at 2, 5, 7 and 9 weeks after planting. Data showed that plant height, number of leaves, and fresh and dry weights were improved under all doses of nano-silicon and nano-calcium compared to non treated control plants. Yield parameters followed also the same trend. Amongst various treatments, nano-silicon concentration of 2 cm^3/l and nano-calcium dose of 1 g /l recorded the highest significant effect in mitigating the negative effects of salinity. It could be concluded that nano-silicon and nan-calcium are effective and efficient in mitigating salinity stress in green bean plants.

Keywords: Green bean, Growth, Yield, Salinity tolerance, Nano-silicon, Nano-calcium

Introduction

Egypt has a significant comparative advantage in the production of horticultural commodities including green beans for export, based on its geographic position and agro-climatic conditions. It was reported that the Egyptian share in the Dutch market reached about 25% with Egypt being the main exporter of green beans to the Netherlands just ahead of Spain (24%) and Kenya (20%) (HEIA, 2003). The Egyptian annual growth in the production of green beans was estimated to represent half of the world's total growth (Wijnands, 2004). However, as most of the expansion of green bean cultivation has taken place in the newly reclaimed lands, this expansion is constrained by such limiting factors as salinity. Also, in the old valley considerable stretch of land areas has become salt affected. According to Gehad (2003), some 90 thousands hectare of Nile Valley and Delta region are salinity affected. The problem is aggravated when there is over withdrawal of underground water or an inefficient drain system is installed in the cultivated soil.

Many studies have been carried out in order to help the growers to overcome these negative effects of salinity. The studies include modification of greenhouse climate (Abdel-Mawgoud *et al*., 2004); application of organic matter such as humate (Abdel-Mawgoud *et al.*, 2007; 2010); application of specific nutrients such as amino acids or growth regulators (El-Abd *et al.*, 2005; Tantawy *et al.*, 2009; 2013) and minerals such as calcium and silicon. The latter two nutrients have been reported to alleviate salinity stress and improve plant performance and production

(Awada *et al.*, 1995; Haghighi *et al.,* 2012; Tantawy *et al*., 2015). However, by introducing nanotechnology into agriculture, many of the agricultural inputs have become more effective and application more efficient. This is due to the fact that nano-technology makes the particles smaller in size with higher active properties. This study aimed at investigating the effect of applying nano calcium and silicon separately in different concentrations on alleviating the negative effects of salinity on green bean plants.

Materials and methods

Two pot experiments were carried out during autumn seasons of 2013 and 2014 in a private farm in Abou Ghalib region, Giza Governorate, to investigate the effects of using nano-calcium in concentration of 0.5 and 1.0 g/l and nano-silicon in concentrations of 1.0 and 2.0 cm^3/l to alleviate the effect of different salinity levels on the growth and yield of green bean plants (*Phaseolus vulgaris*, L.) cv. 'Pulista' under the newly reclaimed land conditions. Green bean seeds were sown in pots (plastic bags with the dimensions of 30 cm diameter, 50 cm deep) filled with 13 kg washed sand. Plants were irrigated with saline water of 500 (control), 1000 and 1500 ppm salinity obtained by using Rachel salt dissolved in fresh water. Salinity treatments started after three weeks from sowing. Pots were irrigated every 2-3 days, with 1000 ml of saline water to keep the water content at field capacity. Plastic pots were perforated to allow drainage. Nano materials, provided by Agro link company, were prepared in the required concentrations (0.5 and 1.0 g/l for nano-calcium and 1.0 and 2.0 cm^3/l for nano-silicon) and applied four times through irrigation in the 3^{rd}, 5^{th}, 7^{th} and 9^{th} week after sawing. Chemical fertilizers were added as recommended by the Ministry of Agriculture for green bean crop.

Data on plant height (cm), fresh and dry weight (g), and leaf number was recorded at the end of the seasons. Leaf area was recorded of the fourth leaf from the apex. Green pods yield was recorded as pickings took place to harvest green pods that reached marketing stage. Pod quality in terms of total fiber content was determined at the second picking using a random sample of 20 pods from each experimental unit. Chlorophyll content was measured on the fourth leaf from the apex using Minolta Chlorophyll meter Model 501 (Yadava, 1986). Mineral content was also analyzed from same leaf sample. Total nitrogen was determined using the micro-Kjeldahl method (Kacar, 1972). Phosphorus was determined spectrophotometrically according to Troug and Meyer (1939). Potassium content was determined using an atomic absorption spectrophotometer (Brown and Lilleland, 1946). Sodium, Ca and Si contents were analyzed and by flame-photometer (Brown and Lilleland, 1946).

Total fiber contents in the pods were determined according to Rai and Mudgal (1988). Total proline content was measured according to Bates *et al.* (1973).

The experimental treatments were arranged in a split plot design with three replicates where, salinity levels were main plots and nano-materials (Ca and Si) were sub plots. The obtained data were statistically analyzed (Gomez and Gomez, 1984).

Results

Table 1 shows the effect of the salinity levels, nano-materials and the interactions among them on plant height, number of leaves and leaf area. As salinity level increased, there was a significant negative effect on plant height, number of leaves and leaf area. These trends were consistent in both growing seasons of the experiment. The application of the highest concentrations of nano Calcium (1g/l) and nano silicon (2 cm3/l) gave the highest positive effects. Nano-calcium showed superiority in the positive effect compared to nano-silicon and the difference was significant. Although the applied nano-materials mitigated the negative effect of salinity within each salinity level significantly, the interaction effect showed clearly the dominant effect of salinity as its level increased

Table 2 shows the effects of the applied treatments on total chlorophyll content, fresh and dry weights of the bean plants. The negative effect of salinity on chlorophyll content was significant compared to control. Although the applied nano materials reduced that negative effect, there was clear superiority of nano Ca (1.0 g/l). Similarly, increasing salinity level reduced fresh and dry weights of the plant significantly and nano-Ca followed by nano-Si mitigated that negative effect. Nano-Ca at concentration of 1.0 g/l showed superiority in its effect compared to all other applied concentrations of nano-Ca or nano-Si. The salinity effects dominated on these parameters despite the mitigation effects of the nano-materials.

The effect of the treatments on the yield and its components was similar to the effects on other parameters reported above. Total yield was significantly reduced as salinity level increased (Table 3). The nano Ca and Si applications markedly improved yields. Nano-Ca at concentration of 1.0 g/l showed the highest mitigation effect under all salinity levels. Similarly, marketable yield was severely reduced as salinity level increased significantly. The marketable yield under 1500 ppm salinity level was almost 50% of that under 500 ppm (control) treatment. The application of nano materials improved the fraction of marketable yield and reduced the negative effects of salinity significantly. Nano-Ca at 1.0 g/l recorded the highest effect in improving marketable yield compared to all other treatments.

The N, P and K content showed a reduction as salinity level increased (Table 4), these reductions were mitigated by the application of nano-materials with nano-calcium recording the highest positive effect at concentration of 1.0 g/l.

As expected, Na content increased in plant tissues as salinity level increased (Table 5) and nano-Ca or nano-Si reduced it. On the other hand, Ca and Si % increased in plant tissues as the concentration of each material increased in the treatment (Table 5). However, as salinity increased, there was a tendency for the content of these nutrients to decrease.

Fiber content of beans increased by increasing salinity level significantly, which indicates a lowering of fruit quality (Table 6). The application of nano materials reduced this effect significantly. Using nano Ca at concentration 1.0 g/l recorded the highest effect compared to all the other treatments.

Proline content as a parameter of stress showed a strong positive response to the increment in salinity level. That response was reduced significantly by the application of nano-Ca or nano-Si

(Table 6). The effect of nano materials was very clear on that parameter where nano-Ca at 1.0 g/l concentration recorded the highest effect and nano-Si at concentration 0.5 cm/l recording the lowest effect.

Table 1. Effect of different salinity levels and nano-chemicals on plant height, number of leaves and leaf area of green bean plants in 2013 and 2014 seasons

Salinity levels	Nano chemical	Plant height (cm)		Number of leaves		Leaf area (cm^2)	
		2013 season	2014 season	2013 season	2014 season	2013 season	2014 season
500 ppm	Control	28.0	30.3	17.6	17.0	410.3	405.1
	Ca (0.5 g / L)	32.6	42.3	20.3	19.7	432.5	427.6
	Ca (1 g / L)	42.0	48.3	24.0	23.7	546.3	541.2
	Si (1 cm^3 / L)	32.3	41.0	20.0	19.0	417.7	412.4
	Si (2 cm^3 / L)	36.3	43.6	22.6	21.6	538.3	533.9
Mean		34.26	41.13	20.93	20.2	469.04	464.04
1000 ppm	Control	24.6	28.0	13.3	12.7	316.7	311.5
	Ca (0.5 g / L)	30.3	37.3	16.3	16.7	386.7	381.3
	Ca (1 g / L)	37.3	42.7	19.7	17.7	478.7	472.4
	Si (1 cm^3 / L)	27.8	34.0	14.7	15.2	356.5	350.3
	Si (2 cm^3 / L)	31.3	39.3	18.7	16.5	440.3	435.1
Mean		30.3	36.26	16.5	15.7	395.77	390.11
1500 ppm	Control	22.2	23.3	11.0	11.3	284.2	278.2
	Ca (0.5 g / L)	28.7	31.3	12.7	13.3	312.7	309.4
	Ca (1 g / L)	32.3	35.7	16.3	15.0	388.3	382.4
	Si (1 cm^3 / L)	25.33	29.33	11.33	12.89	293.34	283.39
	Si (2 cm^3 / L)	29.7	31.3	15.7	14.2	349.3	339.4
Mean		29.67	31.33	13.4	13.36	325.58	318.56
Mean of Nano chemical	Control	24.9	27.2	14.0	13.7	337.0	331.6
	Ca (0.5 g / L)	30.5	37.0	16.4	16.5	377.1	372.7
	Ca (1 g / L)	37.2	42.2	20.0	18.8	471.0	465.3
	Si (1 cm^3 / L)	28.5	34.8	15.3	15.7	355.3	348.7
	Si (2 cm^3 / L)	32.4	38.1	19.0	17.4	442.6	436.2
L.S.D. at 5%	Salinity	1.22	1.49	0.97	0.93	32.41	27.83
	Nano chemical	1.90	1.29	1.75	1.60	12.16	17.35
	Interaction	2.45	2.24	2.22	2.19	21.06	30.05

Table 2. Effect of salinity different levels and nano chemicals on plant fresh and dry weight and total chlorophyll content of green bean plants in 2013 and 2014 seasons

Salinity levels	Nano chemical	Plant fresh weight (g / plant)		Plant dry weight (g / plant)		Total Chlorophyll (SPAD)	
		2013 season	2014 season	2013 season	2014 season	2013 season	2014 season
500 ppm	Control	52.92	51.67	9.87	12.30	40.33	42.58
	Ca (0.5 g/ L)	69.86	63.33	11.14	14.28	42.42	44.67
	Ca (1 g / L)	93.36	97.33	13.08	16.13	49.92	52.34
	Si (1 cm^3 / L)	59.21	60.00	10.95	13.33	42.00	44.29
	Si (2 cm^3 / L)	82.79	79.67	12.13	15.14	44.59	47.54
Mean		71.63	70.40	11.43	14.23	43.85	46.28
1000 ppm	Control	47.55	49.33	7.34	10.36	30.47	29.34
	Ca (0.5 g / L)	65.55	60.33	9.53	12.25	37.33	36.58
	Ca (1 g / L)	89.26	90.67	10.21	13.89	43.67	42.32
	Si (1 cm^3 / L)	57.20	55.00	7.56	10.32	37.39	36.46
	Si (2 cm^3 / L)	75.56	71.54	9.92	12.05	39.33	38.42
Mean		67.00	65.4	8.91	11.77	37.64	36.62
1500 ppm	Control	40.25	40.33	5.21	8.32	23.54	22.36
	Ca (0.5 g / L)	60.83	58.00	7.56	10.38	31.33	30.24
	Ca (1 g / L)	82.48	82.33	8.85	11.8	35.67	34.92
	Si (1 cm^3 / L)	51.70	52.00	6.82	9.01	32.33	31.42
	Si (2 cm^3 / L)	68.48	68.00	7.99	10.31	34.45	34.77
Mean		60.75	60.13	7.28	9.96	34.45	34.77
Mean of Nano chemical	Control	46.9	47.11	7.47	10.32	31.44	31.42
	Ca (0.5 g / L)	65.41	60.55	9.41	12.3	37.02	37.16
	Ca (1 g / L)	88.36	90.11	10.71	13.94	43.08	43.19
	Si (1 cm^3 / L)	56.03	55.66	8.44	10.88	37.24	37.39
	Si (2 cm^3 / L)	75.61	73.07	10.01	12.5	39.45	40.24
L.S.D. at 5%	Salinity	1.42	1.39	0.89	0.78	1.98	1.88
	Nano chemical	2.42	2.34	1.02	0.99	2.01	1.96
	Interaction	3.03	3.15	1.28	1.45	2.24	2.37

Table 3. Effect of different salinity levels and nano chemicals on total yield (g/ plant), marketable yield (g/ plant) and unmarketable yield (g/ plant) of green bean plants in 2013 and 2014 seasons

Salinity levels	Nano chemical	Total yield (g/ plant)		Marketable yield (g/ plant)		Unmarketable yield (g/ plant)	
		2013 season	2014 season	2013 season	2014 season	2013 season	2014 season
500 ppm	Control	65.95	67.99	52.55	53.02	13.40	14.97
	Ca (0.5 g / L)	78.60	73.50	70.93	60.47	7.67	13.03
	Ca (1 g / L)	87.49	86.10	83.36	79.23	4.13	6.87
	Si (1 cm^3 / L)	69.10	70.09	58.43	56.62	10.67	13.47
	Si (2 cm^3 / L)	82.01	79.01	75.43	66.40	6.57	12.60
Mean		76.63	75.33	68.14	63.15	8.48	12.18
1000 ppm	Control	53.25	56.51	32.65	35.33	20.60	21.17
	Ca (0.5 g / L)	68.25	68.10	55.82	55.00	12.43	13.10
	Ca (1 g / L)	77.21	80.44	69.01	72.81	8.20	7.63
	Si (1 cm^3 / L)	62.51	57.49	43.60	37.96	18.90	19.53
	Si (2 cm^3 / L)	69.15	72.10	58.08	60.73	11.07	11.37
Mean		66.07	66.93	51.83	52.37	14.24	14.56
1500 ppm	Control	49.65	48.49	26.48	24.96	23.17	23.53
	Ca (0.5 g / L)	63.00	63.15	49.37	50.02	13.63	13.13
	Ca (1 g / L)	69.19	77.40	58.59	66.13	10.6	11.27
	Si (1 cm^3 / L)	61.39	61.68	41.72	46.25	19.67	15.43
	Si (2 cm^3 / L)	66.00	66.91	53.53	54.27	12.47	12.63
Mean		61.84	63.52	45.94	48.33	15.90	15.19
Mean of Nano chemical	Control	56.28	57.66	37.23	37.77	19.05	19.89
	Ca (0.5 g / L)	69.94	68.25	58.70	55.17	11.24	13.08
	Ca (1 g / L)	77.95	81.30	70.31	72.72	7.64	8.59
	Si (1 cm^3 / L)	64.33	63.09	47.92	46.95	16.41	16.14
	Si (2 cm^3 / L)	72.37	72.66	62.34	60.46	10.03	12.20
L.S.D. at 5%	Salinity	3.56	2.29	0.91	0.86	2.14	2.75
	Nano chemical	1.92	1.10	0.51	0.40	1.09	1.81
	Interaction	1.02	1.90	1.11	1.01	1.89	3.13

Table 4. Effect of different salinity levels and nano chemicals on nitrogen, phosphorus and potassium content (%) of green bean leaves in 2013 and 2014 seasons

Salinity levels	Nano chemical	N (%)		P (%)		K (%)	
		2013 season	2014 season	2013 season	2014 season	2013 season	2014 season
500 ppm	Control	1.84	1.79	0.39	0.39	2.01	2.08
	Ca (0.5 g / L)	2.23	2.36	0.41	0.43	2.36	2.33
	Ca (1 g / L)	2.80	2.79	0.43	0.45	2.63	2.59
	Si (1 cm3 / L)	2.12	2.22	0.42	0.40	2.12	2.23
	Si (2 cm3 / L)	2.42	2.44	0.42	0.41	2.48	2.35
Mean		2.28	2.32	0.41	0.42	2.32	2.32
1000 ppm	Control	1.73	1.84	0.34	0.33	1.79	1.84
	Ca (0.5 g / L)	2.12	2.31	0.37	0.38	1.99	1.87
	Ca (1 g / L)	2.73	2.69	0.36	0.36	2.33	2.46
	Si (1 cm^3 / L)	1.82	1.98	0.35	0.34	2.03	2.09
	Si (2 cm^3 / L)	2.32	2.48	0.38	0.36	1.85	1.94
Mean		2.144	2.26	0.36	0.35	2	2.04
1500 ppm	Control	1.42	1.62	0.29	0.3	1.49	1.51
	Ca (0.5 g / L)	1.83	1.89	0.33	0.34	1.66	1.54
	Ca (1 g / L)	2.45	2.46	0.36	0.35	1.79	1.83
	Si (1 cm^3 / L)	1.64	1.71	0.31	0.32	1.53	1.61
	Si (2 cm^3 / L)	2.14	2.19	0.34	0.34	1.69	1.71
Mean		1.896	1.974	0.326	0.33	1.63	1.64
Mean of Nano chemical	Control	1.66	1.75	0.34	0.34	1.76	1.81
	Ca (0.5 g / L)	2.06	2.19	0.37	0.38	2.00	1.91
	Ca (1 g / L)	2.66	2.65	0.38	0.39	2.25	2.29
	Si (1 cm^3 / L)	1.86	1.97	0.36	0.35	1.89	1.98
	Si (2 cm^3 / L)	2.29	2.37	0.38	0.37	2.01	2.00
L.S.D. at 5%	Salinity	0.13	0.04	0.07	0.05	N.S.	0.2
	Nano chemical	0.09	0.06	0.04	0.02	0.10	0.08
	Interaction	0.15	0.11	0.07	0.03	0.17	0.15

Table 5. Effect of different salinity levels and nano chemicals on sodium, calcium and silicon (%) of green bean leaves in 2013 and 2014 seasons

Salinity levels	Nano chemical	Na (%)		Ca (%)		Si (%)	
		2013 season	2014 season	2013 season	2014 season	2013 season	2014 season
500 ppm	Control	0.34	0.39	2.11	2.03	0.63	0.70
	Ca (0.5 g / L)	0.23	0.24	3.21	3.19	0.84	0.9
	Ca (1 g / L)	0.21	0.2	3.44	3.39	0.96	1.01
	Si (1 cm^3 / L)	0.27	0.26	2.21	2.14	1.17	1.20
	Si (2 cm^3 / L)	0.26	0.28	2.86	2.61	1.29	1.30
Mean		0.26	0.27	2.77	2.67	0.97	1.02
1000 ppm	Control	0.37	0.41	1.85	1.91	0.61	0.6
	Ca (0.5 g / L)	0.31	0.31	2.45	2.38	0.70	0.72
	Ca (1 g / L)	0.26	0.29	3.06	3.11	0.92	0.91
	Si (1 cm^3 / L)	0.34	0.36	2.08	2.14	1.12	1.18
	Si (2 cm^3 / L)	0.32	0.35	2.59	2.85	1.20	1.20
Mean		0.32	0.34	2.41	2.48	0.9	0.92
1500 ppm	Control	0.42	0.45	1.45	1.17	0.49	0.59
	Ca (0.5 g / L)	0.35	0.37	2.17	2.09	0.53	0.52
	Ca (1 g / L)	0.29	0.30	2.81	2.77	0.72	0.8
	Si (1 cm^3 / L)	0.37	0.39	1.92	1.98	1.04	1.00
	Si (2 cm^3 / L)	0.39	0.42	1.81	1.74	1.00	1.10
Mean		0.36	0.38	2.03	1.95	0.75	0.78
Mean of Nano chemical	Control	0.49	0.33	1.8	1.7	0.57	0.60
	Ca (0.5 g / L)	0.29	0.44	2.61	2.55	0.69	0.71
	Ca (1 g / L)	0.27	0.60	3.10	3.09	0.86	0.90
	Si (1 cm^3 / L)	0.33	0.50	2.07	2.09	1.10	1.13
	Si (2 cm^3 / L)	0.31	0.64	2.42	2.40	1.16	1.20
L.S.D. at 5%	Salinity	0.15	0.14	0.13	0.17	0.04	0.07
	Nano chemical	0.09	0.07	0.12	0.20	0.07	0.04
	Interaction	0.11	0.12	0.20	0.31	0.12	0.07

Table 6. Effect of different salinity levels and nano chemical ion on pod fibers (%) and proline (%) in green bean leaves in 2013 and 2014 seasons

Salinity levels	Nano chemical	Fibers (%)		Proline (%)	
		2013 season	2014 season	2013 season	2014 season
500 ppm	Control	10.94	10.87	0.41	0.42
	Ca (0.5 g / L)	10.43	10.79	0.31	0.32
	Ca (1 g / L)	9.13	10.98	0.21	0.23
	Si (1 cm^3 / L)	10.88	10.42	0.39	0.41
	Si (2 cm^3 / L)	10.85	10.65	0.27	0.29
Mean		10.44	10.74	0.31	0.33
1000 ppm	Control	12.98	12.99	0.69	0.75
	Ca (0.5 g / L)	12.44	12.65	0.39	0.41
	Ca (1 g / L)	11.09	11.13	0.31	0.33
	Si (1 cm^3 / L)	12.84	12.73	0.44	0.4
	Si (2 cm^3 / L)	12.16	12.22	0.35	0.39
Mean		12.3	12.34	0.43	0.45
1500 ppm	Control	13.98	13.72	0.78	0.81
	Ca (0.5 g / L)	13.56	13.65	0.52	0.52
	Ca (1 g / L)	12.88	12.82	0.42	0.44
	Si (1 cm^3 / L)	13.79	13.75	0.53	0.49
	Si (2 cm^3 / L)	12.91	12.98	0.48	0.53
Mean		13.42	13.38	0.54	0.55
Mean of Nano chemical	Control	12.63	12.53	0.63	0.66
	Ca (0.5 g / L)	12.14	12.36	0.41	0.42
	Ca (1 g / L)	11.03	11.64	0.31	0.33
	Si (1 cm^3 / L)	12.5	12.3	0.45	0.43
	Si (2 cm^3 / L)	11.97	11.95	0.37	0.40
L.S.D. at 5%	Salinity	0.06	0.11	0.02	0.03
	Nano chemical	0.05	0.08	0.02	0.12
	Interaction	0.09	0.13	0.04	0.20

Discussion

This study was carried out in order to investigate some possible alternatives that may alleviate the negative effect of salinity on a salt sensitive crop such as green bean. The results showed the common negative effects of salinity on all plant growth parameters as well as fresh and dry weights of the plant. Salinity is well known to affect negatively plant water status (Livett, 1980) and the latter is reflected on smaller elongation of plant cells hence shorter plants and smaller leaf areas. Smaller canopy (plant height and leaf area) means smaller light interception hence, lower photo assimilate production leading to lower fruit yield as has been recorded in this study. Not only water status, salinity affects also nutrients uptake negatively (Grattana and Grieve, 1999) as has been observed in this study. This also contributes to the negative effect of salinity on overall plant performance and production.

In this study, application of nano-Ca has shown some mitigation of the negative effects of salinity. Ca is well known to overcome and mitigate salinity effects either by counteracting the effects of Na in the soil and/or by balancing its effect within the plant cells (Gul and Khan, 2006; Arshi *et al*., 2010). It is well known that Ca^{2+} alleviates the adverse effects of salinity in many plant species (Rengel, 1992; Marschner, 1995; Agboola, 1998; Munns, 2002; Ebert *et al.*, 2002) including the toxic effects of Na^+ and Mg^{2+} on the germination (Tobe *et al.*, 1999, 2001; Bliss *et al.,* 1986) as well as the toxicity of various chloride and sulfate salts (Tobe *et al.*, 2002). However, in comparison to the classical form, the nano form of any material, including Ca, increases its activity and enhances its effects in the applied environment **(**Tantawy *et al.*, 2014). This was clear in this study and the effect was increasing as the concentration of nano-Ca increased

Si has also been reported to increase plant tolerance as well as improving plant growth under various biotic and abiotic stresses (Guntzer *et al.*, 2012**)**. For instance, Eneji *et al.* (2008) found good correlations between Si and P uptake from soil. Moreover, Mali and Aery (2008a) found that K uptake both in hydroponics and in soil was improved even at low Si concentrations through the activation of H-ATPase. Mali and Aery (2008a, 2008b) observed also a better absorption of N and Ca for cowpea and wheat fertilized with increasing doses of sodium metasilicate (50–800 mg Si kg^{-1}), as well as a better nodulation and apparently better N_2 fixation in cowpea. These findings support the results of this study where nano silicon application improved plant performance and production, which may be due to better nutritional status as expressed in higher nutrient contents in this study.

Conclusion

Although applied nano-Ca and nano-Si improved plant performance and production in this study, the effect of salinity was dominant specially at higher levels. This is due to either specific ion effect of Na and/or the level of salinity is beyond the maximum level that can be tolerated by the bean plants. However, the application of nano materials reduced the negative effects of each salinity level. This gives the grower an opportunity to grow beans under the tested levels salinity in case the market price is attractive.

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5. Current status of wheat production in Egypt

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Abstract

Historically, wheat yield in Egypt increased gradually over the past seven decades. Wheat total annual production increased from 1.3 million ton in 1950 to about 9 million ton in 2015. However, the production was not able to keep up with the rapidly growing population of the country, whose rate reached 1.8 million /year in 2015. The annual per capita consumption of wheat in Egypt has been estimated to be 180 kg/year, which places it among the top 10% of the wheat consuming countries in the world. This resulted in widening the gap between domestic wheat production and consumption (9 vs. 15 million /ton) in 2015. Therefore, increasing wheat production is an important national goal to reduce the amount of wheat imports, to save foreign currency and provide food security for the Egyptian people. To face these challenges, vigorous efforts within the wheat research program were directed to improve the genetic potential of new wheat cultivars, develop new production package and introduce wheat into new areas. Within the framework of the 2030 Sustainable Agricultural Development Strategy, Agricultural Development Executive Plan 2014/2015 - 2017/2018, it is expected that the current level of wheat self sufficiency, 55-60%, would reach to 74% by 2018 and 85% by 2030. In the last five wheat seasons a great effort was made to increase wheat production through the Wheat National Campaign (WNC) which started in 2011/2012 season with 1257 demonstration plots in 14 wheat major production governorates and reached to 3411 demonstration plots in 2015/2016 season in 24 governorates. The direct impact of this campaign was the increase of the amount of wheat sold to the government; it reached a record 5.3 million ton in 2013/2014 season which is equivalent to 60% of the wheat required for making the subsidized bread (9 million ton). If this trend continued, achieving the goal of 74% self- sufficiency by 2017/2018 would be feasible.

Keyword: Wheat National Campaign, Wheat improvement, Production technology, Self-sufficiency in wheat

6. Enhancement of ABA receptor function confers water-saving drought tolerance in wheat

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Abstract

Global climate change has accelerated land degradation among other environmental disorders, which led to massive loss of crop production and may threaten food security in many countries. Especially, drought is the main cause of decreased crop production, thus novel strategies to enhance crop drought tolerance is urgently needed to secure the stable food supply for expanding population. Abscisic acid (ABA) is a plant hormone involved in drought tolerance. ABA inhibits protein phosphatases (PP2Cs), negative regulators in the ABA signaling pathway, by binding to ABA receptor (PYR/PYL). The inhibition to PP2Cs triggers ABA signaling pathway to activate plant drought tolerance machineries. This ABA signaling pathway is commonly found from terrestrial plants, modulating PYR/PYL can be a good option to improve crop drought tolerance. To investigate the effect of emphasized ABA signaling to drought tolerance and the other physiological traits in wheat, we generated the transgenic wheat overexpressing wheat PYR/PYL (TaPYLox). Transcriptome analysis revealed that many ABA responsive genes were induced in TaPYLox even under non-stress condition, referring TaPYLox acquired preemptive drought response machinery with ABA hypersensitivity. TaPYLox presented decreased stomatal conductance and transpiration rate, suggested the enhanced drought tolerance of TaPYLox is based on repressed transpiration with close-prone stomata. Water-use efficiency based on the rate of photosynthesis and transpiration was increased in TaPYLox, while the biomass amount and seed yield produced from 1L of water is significantly increased in TaPYLox. Our study indicates that the enhancement of ABA receptor expression contributes to not only drought tolerance but also the "water-saving drought tolerance" phenotype which can perform highly efficient CO_2 fixation with limited water.

Keywords: Climate change, Plant hormones, Physiological traits, Wheat, Water use efficiency

7. Defoliation in sorghum and cowpea can increase photosynthetic rate and water use efficiency under drought stress

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Abstract

Drought is the major constraint for realizing high crop yields in dry areas. In these areas, because of low soil moisture and high evapo-transpiration demand, the balance of water uptake and transpiration in plant is incommensurate. On the other hand, water uptake is partly determined by the ratio of root length to leaf area (RL/LA). To optimize the balance and enhance the RL/LA, studies have been made to increase root mass, in particular deep roots. The reverse idea to optimize this ratio is defoliation which is excision of the lower parts of leaves. To evaluate the effects of defoliation, grain sorghum (cv. 'Tabat') and cowpea (line 'TVu-7778') were used as the study materials. Two plants of each crop species were grown in a pot filled with sandy soil. At flowering stage (one of the most sensitive growth stages to drought), different levels of soil moisture treatments were set, and non-defoliated 10 plants (control) in each soil moisture treatment were carried into growth chamber. Photosynthetic rate per plant (P_{plant}) was determined by "chamber method" by monitoring air flow rate, and CO_2 concentration of both input and output in the chamber. Transpiration rate per plant (E_{plant}) was monitored by weighing each pot continuously. Same measurements were conducted for 20%, 40%, 60% and 80% defoliated plants in each soil moisture treatment. Responses to defoliation were almost similar in both crops. P_{plant} decreased with increasing the magnitude of defoliation in wet soil treatments. In dry ones, on the other hand, P_{plant} increased with increasing the magnitude of defoliation, that is, with decreasing leaf area. The most appropriate defoliation magnitude was higher in lower soil moisture. E_{plant} and physiological water use efficiency (P_{plant} / E_{plant}) showed almost similar trend with P_{plant}. These results suggest that defoliation has the potential to become new appropriate crop cultivation technology in the drylands.

Keywords: Drought, Water balance in plants, Root length/leaf area ratio, Defoliation, Cowpea

Theme 2. Sustainable management of scarce water resources

1. Coping with the water scarcity issues through improving water productivity: the case of the irrigated cereal activity in Tunisia

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Abstract

Within the context of climate change and increasing water scarcity, the development of irrigated agriculture is key to deal with the food challenges. Tunisia is facing an imminent risk of water shortage given that water supply has reached its limit with current water availability already being below the poverty line (450m^3/capita/year). The irrigated agriculture consumes 80% of the available water and therefore it remains the main sector that might provide water saving for use in other sectors. However, the irrigated crops should achieve optimum yields in order to increase production and meet peoples' needs. The irrigated cereal crops, which account for only 7% of the total cereal area, contribute to 25% of the total cereal production. However, the yields are far below the potential level. In order to identify reasons for low productivity, field surveys were carried out among a sample of 120 farmers in the governorates of Beja and Siliana during the 2013-2014 cropping year. By using two-step nonparametric approach, the optimal production of the durum wheat crop was estimated in order to assess the yield gap and to identify possible avenues for improvement. The results showed that the water productivity was only 8kg ha^{-1}mm^{-1}, well below the expected potential. The estimates showed that the durum wheat production could be increased by 28% by using improved technology. The results also showed that this improvement is possible, especially among farmers who have received agricultural training. Moreover, farmers might reach better production targets on large size plots and by practicing suitable crop rotation.

Keywords: Water scarcity, irrigated cereals, durum wheat, yield gap, Tunisia.

1. Introduction

By 2050, the global population will reach 9 billion and the main challenge would be how to feed it given the limited resources of land and water within the context of the climate change. In fact, the increase of the food demand and the unwise use of the resources make the production efforts unable to meet needs. It is projected that the consumption per capita will exceed 3000 kcal/day in 2050 because of change in socioeconomic conditions. This, combined with the population growth, would lead to an overall demand for agricultural products to grow at 1.1% per year. Hence FAO suggests that the agricultural production should increase by 60% in order to satisfy the food demand by 2050 (Alexandratos, 2012).

On the other hand, agricultural activity is facing resources constraint that may jeopardize the production efforts to feed the growing population. The major concerns are the land and water availability. The available land per capita will decrease to 0.181 ha by 2050 from 0.4 ha in 1960. The water supply per capita will decrease to well below 6000 m^3 by 2030 from over 12000m^3 in 1960s. Any country using more than 20% of its renewable resources for irrigation is crossing the threshold of water scarcity (Alexandratos, 2012; Postel, 2000).

Tunisia is facing an imminent risk of water shortage as the current water availability is already below the poverty line (450m^3/capita/year). The irrigated agriculture consumes 80% of the availabe water and therefore it remains the main sector that might provide water saving for other sectors. However, the irrigated sector plays the key role in the agricultural development by providing 35% of the national agricultural production and Tunisian government plans to increase this share to reach 50%. Hence, the irrigated agriculture should achieve optimum yields in order to increase production and meet the domestic needs.

The irrigated agriculture faces difficulties of aging irrigation system, soil salinization and inefficient use of the water. Irrigated cereals contribute to 20% of the cereal production; this could reach up to 40% in the dry year. Despite that, the current yields remain well below the potential (>70 q/ha). Hence, one should ask two main questions: (i) What are the optimal yields that might be achieved by using resources efficiently? (ii) What are the significant factors impacting the production process? This study analyzes the technical efficiency of the irrigated cereal production and attempts to identify factors that cause variability.

2. Materials and method

2.1 Cereal sector and importance of the irrigated activity

The cereal production is the main strategic activity in Tunisia. The average area is around 1.4 million ha, about one-third of the total arable land, involving some 250 000 farms (50% of the total number of Tunisian farms). The sector provides some 2 millions work-days per year and contributes 13% to the agricultural GDP of the country. However, the cereal production is mainly rainfed activity. Hence, as showed in Figure 1 and Figure 2, the area and production fluctuate from year to year.

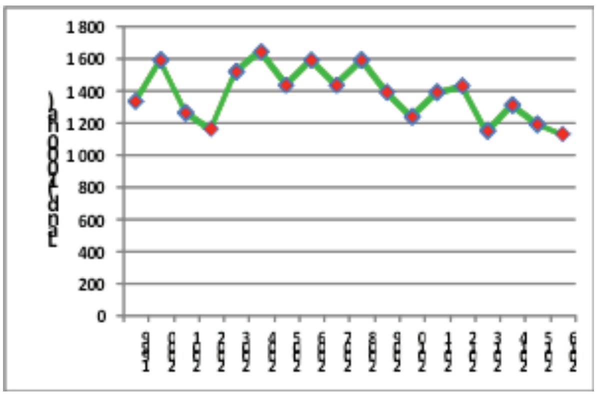

Figure 1. Evolution of cereal area

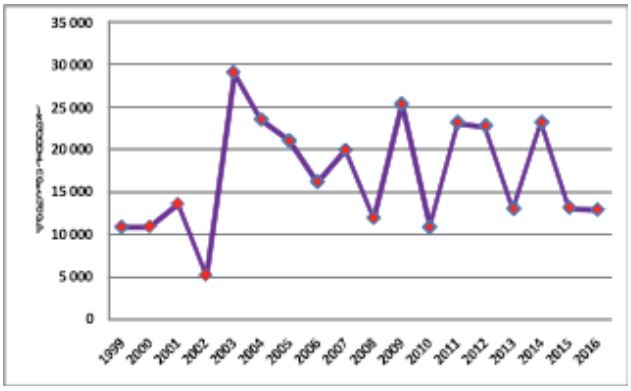

Figure 2. Evolution of cereal production

In order to minimize this fluctuation, the irrigated cereal activity was developed and the area reached up to 100,000 ha in 2010 (Fig. 3). This irrigated activity accounts for only 6% of the total cereal area providing around 22% of the total national cereal production. In the years of drought this could reach up to 40%, as was the case in 2002. It showed less fluctuation (Fig. 4) than the rainfed production. The sector grew because of the efforts of the State to provide several incentives to farmers (subvention of the irrigated equipments, preferential water price, etc.).

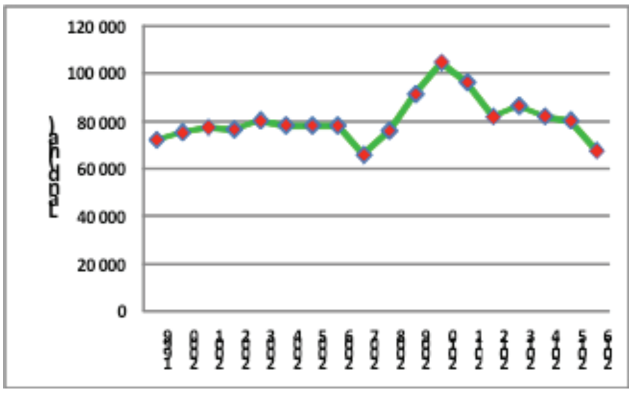

Figure 3. Evolution of the irrigated cereal area.

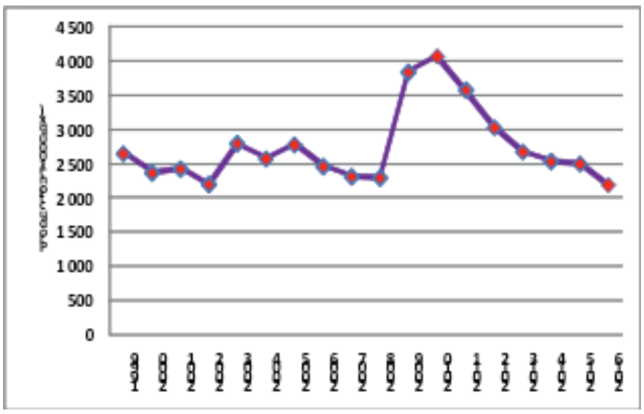

Figure 4. Evolution of irrigated cereal production.

2.2 Research field and survey

Despite of the efforts to enhance the irrigated cereal activity, the yields remain well below the expected potential. The currently average yields, 36 qx/ha, should be improved in order to ensure more production and enhance the valorization of the irrigation. In order to make diagnosis of the activity we have carried out survey with a sample of 120 farms in two different regions, Beja and Siliana, located in the North of the country (Fig. 5). The average rainfall is 600 mm/year and 400mm/year, respectively in the two regions. In Beja the water for irrigation is from a dam (a public resource) while in Siliana both public (dam) and private (wells) resources are used. This difference gives us the opportunity to analyze two different systems of the irrigation management. In fact, the public resource is managed collectively by farmers with limited access, while the private resource provides free access in quantity and time.

The survey was carried out in 2015 by interviewing farmers using a questioner. The questioner characterized the faming system and got technical and economical data regarding the irrigated cereal activity experienced during the previous crop year 2014.

Figure 5. Location of the Gouvernorates Beja (green) and Siliana (red).

2.3 Analysis Approach

Improving the water productivity is possible by ensuring an increased yield and/or by enhancing the water use efficiency. In order to deal with issues we assessed the farms performance using the Data Envelopment Analysis (DEA) approach (Thanassoulis, 2001; Liu, et al., 2013). In addition we tried to identify some drivers affecting this performance in order to set up suitable strategies that might help to improve the productivity. For that we used Tobit model (Tobin, 1958; Wilson et al., 2001, Latruffe et al., 2002; Wadud, 2003; Dimara et al., 2005; Wossink and Demaux, 2006).

3. Results and discussion

3.1 Descriptive analysis

The total agricultural area covered in the survey was 3628 ha. The potential irrigable area

was 2182 ha (1516 ha in the Beja all irrigated from dams and 666 ha in the Siliana region of which 273 ha were irrigated from dams and 393 ha irrigated from wells. Farmers practice complimentary irrigation using mainly sprinkler system. However, the total land use was 2120 ha, which represented only 58% the total agricultural area. The total area of the cereal crops was 1104 ha of which 705 ha was under durum wheat cultivated by 106 farmers. Therefore, given the importance of the durum wheat, we will focus our analysis on this crop.

3.1.1 Water consumption and productivity

In order to irrigate the durum wheat, the farmers used the available water at the level of 930 m^3/ha, with large differences in the two regions. In Beja, the water consumption was 789 m^3/ha while in Siliana it was 1034 m^3/ha, perhaps because of the difference This difference in the rainfall. In fact by considering only the farms from the public irrigated area the consumption was 1191 m^3/ha in Siliana. The farmers from the private irrigated area of Siliana consumed only 849 m^3/ha.

The practice of the complementary irrigation allowed the surveyed farmers to achieve an average yield of 39 qx/ha. The result showed only a small difference between Siliana and Beja (39.5 qx/ha against 38.6 qx/ha). The farms from private irrigated area of Siliana achieved 37.5 qx/ha yield while those from the public irrigated area achieved 41.2 qx/ha. These results may confirm the straightforward relationship between the water consumption and the achieved yields. So the water productivity remains a principal question that should be addressed. In fact, by taking into account the rainfall, the productivity reached only 8kg/ha/mm which is far from the expected potential productivity of 16 kg/ha/mm (Lasram *et al*., 2015; Sander and Win, 2014). This low water productivity was also confirmed by El Amri *et al.* (2014).

3.1.2 Economic analysis

The results (Table 1) showed that the total cost of production was 1221.04 Tunisian Dinars (TND)/ha. The main expenditure items were harvesting and fertilizers, which represented 24% and 18%, respectively of the total costs. The irrigation costs was 87.58 TND/ ha (only 7% of the total costs).

Table 1. Distribution of the item costs of the durum wheat

	TDN/ha	%	Min	Max	S.D
Seeds	162.28	13	69.6	264	35.43
Mecanization	147.94	12	45	367	60.51
Fertilization	218.97	18	49.5	378	76.48
Irrigation	87.58	7	17.82	393.12	71.02
Patologic treatment	144.34	12	0	750	134.53
Hired labor	84.40	7	6.42	600	73.94
Harvest	290.60	24	112	500	56.68
Transport	84.93	7	0	496	99.92
Total	1221.04	100	752.95	1958.70	276.46

The gross returns reached an average of 2813 TND/ha (Table 2), giving a profit margin of 1592 TND/ha. The results did not show huge difference between the two regions as well as between the type of water resources. However, although the total costs in Siliana and public water resource area exceed respectively those in Beja and private water resource area, the achieved production value allowed better gross margin in both the cases.

Table 2. Economical results of the durum wheat crop (TND/hectare)

	Production	Expenditures	Gross Margin
Beja	2767	1193	1574
Siliana	2846	1241	1605
Private resource	2741	1201	1540
Public resource	2838	1228	1610
Total	2813	1221	1592

3.2 Efficiency analysis

In order to assess the performance of the durum wheat activity we assume that the technology process may be represented by the function given blow:

$$\text{Prod} = \boldsymbol{f}(\text{Sup, Sem, Mecan, Fert, wat})$$

Where, **Prod:** durum wheat production in qx**; Sup:** Cultivated area in hectare**; Sem:** the quantity of the seeds in qx**; Mecan:** the number of tillage hour; **Fert:** the quantity of used fertilizer in qx; and **Wat:** the quantity of the irrigation water in m^3**.** The descriptive statics of these variables were showed in the Table 3.

Table 3. Descriptive Statistics of DEA variables

Variable	Average	Min	Max	S. D.
Prod (qx)	263.91	17	5600	600.94
Sup (ha)	6.65	0.5	140	14.60
Sem (qx)	12.31	1	266	27.69
Mecan (h)	43.16	2.5	1120	117.88
Fert (qx)	33.09	1	630	73.26
Wat (m3)	5057.44	288	70000	8456.11

By considering the technology process and solving the linear program P1 and P2, we have computed the technical efficiency. The results (Table 4) showed that the average technical efficiency reached 0.65 and 0.72 under the CRS and VRS assumption, respectively. This means that given the current level of the input use the production of the durum wheat should be increased by 28%. As showed in the Table 4, only 15 farmers (14%) performed perfectly the technology process and they were able to use the inputs optimally. Only 10 farms were operated at their optimal size by reaching an efficiency scale of 100% .Regarding the type of the water resource, the results showed that farms using private water resource were more efficient than those using the public water resource.

Table 4. Results of the technical efficiency measurements

	Average	Min	Max	SD	ET=1	Public Resource	Private Resource
ETCRS	0.65	0.32	1	0.16	7	0.64	0.69
ETVRS	0.72	0.34	1	0.17	15	0.71	0.76
ES	0.90	0.62	1	0.08	10	0.90	0.91
WUE	0.42	0.06	1	0.22	5	0.42	0.41

We computed the water use efficiency by solving the linear program P3. The results showed that the average water use efficiency was only 42%, indicating that more than 50% of the used quantity was an overconsumption.

By clustering farms in three groups regarding their performance level (Table 5) the results showed that 63 farms (59.8%) achieved technical efficiency level under 75%. This meant that more attention should be payed to these farms in order to increase effectively the technical efficiency and gain more productivity. Furthermore the results showed that 69% of farms were under 50% of water use efficiency, which confirm that it is really possible to improve water productivity through saving the overconsumption.

Table 5. Distribution of the farms number regarding the level scores

Scores	<0.5		0.5=<scores<0.75		>=0.75	
	Number	%	Number	%	Number	%
CRS	20	18.8	59	55.7	27	25.5
VRS	7	6.6	56	52.8	43	40.6
SE	0	0	6	5.5	100	94.5
WUE	73	69	23	22	10	9

3.3 Determinants of the technical efficiency

In order to develop suitable strategies for improving technical efficiency, we have to identify some exogenous variables that may affect the ability of the farmers to master the technology process. These variables include farm structure, farming system and agronomical practices, the social components of households, the land ownerships, the market access, etc. In order to estimate the Tobit model we selected six variables as follows:

- **sup** : Cultivated area in hectare
- **Age** : Farmers age
- **fag** : agricultural training (١=yes, ٠=No)
- **Mfv** : Landownership (1=yes, 0=No)
- **Ass** : Crops rotation practice, (1=yes, 0=No)
- **Elv** : Livestock activity (1=yes, 0=No)

The descriptive statistics of these variables are presented in the Table 6. Given this selection of variables we have estimated the following Tobit model

$$ET_{vrs} = \beta_0 + (\beta_1 * \sup) + (\beta_2 * Age) + (\beta_3 * fag) + (\beta_4 * Mfv) + (\beta_5 * Ass) + (\beta_6 * Elv) + \mu$$

The results (Table 7) showed that four variables explained the technical efficiency distribution and had significant impact on the production performance.

Table 6. Descriptive statistics of the explicative variables

Variable	Average	Min	Max	S. D
Sup	6.65	1	140	14.605
Age	48.25	22	86	12.213
Fag	0.24	0	1	0.427
Mfv	0.81	0	1	0.393
Ass	0.57	0	1	0.498
Elv	0.61	0	1	0.489

Table 7. Results of the Tobit Model

LR chi(2)=36,60			Prob>chi(2)=0,0000	
Variable	**Coefficient**	**S.E.**	**t**	**Prob>t**
Sup	0,0096	0,0032	2,93	0,004***
Age	-0,0013	0,0014	-0,92	0,361
Fag	0,1474	0,0411	3,58	0,001***
Mfv	-0,0727	0,0436	-1,67	0,099*
Ass	0,0618	0,0342	1,81	0,074*
Elv	0,0365	0,0346	1,05	0,295
Constant	0,7152	0,0865	8,26	0,000

***Significant at 1%*Significatif at 5%

The results showed that farmers who cultivated large area were more technically efficient. Farmers whom had participated in agricultural trainings achieved higher efficiency scores. The practice of the crop rotation also led to a better level of technical efficiency. On the other hand, the landowners were less technically efficient than the leaseholder farmers.

3.4 Discussion

By proving the weakness of the technical efficiency, the results revealed a production gap that should be bridged in order to improve the water productivity. Given the current mix of inputs, farmers could increase their production by 28%. This meant that the average of yield could be increased up to 50 qx/ha, which may increase the water productivity up to 10kgha^{-1}mm^{-1}. Regarding the irrigation practice the results showed inefficient use of the water resource was 60%. Recent studies showed that using properly, the complementary irrigation should improve water use efficiency and therefore the increase the water productivity. Hammami *et al.* (2016) pointed out that complementary irrigation in the public irrigated area of Mateur and Medjez el Bab (Beja) allowed a 33.5% and 7% increase, respectively, compared to rainfed crop production. Mailhol *et al.* (2004) reported that by following a perfect irrigation scheduling and irrigation dose the yield could reach 60 qx/ha.

However, the possibility to enhance water use efficiency and to increase the water productivity supposes some farms physical features and household characteristics. In our case, we have demonstrated that holding and cultivating large area have a positive effect on the technical efficiency and therefore in improving the water productivity. This result was confirmed also by numerous previous studies (Chebil *et al.,* 2013; Albouchi *et al.,* 2007; Chemak *et al*., 2014)

Benbella *et al.* (2003) argued that the adoption of economic irrigation system and novel techniques allowed rational use of the irrigation water and improved the productivity. In order to master these techniques farmers need training and some technical assistance. Our results showed that farmers receiving training were more technically efficient, as confirmed also by Frija *et al.* (2009)

Our results also showed that farmers practicing crop rotation were technically more efficient. As reported by Hatfield *et al.* (2001) and Tennakoon and Hullugalle (2006), the adoption of crop rotation may improve the water use efficiency by 25 to 40%.

4. Conclusion

Improving water productivity remains one of the main alternatives to deal with the water scarcity issues and to ensure agriculture production to meet population needs. Tunisia is facing serious water shortage constraints and farmers should use water irrigation efficiently. Given the current state of the irrigated activity and based on our results, it is really possible to improve the water productivity. Our study showed that given the current mix of the inputs use the production of the wheat can be increased by 28% with simultaneous increase in water productivity. Moreover, the results showed that farmers were having an overconsumption of the irrigation water. There was a need for setting up training programs to improve farmers' skills regarding the irrigation and agronomical practices. Renting the land to farmers may also encourage them to work adequately and to improve the water productivity. Moreover, sensitizing farmers to reserve large plots for the durum wheat crop will also help.

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2. Rainfall fluctuation at the central dry zone, Myanmar

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Abstract

Annual rainfall of the central semi-arid zone of Myanmar is about 600 mm and the coefficient of variation is 0.25. Seasonal and inter-annual fluctuations are common. The wet season is separated into two periods, the early monsoon (May – June) and the late monsoon (August – October). Correlation between inter-annual time series of the early and the late monsoon is not significant (r = -0.25). There is no remarkable correlation of inter-annual time series of the early monsoon with Southern Oscillation Index (SOI), North Atlantic Oscillation (NAO) and Arctic Oscillation (AO). On the other hand, there are significant correlations of the late monsoon with SOI at lag 0 – 5 months and with NAO and AO at lag 7 – 10 months. It is expected that there are tele-connections of the late monsoon with the Pacific Ocean at lag 0 – 5 month and with the Atlantic Ocean at lag 7 – 10 months. Regarding the correlations of inter-annual time series of the early and late monsoon with Global Sea Surface Temperature (GSST), there are significant correlations of the early monsoon on the Pacific and Indian Ocean and those of the late monsoon on the Pacific and Atlantic Ocean. The sea area on the Pacific Ocean of the significant correlations with the early monsoon is different from that with the late monsoon. Anomaly time series of the spatial averaged SST value over the significant correlated sea area indicates significant correlations with anomaly time series of the early and late monsoon (at the significance level <0.01). Time series of SST difference between the positive and negative correlated areas of dipole (positive – negative) indicates stronger correlations with the original time series of the monsoon rainfall ($|r|$>0.6).

Keywords: Inter-annual rainfall fluctuations, Southern Oscillation Index, North Atlantic Oscillation, Global Sea Surface Temperature, Monsoon

Introduction

In arid lands, rainfall time series shows apparent fluctuations in addition to low amounts (Goody and Wilkinson, 1987). Such fluctuations of rainfall time series are critical for rainfed agriculture in arid lands (Lee *et al.,* 2014). Prior to the planning of water resources, agricultural and forest development, hydrological and meteorological investigations are essential. Especially evaluation of seasonal and interannual rainfall fluctuation is important step.

Myanmar is located in the tropical zone of Southeast Asia and extends from the southwester coastal region facing the Indian Ocean to inland highland region. While the annual rainfall is more than 1,000 mm mostly over the land, it is only about several hundred mm in the central zone. Therefore rice cultivation in paddy field is not common there and rainfed agriculture is conducted instead. However the life of inhabitant is often swayed by the fluctuation of rainfall.

As a major factor of rainfall variations, effects of teleconnections such as El Nino and La Nina have been reported. Teleconnection with Global Sea Surface Temperature (GSST) promotes transport of heat and moisture and causes change in rainfall and temperature. For example, it is well known that the Southern Oscillation Index (SOI), which is given as gradient of atmospheric pressure between Darwin and Tahiti, has connections with climate in various places in the world (Jin *et al.,* 2005; Zaroug *et al.,* 2014). Connection of the North Atlantic Oscillation (NAO), which is given as pressure difference between the Iceland low and Azores high, with meteorology in the Asia-Pacific region in addition to Europe-Africa region has been reported (Pozo-Vazquez *et al.,* 2000; Rodriguez-Fonseca *et al*., 2006; Sun *et al.,* 2015).The Arctic Oscillation (AO) has been reported to have influence on whole of the northern hemisphere and its connection with Asian climate has also been reported (Gong *et al.,* 2011).

In this study connection of these indices, SOI, NAO and AO with rainfall in the central dry zone of Myanmar is presented. Link of rainfall time series of various areas in the world with SST over the oceans has been reported by plethora of researchers (Shinoda and Kawamura, 1994; Yasuda *et al.,* 2009; Funk *et al.,* 2014; Kumbuyo *et al.,* 2015).

Effects of SST difference between two sea regions (dipole) on local climate have been reported (Iizuka *et al.,* 2000). Summer monsoon in the eastern Asia is related with SST anomaly of the northern Pacific dipole (Zheng *et al.,* 2014). Shankar *et al.* (2007) reported that SST difference between two sea areas provokes heat and moisture transport and causes rainfall events. Yasuda *et al.* (2009)presented prediction model of summer rainfall over the Loess Plateau of China using strong correlation between the summer rainfall and SST difference over northern Pacific Ocean. This study deals with the connection of interannual time series of rainfall of the central dry zone of Myanmar with global sea surface temperature.

2. Data and methodology

2.1 Rainfall

In this study, monthly rainfall data at Nyaung Oo in the central dry zone (Figure 1) for 34 years from 1980 to 2013 was obtained from the Meteorological Agency, Myanmar and used for analysis. As shown in Figure 2, variation of the annual rainfall is quite large. The average of the annual rainfall is 633 mm and the coefficient of variation is 0.25. For the 34 years, the maximum and minimum rainfall was 1024 mm in 2011, 273 mm in 1982 respectively.

The tendency of low rainfall appeared in 1990's and that of high appeared in 2000's. The return period of drought is shown in Table 1. Since the return period of 5 and 10 years is for 486 and 407 mm respectively, there is large vulnerability of rainfed agriculture to drought. As shown in Figure 3, monthly average rainfall indicates bimodal (two peaks), the early (May and June) and late (August, September and October) monsoon. The mean rainfall of the early and late monsoon is 180 and 361 mm respectively. The variations of the two monsoons ahave significant effect on the rainfed agriculture in the central zone.

Figure 1. Location of Nyaung-Oo in Myanmar

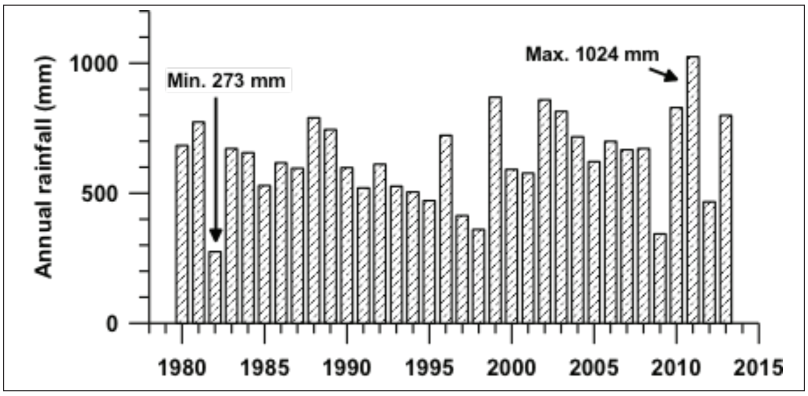

Figure 2. Annual rainfall. The average: 633 mm, CV: 0.25.

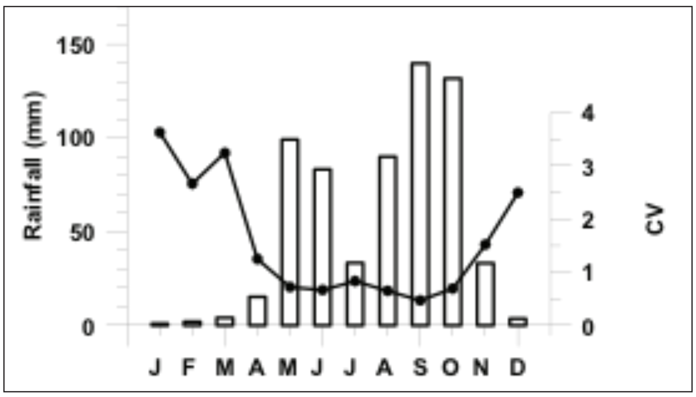

Figure 3. Monthly average rainfall and the coefficient of variance (CV).

Table 1. Return period of drought occurrence (Annual rainfall)

Return period (year)	5	10	20	30
Rainfall (mm)	486	407	343	309

Figure 4 shows the time series of annual anomaly of the early and late monsoon. As correlation of the two time series is -0.25, there is no significant correlation between the two. There was tendency of dry season from 1991 to 1998 and that of wet season from 1999 to 2005. These periods suggest periodicity of monsoon synchronisation. On the other hand, from 1980 to 1990 and from 2006 to 2013, positive and negative condition of the early and late monsoon was often seen in addition to large annual fluctuation. Such large fluctuation hampers effective management of water resources in rainfed agriculture. The two monsoons depend on different weather factors.

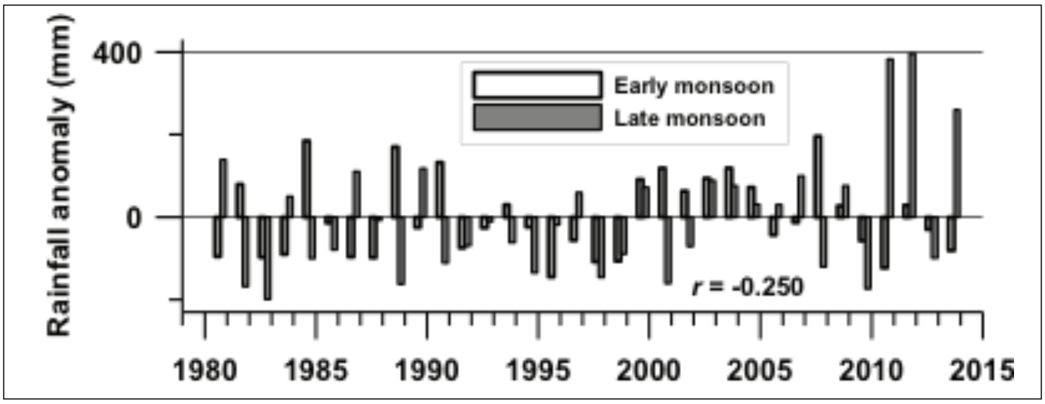

Figure 4. Interannual anomaly of rainfall. Total amount of rainfall for the early monsoon (MJ) and the later monsoon (ASO) is shown as anomaly.

2.2 Sea Surface Temperature (SST)

In this study, teleconnections of rainfall during the monsoons with Global Sea Surface Temperature (GSST) were evaluated. Data of Hadley Centre Global Sea Ice and Sea Surface Temperature (HadISST) was used (Rayner *et al*., 2003). Cross-correlations of interannual anomaly of monsoon rainfall with anomaly of GSST were calculated. For the early monsoon, cross-correlations of interannual anomaly time series of total rainfall from May to June with that of GSST at monthly lags were obtained. For the late monsoon, those from August to October with GSST were obtained. For the evaluation of real time phenomenon and prediction several months in advance, cross-correlations at lag 0-1 month and 5-8 months were evaluated. Cross-correlations of interannual anomaly of SST difference between dipole sea regions (positive and negative correlations) with that of monsoon rainfall were evaluated (Zheng *et al.,* 2004; Shankar *et al.,* 2007; Yasuda *et al.,* 2009).

3. Analysis and discussion

3.1 Cross-correlations of rainfall during the monsoons with SOI, NAO and AO.

Table 2 indicates cross-correlations of rainfall during the monsoons with SOI, NAO and AO. While the early monsoon shows significant correlation (the significance level < 0.05) with NAO and AO only at lag 4 months, apparent correlation is not there. The late monsoon shows significant correlations with SOI at 0 – 5 months lag and NAO and AO at 8 – 10 months lag. Especially at lag 7- 8 months, correlation is strong. The late monsoon has teleconnection with the Pacific Ocean at 0 – 5 months. With the Atlantic Ocean and the northern hemisphere teleconnection is at lag 8 – 10 months.

3.2 Correlations of interannual time series of rainfall in the monsoons with GSST

Cross-correlations of interannual rainfall time series of the early and late monsoon at 0-1 month and 5 -8 months are shown in Figure 5-1. Correlation value, $|r|$ = 0.33, 0.43, and 0.53 are corresponding to the significance level 0.05, 0.01, and 0.001 respectively. At shorter lags, 0 -1 months, the negative correlation region spread off coast of Peru and the negative correlation region spread over the western Pacific Ocean. A dipole is formed in the east and west of the Pacific Ocean. The negative correlations are shown over few areas in the Indian Ocean and these suggest effects of monsoon from the Indian Ocean.

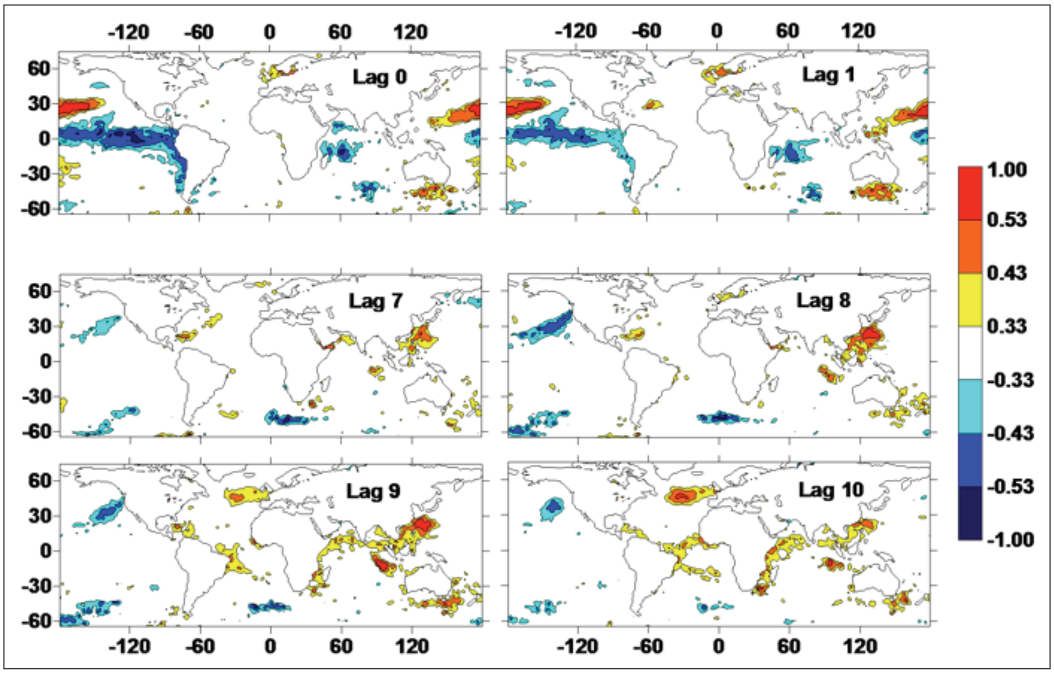

Figure 5-1. Correlation of rainfall anomaly of the early monsoon (MJ) with SST anomaly. Correlation, 0.33, 0.43 and 0.53 is corresponding to the significance level, 0.05, 0.01, and 0.001 respectively.

At longer lags, 5-6 months, significant positive and negative correlations are seen over the Chinese Offing and off the western coast of North America, respectively. These correlated sea regions form a dipole over the Pacific Ocean. At lag 7 – 10 months, significant negative correlations are over the southwest of South Africa in the Indian Ocean. At lag 9- 10 months, positive correlations are spread west of Britain Island in the Atlantic.

Cross-correlations of rainfall in the late monsoon with the GSST are shown in Figure 5-2. Rainfall in the late monsoon shows significant positive correlations over the Atlantic Ocean more than that of the early monsoon. At all lags in the figure, significant positive correlations are spread from off the northeastern coast of South America to off the northwestern coast of Africa. Positive correlations are seen also in the south of Greenland at all lags.

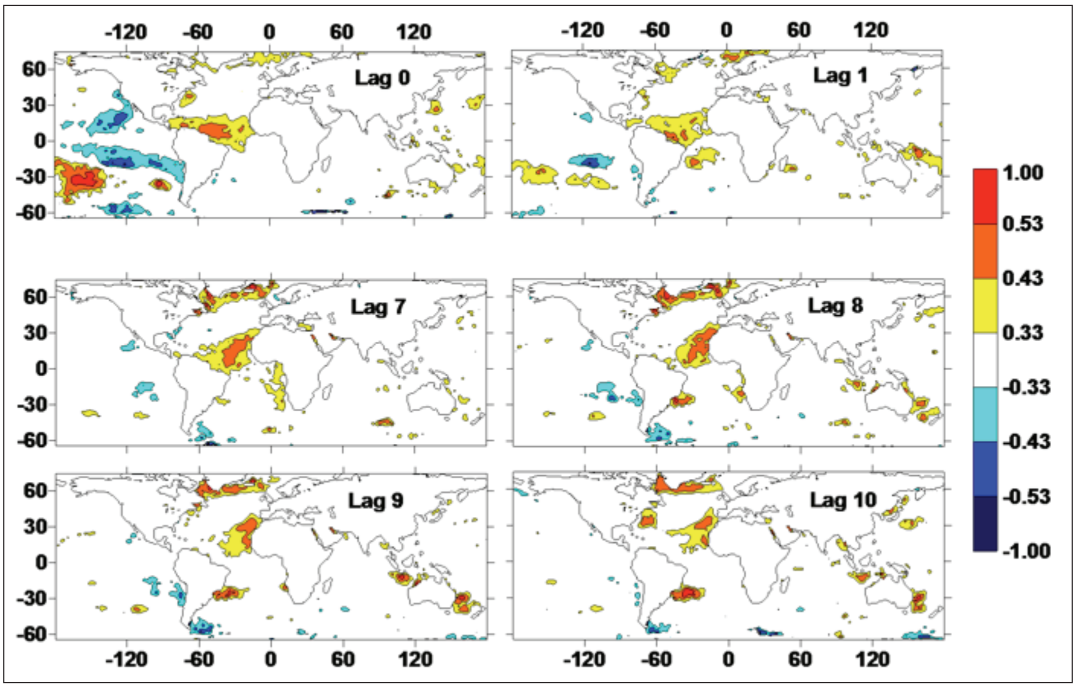

Figure 5-2. Correlation of summer rainfall anomaly of the late monsoon (ASO) with SST anomaly. Correlation, 0.33, 0.43 and 0.53 is corresponding to the significance level, 0.05, 0.01, and 0.001 respectively.

At lag 0, strong positive and negative correlations are spread over the east-southern Pacific Ocean. Positive correlations are spread in area between the South America and Africa. At lag 1 month, the positive and negative correlations in the Pacific Ocean continue and become weaker. Positive correlated areas are scattered in the northern Atlantic Ocean. At lag 7 – 10 months, while correlated areas in the Pacific Ocean disappear, the positive correlated areas in the Atlantic Ocean remain and spread expansively. At lag 8-10 moths, positive correlated area exists in the west of Indonesia of the Indian Ocean.

In the comparison between the early and late monsoon, distribution of significant correlations of the early monsoons are different from that of the late monsoon. At longer lags (7 – 10 months) strong correlations of the early monsoon are emphasized over the Pacific and Indian Ocean, while those of the late monsoon are remarkable over the Atlantic Ocean. At lag 0 (real time), dipoles of the both monsoon are formed in different location. Such difference in teleconnection suggests that weather factor of the two monsoons are also different.

3.3 Extraction of significant correlated SST

To evaluate relationship between the interannual time series of rainfall in the monsoon and SST, spatial average of correlated SST was obtained. As shown in Figure 6-1-a, a dipole is formed over the Indian Ocean (off south of Australia: positive and off the northeastern coast of Madagascar: negative). Figure 6-1-b (the top and middle) indicates the interannual time series of spatial averaged SST of these two SST regions. Correlation of the two regions with the rainfall is 0.529 and -0.519 respectively. Correlation of the difference time series of the two SST (positive – negative) with the rainfall is 0.608 (the significance level <0.001) and it is stronger than each original correlation (the bottom of Figure 6-1-b).

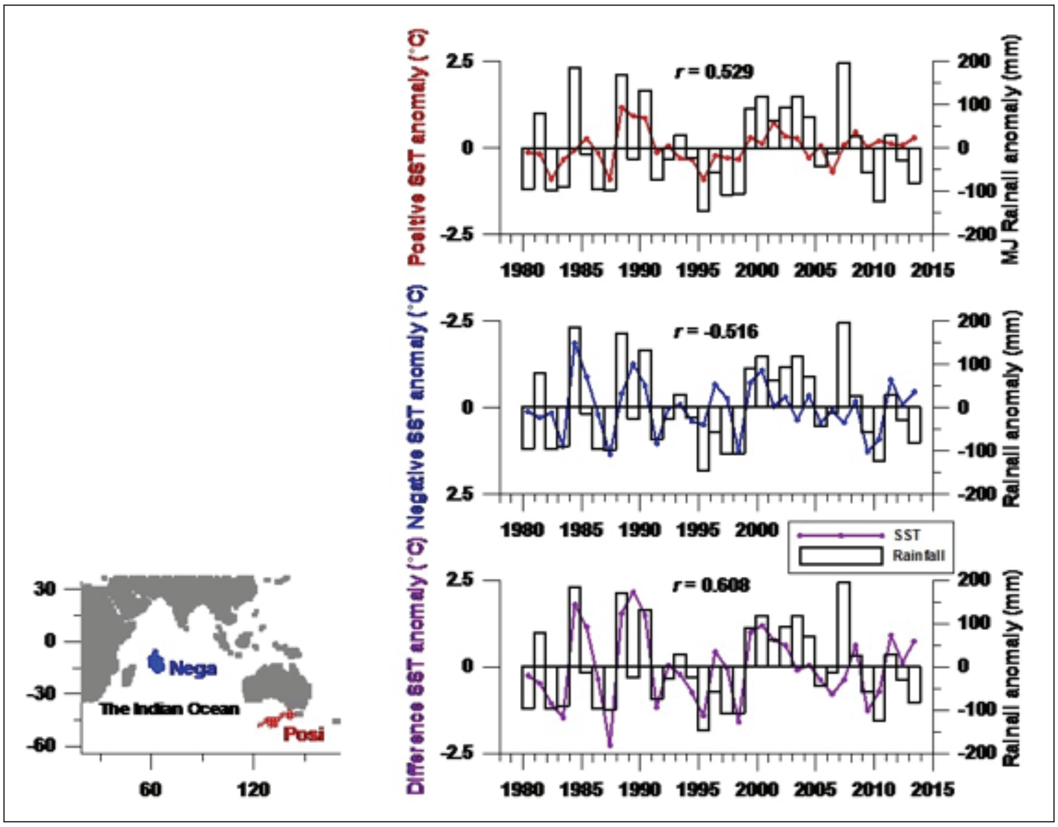

Fig. 6-1a **Fig. 6-1b**

Figure 6-1a. Extracted SST zones of significant correlation with the early monsoon at lag 0 (|r| ≥ 0.43).

Figure 6-1b. Interannual time series of rainfall anomaly (MJ) and spatial averaged SST anomaly at lag 0.

At lag 8 months, positive correlated area in the Eastern China Sea and negative correlated area off the western coast of North America form a dipole at the east and west of the middle latitude of northern Pacific Ocean. Spatial average SST time series of the positive and negative correlated area are shown in Figure 6-2a with total rainfall in the early monsoon. Correlation of the spatial average positive and negative correlated SST with the total rainfall in the early monsoon was -0.542 and 0.596 respectively. Time series of the SST difference between the positive and negative correlated SST (positive – negative) indicated correlation, -0.687 with the rainfall (6-2-b). The correlation is approximately 10 % stronger than each original time series.

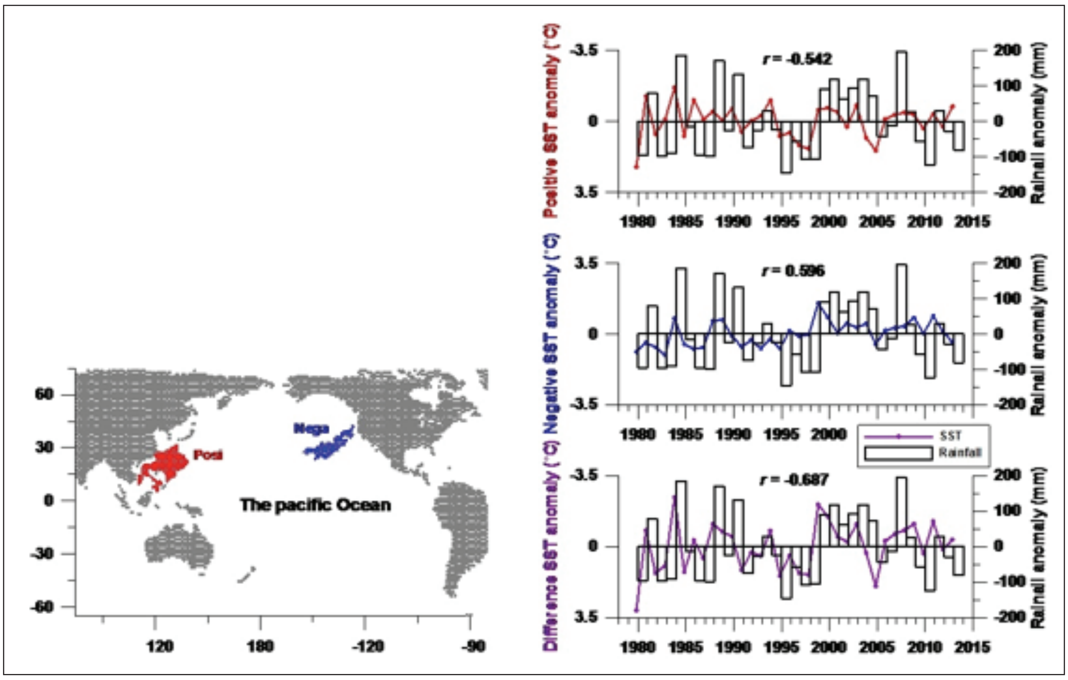

Fig. 6-2a Fig. 6-2b

Figure 6-2a. Extracted SST zones of significant correlation with the early monsoon at lag 8 (|r| ≥ 0.43).

Figure 6-2b. Interannual time series of rainfall anomaly (MJ) and spatial averaged SST anomaly at lag 8.

In the same manner, a dipole over the southern Pacific Ocean at lag 0 is shown in Figure 7-1-a. Spatial average time series of these two SST areas is shown in Figure 7-1-b (the top and middle). Time series of the SST difference between the positive and negative correlated SST (positive – negative) indicated correlation coefficient of -0.687 with the rainfall (6-2-b). The correlation is approximately stronger than each original time series. It indicates that the late monsoon has link with the dipole over the southern Pacific Ocean in the real time.

Correlations of the interannual rainfall time series of the late monsoon with the GSST at lag 0 indicate remarkable distributions over the Atlantic Ocean as the correlation with NAO suggests (Table 2). However a dipole over positive and negative correlated SST areas was not formed. At lag 7 months, significantly correlated SST areas (the significant level < 0.001; $r \geq 0.53$) were extracted as shown in Figure 7-2-a. Two areas, SST area off the northern-east of Iceland (E) and SST area off southern-east Greenland, were extracted. Spatial averaged SST time series of these two areas are shown in Figure 7-2-b. Correlation of these two time series with the late monsoon is 0.590 (E) and 0.600 (W). The rainfall of the late monsoon has links with SST over the northern Atlantic Ocean at lag 7 months. It suggests possibility of prediction of rainfall in the rainy season from GSST.

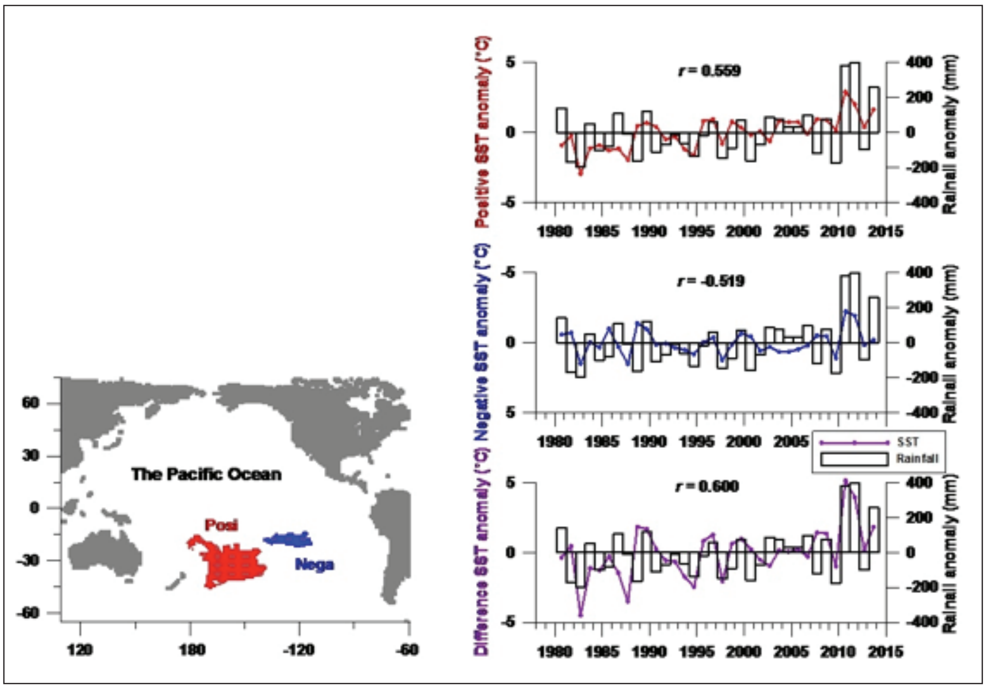

Fig. 7-1a Fig. 7-1b

Figure 7-1a. Extracted SST zones of significant correlation with the late monsoon at lag 0 (|r| ≥ 0.43).

Figure 7-1b. Interannual time series of rainfall anomaly (MJ) and spatial averaged SST anomaly at lag 0.

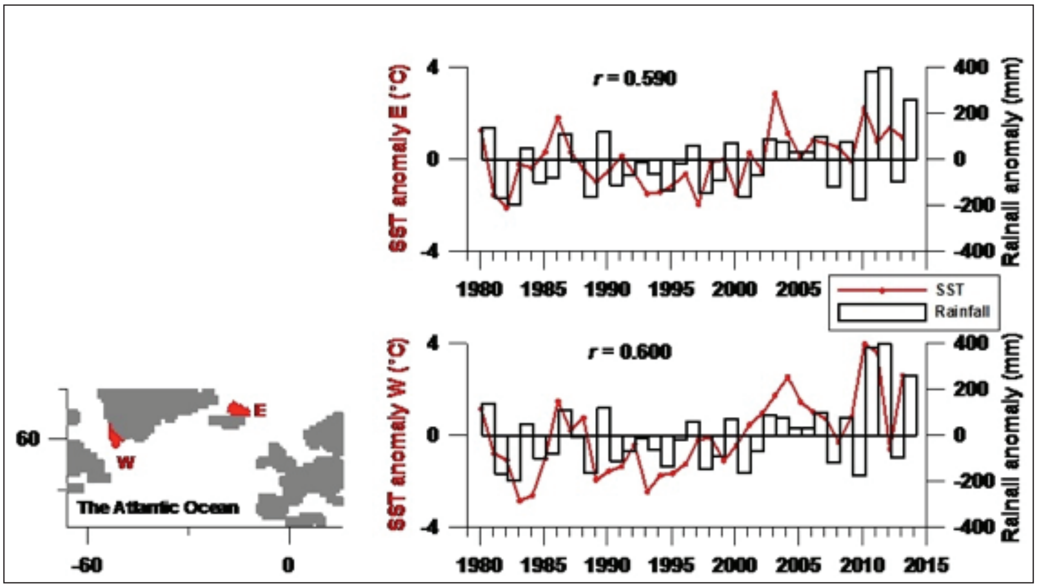

Fig. 7-2a Fig. 7-2b

Figure 7-2a. Extracted SST zones of positive significant correlation (r ≥ 0.53) at lag 7.

Figure 7-2b. Interannual time series of rainfall anomaly (MJ) and spatial averaged SST anomaly at lag 0.

Table 2. Correlations between rainfall anomaly and SOI, NAO and AO.

	Lag (month)	0	1	2	3	4	5	6	7	8	9	10	11
Early monsoon	SOI	0.154	0.295	0.226	0.244	0.211	0.173	0.252	0.270	0.180	0.087	-0.037	-0.078
	NAO	0.268	0.230	0.047	0.151	0.348	0.148	-0.023	-0.071	-0.189	-0.278	-0.040	0.095
	AO	0.308	0.283	0.120	0.171	0.345	0.288	-0.032	-0.154	0.122	0.110	0.111	0.209
Late monsoon	SOI	0.362	0.369	0.365	0.375	0.398	0.371	0.211	0.127	0.039	0.057	0.048	0.152
	NAO	-0.189	-0.177	-0.066	0.011	0.099	-0.126	-0.233	-0.424	-0.458	-0.331	-0.343	-0.154
	AO	-0.063	-0.167	0.065	0.123	0.021	-0.161	-0.184	-0.273	-0.393	-0.360	-0.412	-0.146

Underline indicates the significance level ≤0.05 (|r|≥ 0.33).

4. Conclusions

In the central dry zone of Myanmar (the average annual rainfall, 633 mm), fluctuation of annual rainfall time series is large (CV=0.25). The average monthly rainfall shows two peaks, the early (MJ) and late (ASO) monsoon. There is not significant correlation between the two monsoons. The late monsoon has significant correlation with SOI at lag 0 – 2 months and with NAO and AO at lag 4-7 months. Cross-correlations of the interannual time series of the early and late monsoon were obtained. The early monsoon shows significant correlations mainly over the Indian and Pacific Ocean. The late monsoon shows significant correlations mainly over the Atlantic and Pacific Ocean. Since correlations of spatial average over the significantly correlated SST area with the early and late monsoon are 0.6 - 0.7 at lag 7 – 8 months, possibility of rainfall prediction in the monsoons is suggested. Differences between positive and negative correlated SST areas (positive – negative) show stronger correlation than the original correlation of the each.

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3. Characteristics of individual rainfall events and its dependency on the minimum inter-event time in a dry desert area in north China

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Abstract

The intensity and duration of rainfall event are critical for the infiltration processes and soil moisture replenishment in water-limited ecosystems. What is more, the rainfall event timing and magnitude are important drivers of ecosystem processes and are instrumental in creating landscape heterogeneity in arid regions. To better characterize the individual rainfall events in a dry desert area, a pluviograph record of rainfall processes was analyzed between the year of 2008 and 2015 from Shapotou in the Tengger Desert, China. Results show changing the minimum inter-event time (MIT) alters the number of rainfall events remarkably, the mean rainfall rate declines and the geometric mean event duration rises. The number of rainfall events, the mean rainfall rate, and the geometric mean event duration differed under different criteria of individual rainfall depth (e.g., 0.1, 0.5, 1.0, 5.0 mm), except that for an individual rainfall depth of 0.5, 1.0, and 5.0 mm, the features (the number of rainfall events, the mean rainfall rate, and the geometric mean event duration) mentioned above are identical for MIT=2 and 3 h. Therefore, there is no need for further identification to set MIT at two or three hours in this specific arid desert area. This wide variation in the properties of rainfall events indicates that more attention needs to be paid to the selection and reporting of event criteria in studies of event-based infiltration process and soil water cycling. The selection of a MIT criterion is shown to involve a compromise between the independence of widely-spaced events and their increasingly variable intra-event characteristics.

Keywords: Water-limited ecosystems, Rainfall event, Rainwater infiltration, Soil water recycling

4. An overview of the GCC Unified Water Strategy 2016-2035

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Abstract

The Gulf Cooperation Council (GCC) Countries are situated in one of the most arid regions in the world, with extremely poor endowment of freshwater resources. Despite the water scarcity, the GCC countries have done well in providing water for their ever-increasing population and rapidly expanding economic base. However, this has been achieved only by resorting to relatively very expensive and costly investments in water supply sources and infrastructures manifested by desalination, water treatment, dams construction, as well as groundwater over-drafting. Being an important vector for socio-economic development, there is a need for an efficient and sustainable water management to ensure that the water sector can continue to serve the region's development needs. However, currently the GCC countries are facing several major challenges that are threatening the water sector sustainability. These include increasing water scarcity, increasing costs for infrastructure and service delivery, resources deterioration, increasing environmental and economic externalities, and many others. The main driving forces of these challenges are population growth and changing consumption patterns, low supply efficiencies, lower rates of water reuse and recycling, and low energy efficiency in the water sector. The intensity of these challenges is expected to increase in the future due to the additional driving force of the impacts of climate change. Realizing these challenges, the GCC Supreme Council has issued in its 31st summit (2010) the directive of "*serious and speedy steps should be taken and endorsed by the GCC Supreme Council towards a long-term comprehensive Gulf water strategy*". In 2016, a GCC Unified Water Strategy, 2016-2035 (GCC UWS) has been finalized by the GCC Secretariat General and recently approved by the GCC water ministers. This paper will present the main challenges facing the sustainability of the water sector in the GCC countries, the formulated GCC UWS (main themes and strategic objectives, and targets), the simulated financial, economic and environmental benefits resulting from its implementation, and its expected overall contribution to the water sector sustainability in the GCC countries.

Keywords: Gulf Cooperation Council, Water scarcity, Resource deterioration, Environmental benefits

5. Temperature and precipitation changes in Extensive Hexi Region, China, 1960–2011

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Abstract

Global change has been evident in many places worldwide. This study provides a better understanding of the variability and changes in frequency, intensity, and duration of temperature, precipitation, and climate extremes in the Extensive Hexi Region, based on meteorological data from 26 stations. The analysis of average, maximum, and minimum temperatures revealed that statistically significant warming occurred from 1960 to 2011. All temperature extremes displayed trends consistent with warming, with the exception of coldest-night temperature (TNn) and coldest-day temperature (TXn), particularly evident in high-altitude areas and at night. Precipitation and rainy days slowly increased with no significant regional trends, mainly occurring in the Qilian Mountains and Hexi Corridor. The significance of changes in precipitation extremes during 1960–2011 was high, but the regional trend of maximum 5-day precipitation (RX5day), the average precipitation on wet days (SDII), and consecutive wet days (CWD) were not significant. The variations in the studied parameters indicate an increase in both the extremity and strength of precipitation events, particularly in higher altitude regions. Furthermore, the contribution from very wet precipitation (R95) and extremely wet precipitation (R99) to total precipitation also increased between 1960 and 2011. The assessment of these changes in temperature and precipitation may help in developing better management practices for water resources. Future studies in the region should focus on the impact of these changes on runoffs and glaciers.

Keywords: Climate change, Global warming, Extreme events, China

Theme 3. Agronomic and crop improvement interventions for sustainably enhancing agricultural productivity of small-holder farmers in dry areas

1. Effect of irrigation intervals and antitranspirants on vegetative growth, fruit and seed yield of summer squash (*Cucurbita peop* L.)

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Abstract

Strategies such as foliar application of antitranspirants show possibilities for conserving irrigation water and aiding plant survival under dry conditions. In this study, two field experiments were carried out during the summer seasons of 2012 and 2013 to examine the response of summer squash (*Cucurbita peop* L.) to the foliar application of three antitranspirants (Kaolin, K_2SO_4 and $CaCO_3$) plus control under three irrigation intervals (7, 11 or 15 days).The results indicated that the better plant growth vigor, heavier total yield, and better seed yield and quality were recorded when squash plants were irrigated at shorter interval (7 days interval). Foliar spray of different antitranspirants led to more growth vigor, more fruits yield as well as seed yield and quality compared with control plants and Kaolin was the best antitranspirant. Irrigating squash plants every 7 days and spraying with Kaolin resulted in best fruit and seed yields. It could be recommended that using antitranspirants as foliar application especially Kaolin is an effective tool in reducing the level of drought stress.

Keywords: Squash, Irrigation intervals, Drought stress, Antitranspirants, Yield

2. Determination of irrigation depths for potato using a process model and quantitative weather forecast

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Abstract

A field experiments was carried out to evaluate the effectiveness of a new scheme for determining irrigation depth using a numerical model of crop response to irrigation and quantitative weather forecast. Potato crop was grown in summer season of 2015 using a drip irrigation system at the Arid Land Research Center, Tottori, Japan. Two treatments were tested, automated irrigation (A) and proposed scheme (S), with two replicates for each. Irrigation interval was set at 2 days for treatment S, while for A treatment water was applied for 1 hour when water content at the depth of 15 cm became less than 0.09 m3 m-3. Results indicated that predicted water content agreed well with observation although some underestimation of water content due to overestimation of transpiration was observed. Proposed scheme (S) could save water by 16%, while yield was increased by 15%, resulting in higher net income as compared to A. These results reveal that proposed scheme could improve net return and save costs for equipment such as soil moisture probes, data loggers and solenoid valves.

Keywords: Irrigation, Potato, Weather forecast, Transpiration, Water saving, Net return

1. Introduction

Rapidly increasing population and intensified scarcity of water resources bring a new emphasis on efficient use of water in irrigation. Farmers are still widely relying on their intuition to determine an irrigation depth even in industrialized countries. Such conventional irrigation scheme may have caused yield reduction or resulted in the wastage of water. To save irrigation water, a concept of deficit irrigation was introduced and many field studies have been carried out (Ati and Nafaou, 2012; Makau *et al.,* 2014). In such studies, water use efficiency or water productivity, which is generally defined as yield per unit amount of irrigation water, have widely been used as target value to be maximized. However, for a farmer, net return, not water use efficiency, should be of primary concern. Therefore, we believe that net return should be the target value to be maximized.

Automatic irrigation systems using sensors may be another alternative developed to precisely meet crop water requirements and respond to drought stress quickly. Such systems require high initial investment and have difficulty in adjusting irrigation depth to weather forecasts. Expensive monitoring using sensors can be altered by numerical simulation of waterflow and crop growth. Personal computers are getting affordable even for farmers in developing countries. Not only monitoring current status, a numerical model can predict upcoming conditions. Today, freely accessible quantitative weather forecasts, whose accuracy is improving, have been available on the web (e.g. accuweather.com). These technical, as well as, social progress have enabled us to optimize irrigation depths using quantitative weather forecast as input data for numerical models to achieve net return maximization.

Several researchers have proposed to use weather forecasts for irrigation scheduling. Venäläinen *et al.* (2005) evaluated accuracy of SWAP (van Dam, 1997) and AMBAV models by inputting numerical weather forecast as atmospheric boundary conditions. Wang and Cai (2009) presented methods that combine the SWAP model and weather forecast. They suggested to apply water when predicted stress index (actual to potential transpiration ratio) becomes less than 0.85 and irrigation depth is determined to bring the root zone soil moisture to field capacity. They also presented an entire-season optimization scheme to maximize net return considering cost for water using genetic algorithm (GA). They evaluated potential advantage of their methods in terms of net return by performing numerical experiments. Lorite *et al.* (2015) presented a scheme that combines freely accessible weather forecast and AquaCrop model (Steduto *et al.* 2009) and evaluated the effect of uncertainty in weather forecast on simulated yield. Irrigation depth is determined so that soil moisture in the root zone returns to field capacity.

AquaCrop is a water balance model which does not use Richards equation to simulate water flow and therefore its accuracy is inherently limited. Seidel *et al.* (2015) used HYDRUS model to minimize irrigation water applied. Delgoda *et al.* (2016) presented a scheme to determine irrigation depth using weather forecast to minimize both root zone soil moisture deficit and irrigation amount. They used a simple water balance model to calculate root zone soil moisture deficit. Fujimaki *et al.* (2015) presented a new scheme to optimize irrigation depths using weather forecast as input data for a numerical model that solves two-dimensional Richard's equation such that net return is maximized. They also presented results of preliminary two field experiments. However, the effectiveness of the new scheme has not been extensively evaluated under various combinations of soil, climate and crops. This paper presents outline of this scheme and experimental results to evaluate its effectiveness.

2. New scheme to determine irrigation depth

2.1. Maximization of virtual net return

If we can calculate net return until the next irrigation, the irrigation depth can be optimized such that net return is maximized. Although actual income is realized when crop is harvested and sold, we assume that a farmer can obtain virtual income, which is proportional to an increment of dry matter attained during an interval. Also, water must be priced high enough to give farmers incentive to save water. Virtual net return, I_n (\$ a^{-1}), during an interval is then defined as:

$$I_n = P_c \varepsilon \tau_i k_i - P_w W - C_{ot} \quad (1)$$

where P_c is the price of crop (\$ kg^{-1}DM), ε is water use efficiency of the crop, τ_i is cumulative transpiration during an interval (1 cm =10^5 kg ha^{-1}), k_i is income correction factor, P_w is the price of water (\$ kg^{-1}), W is the irrigation depth (1 cm =10^5 kg ha^{-1}), and C_{ot} is the other costs (\$ ha^{-1}). Again, I_n does not mean real but imaginary one. Note that the P_c is producer price and market price is the sum of producer's price and costs for distribution and retailing. The amount of valuable part (fruit, grain etc.) of the crop is assumed to be proportional to dry matter production, which is well known to be approximately proportional to cumulative transpiration. Under given conditions, I_n is a function of W. Wang and Cai (2009) also presented an equation similar to Eq. (1) but for entire cropping period. They did not clearly present how to maximize net return at each irrigation.

To estimate transpiration, τ_i, which dynamically responds to matric and osmotic potential in soil and, therefore, irrigation, a sophisticated model of the response of crop to irrigation is required. Numerical models such as HYDRUS (Šimůnek *et al.,* 2006), SWAP (Van Dam *et al.,* 1997), or RZWQM (Ahuja *et al.,* 2000) can be such ones.

2.2 Income correction factor

One possible negative result of the concept of virtual income is that initial growth may not be secured, since transpiration of initial stage is smaller than later stage while initial growth may be equally important. To correct the possible underestimation of contribution of transpiration during early stage, income correction factor, ki, may be used. Formula to calculate ki is presented in Fujimaki et al. (2015).

2.3 Estimation of optimum irrigation depth

If transpiration, τ_i, during an interval is quickly predicted, normal one-dimensional search algorithms such as the golden section method (Press *et al.* 1989) may be used. But sophisticated models for predicting two or three dimensional water flow often require heavy computation. Since the optimization should be completed within a few hours practically, Fujimaki *et al.* (2015) developed an estimation method of optimum irrigation depth.

2.4 Procedure

The steps of the scheme are illustrated in Figure 1. In the early morning of irrigation day, using the records of climatic condition (1), numerical simulation is performed to estimate the current status (2). Then, download quantitative weather forecast as input data (3) and repeat simulations for the three times (4). Then perform irrigation. On next irrigation day, current status is estimated by simulation (6) using the actual records of irrigation depth and climatic condition from the last irrigation until the moment (5). This cycle continues until the last irrigation.

A software (WeatherForecastDownloader) has been developed by Haruyuki Fujimaki to download the HTML file and parse the HTML for WeatherUnderground (http://www.wunderground.com) and Yahoo! Japan (http://weather.yahoo.co. jp/weather/jp/31/6910/31302.html) for consecutive days. Usually, quantitative weather forecasts provide values except for solar radiation. For example, WeatherUnderground provides cloud cover instead of solar radiation. In such case, empirically known relationship between cloud cover and the ratio of extra to inner terrestrial radiation may be applied. Yahoo! Japan provides four qualitative descriptions, “clear”, “cloudy”, “rain”, and “heavy rain”. In this case, empirically determined average ratio of extra to inner terrestrial radiation for each description (e.g. “clear” = 0.82, “cloudy” = 0.63, “rain” = 0.32) may be multiplied to extra-terrestrial short wave radiation.

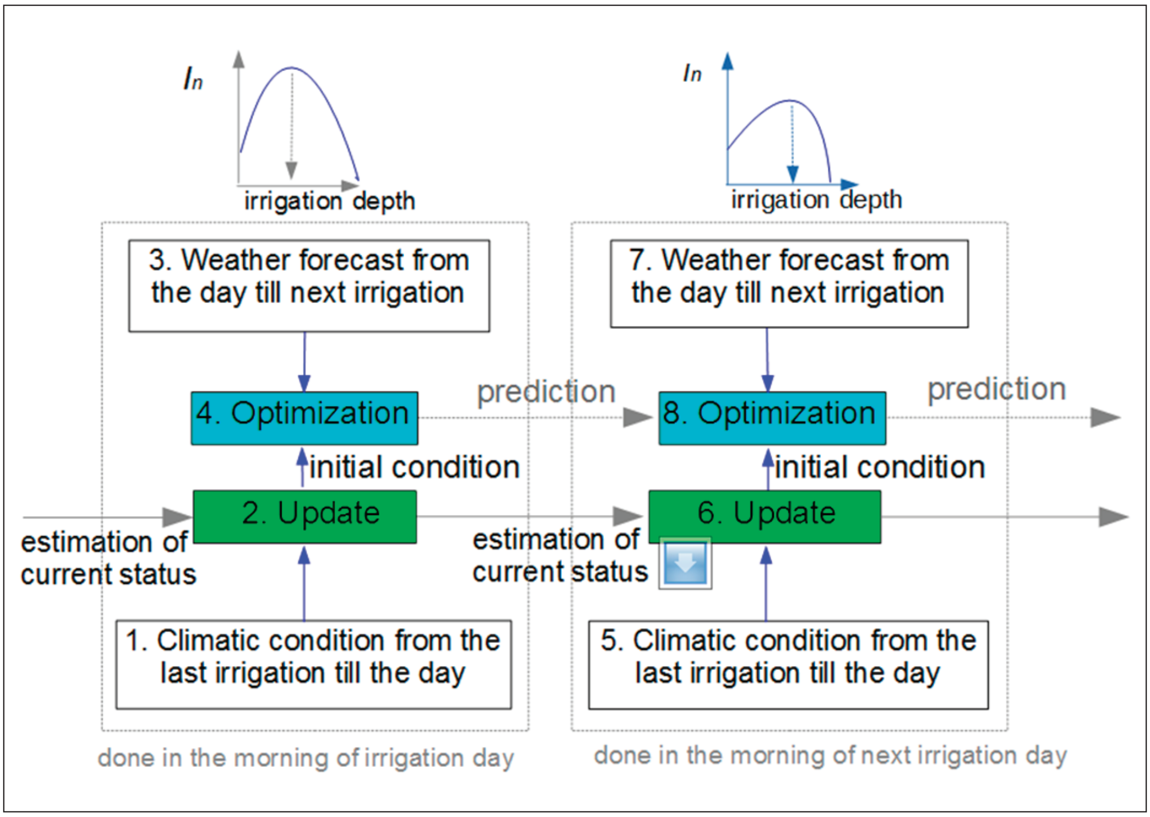

Figure 1. New procedure to determine irrigation depth.

2.5 Numerical model

Algorithm described above and user interface for inputting parameter have been incorporated into a numerical model, WASH_2D, which solves governing equations for two-dimensional movement of water, solute and heat in soils with the finite difference method. It automatically repeats simulation three times to obtain *W*. The software is freely distributed with source code under the general public license from website of Arid Land Research Center, Tottori University (http://www.alrc.tottori-u.ac.jp/fujimaki/download/WASH_2D). Governing equations for water, solute, and heat movement are presented in Fujimaki *et al.* (2014).

3. Field Experiment

3.1 Treatments

A field experiment was carried out in Arid Land Research Center in Tottori (35°32’09”N 134°12’39”E), Japan, in 2015. Two treatments were established: crop was irrigated with an automatic irrigation system in treatment-A and proposed method with simulation was applied to the other treatment, treatment-S. Each treatment had two plots as replicates; each had a 15 m long and 16 m wide. To monitor water content, 12 TDR probes were inserted for each treatment.

Evapotranspiration was measured for treatment-S with a weighing lysimeter whose diameter was 150 cm.

3.2 Irrigation

Irrigation was applied through a drip irrigation system whose lateral distance was 90 cm and emitter distance was 20 cm. Automatic irrigation was set such that water was applied for one hour when θ at the depth of 15 cm became less than 0.09 cm^3cm^{-3}. Irrigation interval for treatment-S was set at two days. The records of climatic condition were downloaded from the website of Japan Meteorological Agency (http://www.kishou.go.jp) and quantitative weather forecasts were downloaded from the website of Yahoo! JAPAN (http://www.yahoo.co.jp). Price of crop were set at 0.7 \$ kg^{-1}DM by referring producer price in the USA in 2011 (FAOSTAT, http://faostat.fao.org/). Price of water was set at 0.00025 \$ kg^{-1} based on that in Israel (Cornish et al. 2004). Liquid fertilizer (N = 10%, P_2O_5 = 4%, K_2O = 8%) and calcium chloride were mixed such that daily application rate became constant throughout growing season. Totally applied nitrogen was 3.8 g/m^2 for each treatment. Since salinity of irrigation water was very low and current version of WASH_2D can simulate only one solute, "conceptual nutrient solute" whose passive uptake ratio is unity. We did not consider the effect of uptake of nutrient on growth and assumed that growth depends simply on cumulative transpiration regardless of nutrient uptake.

3.3 Soil

Soil of the field was sand whose hydraulic properties are shown in Figure 2. Solute transport parameters such as dispersivity (0.59 cm) and dependence of tortuosity factor for ionic diffusion on water content were also measured in laboratory. Independently measured thermal properties such as dependence of thermal conductivity and albedo on water content and were also used.

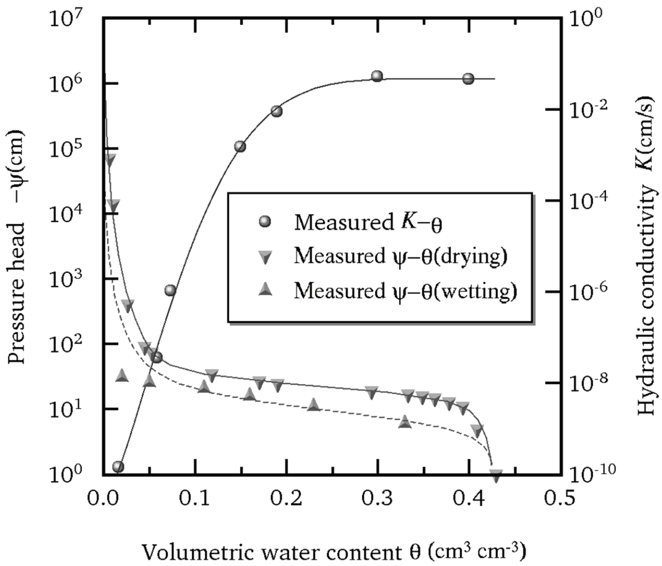

Figure 2. Hydraulic properties of Tottori sand.

3.4 Plant

A cultivar of potato, May-Queen, was sown on 14 April 2015. Since stress response function of the plant has not been determined, tentatively set parameter values listed in Table 1 were used. These values are comparable for canola (Yanagawa and Fujimaki, 2013). As shown in Figure 3, parameter values for crop coefficient function were updated twice such that simulated evapotranspiration matched with measured values. Parameters values for root distribution and leaf area index were chosen based on data obtained through growth measurement. Water use efficiency was set at 0.003. Unfortunately, disease of potato blight (*Phytophthora infestans)* was widespread in June particularly for treatment-A in spite of application of fungicide and yield was thus smaller than general for both treatments. Potato was harvested on 21 July 2015.

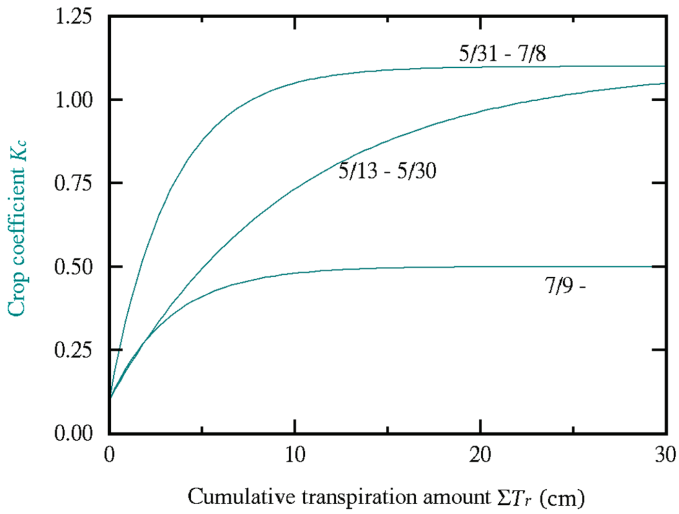

Figure 3. Crop coefficient (for transpiration) as a function of cumulative transpiration.

4. Results and Discussion

Both leaf area index and biomass were measured twice as shown in Figure 4. The leaf area was higher for the treatment S in June 9 despite the biomass was almost the same. This higher leaf area might have led subsequent larger dry matter production. Both are smaller than normal potato cultivation. This poor growth may be due to late sowing date and potato blight.

Figure 5 shows the comparison between measured and simulated water content for a selected period. Legends *x* and *z* represent the horizontal distance from the drip tube and soil depth, respectively. The results show that the model underestimated water content at (x, z) = (0, 5 cm). This might be due to an over-estimation of potential transpiration and root water uptake. On the other hand, the model could relatively accurately simulate the internal drainage which occurred after each irrigation for (x, z) = (0, 45 cm) and nearly bare condition for (x, z) = (40, 5 cm).

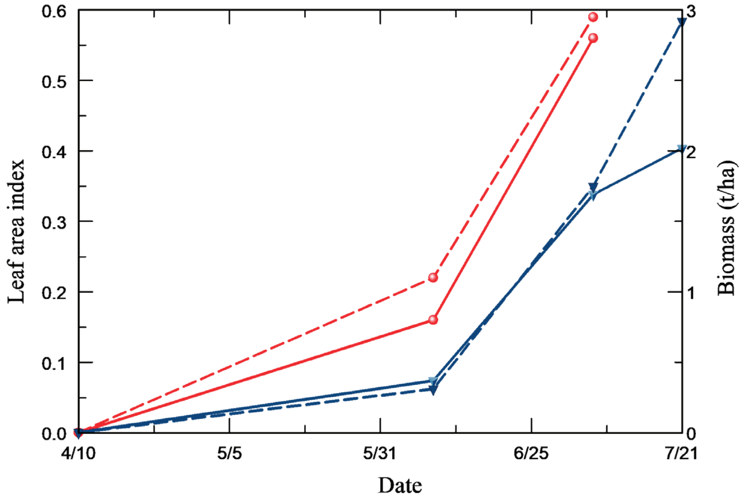

Figure 4. Time evolution of leaf area and biomass.

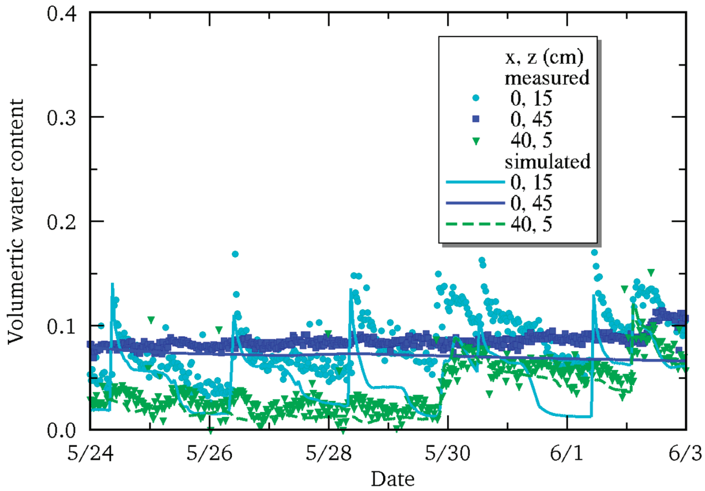

Figure 5. Measured and simulated water content for treatment S.

Figure 6 compares measured and simulated evapotranspiration (ET) for a selected period. The simulation model tended to overestimate ET owing to unexpectedly slow growth of leaf area. We also have discrepancy in hourly pattern. Measured ET tends to more sharply rise in early morning and more steeply drop in early afternoon. One of these reasons would be underestimation in evaporation rate. Sharply drop in the afternoon might partly be due to the formation of dry sand layer. In the simulation, however, evaporation rate did not sharply decrease owing to larger leaf area than actual one. Evaporation rate tents to decrease as leaf area increases owing to shadowing and enhanced aerodynamic resistance. Both mechanisms are incorporated into the numerical model and therefore an overestimation of leaf area leads to an underestimation of evaporation rate. Thus, in the simulation, evaporation rate persisted at low rates in the afternoon. Second reason might be a measurement error owing to thermal deformation of drip tube. Edge of the lysimeter was raised by about 3 cm above the ground and two drip tubes were on the lysimeter. In early morning when temperature was sharply increasing, the polyethylene drip tube might have become loosing and it might have eased downward tension and led underestimation of weight. Opposite mechanism might have occurred in the afternoon.

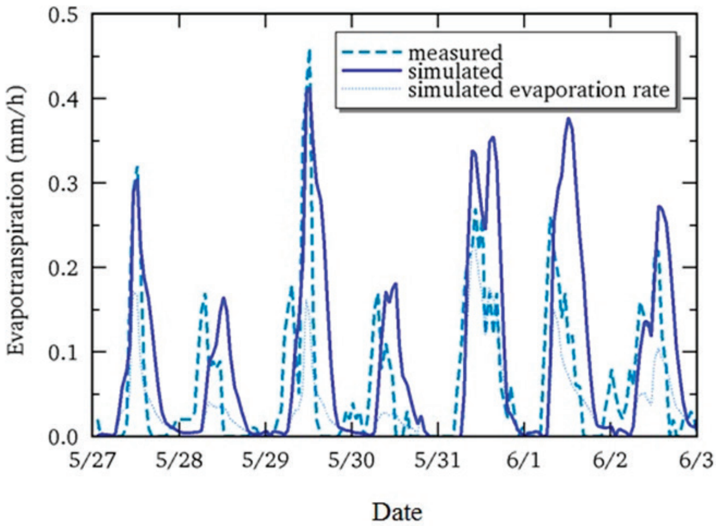

Figure 6. Comparison of measured and simulated ET.

Despite the treatment S received 16 % lower water than treatment A, it attained higher yield by 15 %. As a result, the treatment S achieved higher net return than treatment A as shown in Figure 7. Larger irrigation amount for treatment A might be partly owing to inability of the automatic system to respond to weather forecast. For example, a 2.7 mm of water was applied to treatment A in the morning of 8 June 2015 in spite of a 42 mm rain was forecast and it actually rained for 14 mm in the afternoon. On the other hand, WASH_2D suggested smaller irrigation depth of 0.9 mm on that day. Higher yield for S might partly be attributed to lower nutrient loss due to lower deep percolation by considering forecast rain events. Evaluation of such a side effect of present scheme requires further intensive studies on nutrient balance.

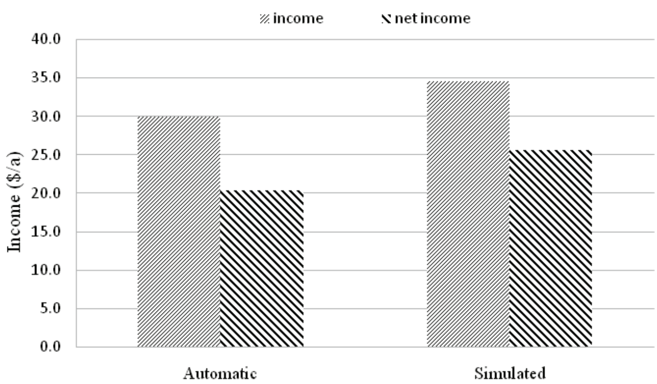

Figure 7. Comparison between income and attained net return.

5. Conclusion

We presented a scheme for determining irrigation depth using a numerical model of crop response to irrigation and quantitative weather forecast. A concept of virtual income is presented to optimize irrigation depth for each interval. A field experiment was carried out to compare net return attained by the new scheme with that by the automatic irrigation method. Results showed higher net income of presented scheme although the accuracy of simulation needs to be improved in terms of potential transpiration, particularly. Further validation studies are required using more reliable parameter values in the model.

Acknowledgments

We thank the staffs of Arid Land Research Center who secure such facilities to perform that research. We also thank to Mr. Mohamad Mahdavi for his great assistance to our field work.

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3. Use of biosensor for estimating abiotic stresses and technical management of the olive groves

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Abstract

Global climate changes will introduce major changes in the agricultural ecosystems, which will affect the agricultural productivity. Water stress is considered to be the most important factor limiting plant growth and production, particularly in the dry areas. Thus, monitoring of plant water status in field-grown plants is of great interest. Changes in plant water status could be described by using a sensitive physiological indicator that integrates the soil and climatic conditions. The aim of our study was to evaluate a quantitative direct relationship of the olive tree water status, which is necessary for scheduling irrigation or management of olive plantation. The assessment techniques used is the magnetic leaf patch clamp pressure probe (LPCP probe) that allows us to monitor easily and continuously the leaf water turgor potential. The experiments were conducted in a hedgerow 4 ha olive orchard, which is located in Jemmel in the central-east part of Tunisia. The treatments were set up in the same plot on olive tree planted at a density of 69 trees ha-1. The aim was to observe the water status of olive trees with two different cultural conditions: T0: conventional supplemental irrigation (control) and T1: supplemental irrigation with a hydro-absorbent product injected into the soil. The results indicated that the instantaneous data provided by the technology of LPCP probe allowed us to detect precociously the water deficit and to have accurate information on the hydraulic behavior of the olive trees and the efficiency of hydro-absorbent product to enhance the management of the available water. Indeed, we found that the effect of the water made available to the olive trees by the hydro-absorbent is not instantaneous, as is the case of direct water supply, but has lag time of a few days.

Keywords: Water stress, Olive trees, Irrigation management, LPCP probe

4. Changes in essential oil yield and composition of dill (*Anethum graveloens* Linn.) in response to climate conditions

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Abstract

The increasing tendency toward herbal medicine for curing diseases makes the need to cultivate various medicinal plants inevitable, both at worldwide level and inside Egypt. Change in planting time leads to significant change in weather parameters and consequently the performance of the crop in oil accumulation in herbal medicinal plant. Two field experiments were carried out during the winter seasons of 2013/2014 and 2014/2015 to examine the response of dill (*Anethum graveloens* Linn.) to climate conditions for oil accumulation and composition under five sowing dates i.e. mid-November, end-November, mid-December, end-December, and mid-January. Results indicated that essential oil yield declined as planting date was delayed. Late planting times (end-December and mid-January) resulted in low oil yield in comparison to the early sowing dates and the essential oil percentages for different planting times were 3.53% (mid-November), 3.26% (end November), 2.65% (mid-December), 2.1% (end December) and 1.4% (mid-January). Generally, the major compounds of the essential oil were also affected by different planting dates. It could be recommended that for high yields of dill oil, mid-November is the best sowing time under Mansoura conditions in Egypt and avoiding late sowing is crucial to producing high yield and quality of dill oil.

Keywords: Dill (*Anethum graveloens* Linn.), Essential oil, Yield, Sowing time

5. Carnation production using different soilless culture systems under protected cultivation in Egypt

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Abstract

The limited water resources are the major factor that drew the attention towards the use of intensive agriculture in arid land. Protected cultivation was the first step and in recent decades. Soilless culture has attracted more attention specially under conditions of aridity, water shortage, and the need for maximizing crop yield per square meter of soil as well as per cubic meter of water. Also, producing cut flowers, that are considered one of the cash crops, using soilless technology will help to maximizing the net profit of the agriculture sector. An experiment was, therefore, carried out in the experimental site of Arid Land Agricultural Services and Research Center (ALARC), Faculty of Agriculture, Ain Shams University under unheated plastic house during two successive seasons, 2007/2008 and 2008 /2009. The experiment aimed at determining the best soilless culture system for producing carnations with high yield and flower quality. Standard carnation '*Dianthus caryophyllus*' was used in this experiment. Carnation seedlings were planted in five soilless systems: Aeroponics (Aero.), Nutrient Film Technique (NFT), Shallow container (10 cm depth) filled with perlite (CA), Deep container (20 cm depth) filled with perlite (CB), and Horizontal bag filled with perlite (HB). Plant height, shoot and root fresh weight, number of flowers/m^2, flower stem length, flower head diameter, flower weight, N, P, K % in the leaves and water use efficiency were recorded at various stages. The results showed that aeroponics system was the most suitable soilless system for producing carnations. Plants grown in aeroponics recorded the highest values for plant height, shoot and root fresh weights, number of flowers per m^2 and higher flowers quality measurements than the other tested soilless systems. Moreover, aeroponics recorded the highest water use efficiency and thus more flowers per drop of water.

Keywords: Carnation, Aeroponics, Hydroponics, Soilless culture, Water use efficiency

Introduction

Flowers are prized as objects of great beauty and diversity, and are commercially valuable (involving US$ 4.5 billion in international trade yearly). But they are highly perishable (O'Donoghue, 2006). The interest in cut flower cultivation in many countries in the Mediterranean region is increasing because of the internal market demand, and the climatic advantage of the region.

Carnation is one of the most popular cut flower plants grown world over and is of highest economic importance in the floriculture industry (Nukui *et al.,* 2004). In Turkey 52% of the total cut flower production consists of carnation only (Aydınşakir *et al.,* 2009). But carnation is very susceptible to soil-borne diseases such as the wilt caused by *Fusarium oxysporum* f. *dianthi*.

Since it occupies the beds for a period of 1 to 2 years and is grown in monoculture, the spread of soil borne diseases can prove disastrous (Robinson, 1983). Occasionally, methyl bromide is used for soil fumigation. Many carnation, lily and gerbera producers use methyl bromide in their greenhouses because no other chemical has the same broad spectrum activity (Reis, 1998). But carnation is very sensitive to bromide residues. At the same time, use of methyl bromide will not be permitted in the near future in Egypt because of the Montréal Environmental Agreement as the chemical is extremely toxic to the environment (UNEP, 2000).

Olympios (2011) reported that the growers in the arid region nowadays should move to the soilless culture. Soilless culture offers an ideal alternative crop production system to traditional cultivation in soil when there is no soil available at all, or there is no suitable soil for crop production, when soil salinity is high or there are toxic materials or soil borne diseases or weeds. Soilless culture helps in increasing productivity and obtaining better crops. Soilless culture helps in saving water because more accurate water supply control is practiced. Also, it provides possibility for more accurate control of temperature and oxygen supply. Labour and power-intensive field operations needed for normal field cultivation are avoided. Also, the number of cycles of crop grown in a season can be increased.

Soilless production has been introduced for carnation with very good results in terms of yield and quality (Yilmaz *et al*., 2006). About 25% transition from soil cultivation to soilless culture has occurred in the case of a number of flowering plants such as calla, lilies, gerberas and carnations (UNEP, 2008).

The aim of this work was to compare five different soilless cultivation systems (aeroponics, NFT, shallow containers, deep containers and horizontal bags) with respect to yield and flower quality of carnations under Egyptian dryland conditions.

Materials and methods

The experiment was carried out in the experimental site of the Arid Land Agricultural Services and Research Center (ALARC), Faculty of Agriculture, Ain Shams University, under unheated plastic house, during the 2007/2008 and 2008 /2009 seasons. Rooted cuttings of standard carnations (cv. 'Crimson Tempo') were used in this experiment. The cuttings were cultivated in net cups filled with perlite: peat mix (2:1 v/v) to form new roots and the rooted cuttings were transplanted in soilless culture under Quonset shaped house with net cover on 1st September. At the end of October the net was replaced by a plastic cover. When plants reached seven nodes, a pinching treatment was applied to encourage side branching. The experiment ended in May.

Five soilless systems were used in this experiment: aeroponics (Aero.), nutrient film technique (NFT), shallow container (10 cm depth) filled with perlite (C.A), deep container system (20 cm depth) filled with perlite (C.B), and horizontal bag system filled with perlite (H.B).

The aeroponics system was installed above sloped beds by establishing border of several layers of baked bricks around the bed. Then it was lined with black polyethylene sheet to help in collecting the excess nutrient solution and return it back to catchment tank. A high-density polystyrene sheet was used to cover the formed container. Holes were made in the polystyrene sheet to fix the plants. The irrigation network consisted of PVC tubes installed along the aeroponic system and mist nozzles fixed in it to deliver water and nutrient solution over the root system.

The NFT system was similar to aeroponics system except that only one layer of baked bricks was used for forming a cultivation gully. The irrigation network consisted of black polyethylene pipes (18 mm) delivering water at the end of each cultivation gully.

The container system consisted of rectangular shape containers (240cm long, 40cm wide). They were made from a black polyethylene sheet (1mm thickness). Holes were made in the lowermost part in both sides of each container for draining the excess nutrient solution. Two depths for substrate (10 and 20cm) were used by filling with 100 and 200L of perlite. Containers were laid on a gully made from black on white polyethylene sheet (0.2mm thickness) on beds prepared with 1.0 % slope for collecting the drained nutrient solution.

Horizontal bag system consisted of horizontal bags made from black on white polyethylene sheet. Each bag was filled with 10L of perlite. Holes were made in the lower part on both sides of each bag for draining the excess nutrient solution and holes in the surface were made to grow the plants. Bags were laid on a gully made from black on white polyethylene sheet (0.2mm thickness) on beds prepared with a 1.0 % slope for collecting the drained nutrient solution.

Each bed had two catchment tanks and two submersible pumps for pumping water and nutrient solution to plants. The excess nutrient solution returned back to the catchment tank by gravity. The nutrient solution described by El-Behairy (1994) was used. The electrical conductivity (EC) was adjusted to range between 2.0 and 2.5 dS/m and pH maintained between 5.5 and 6.0 through out the duration of the experiment. The experiment was arranged in a complete randomized blocks design with three replicates. The collected data were analyzed using ANOVA statistical analysis as per Snedicor and Cochran (1980) and the least significant difference (LSD) was used to compare the means.

Results

Data in Table 1 presents the effect of different systems on vegetative growth of carnation plants. The plant height was significantly the highest in aeroponics system. Increasing perlite depth from 10 to 20cm in container system increased plant height significantly, while there was a significant difference between container system with 10 cm depth and horizontal bags. The lowest plant height was recorded in NFT system. Similar trends were observed in the second season.

The plants grown in aeroponics system recorded the highest shoot fresh weight followed by container system with 10cm depth then horizontal bags with a significant difference between them. The lowest shoot fresh weight was recorded in NFT system. Trends were same in the second season. Superior root fresh weight was found in aeroponics system which was significantly higher than in other systems. Increasing the substrate depth from 10 to 20cm did not affect root fresh weight significantly. However, the lowest root fresh weight was found in horizontal bag treatment. Similar trends were recorded in the second season.

The total number of flowers/m^2 (Figure1) was highest in aeroponics system. This was followed by C.B and C.A systems. On the other hand, there was no significant difference between 10cm and 20cm substrate depth systems. The lowest number of flower/m^2 was recorded in the NFT system. Similar trend was observed in the second season.

Table 2 presents the effect of different soilless culture systems on flower quality parameters of carnation. The highest flower stem length was obtained by aeroponics system in both the seasons. The difference between aeroponics system and all other treatments was significant. Both flower head diameter and flower weight were significantly the highest under aeroponics system followed by C.B system. The lowest flower head diameter and weight were recorded under horizontal bag and NFT systems.

Table 3 presents the effect of different soilless culture systems on the N, P, and K % in carnation leaves. The highest N% was recorded in the plants cultivated in aeroponics system followed by C.A system and then NFT system, while the lowest N% was recorded in H.B. The highest P% was also recorded in aeroponic system followed by NFT then C.B and horizontal bag system, while the lowest P% was recorded by C.A treatment. Data showed also that increasing substrate depth from 10 to 20cm increased P% in carnation leaves significantly. The K% in the leaves showed similar trend.

In Figure 2 are the data on the water use efficiency, in terms of no. of flowers/ m^3 of water, for different soilless culture systems. In both seasons, the aeroponics system recorded the highest water use efficiency followed by NFT system and then H.B and C.A. while the lowest water use efficiency was recorded under C.B system. Increasing the substrate depth from 10 to 20cm in the container system did not affect water use efficiency significantly.

Discussion

It is clear from the data on different parameters measured in this study that using aeroponics system was the best. It increased carnations yield and flower quality and water use efficiency. This could be attributed to the fact that aeroponics system ensures good aeration, and water and nutrient supply to the root system. This helps the plant to take up adequate amount of nitrogen for good vegetative growth and also ensures good uptake of phosphorus and potassium, which promote the flower quality. Barak *et al.* (1996) stated that aeroponics system provides complete control of the root zone environment, including temperature, nutrient level, pH, humidity, and oxygen availability. Plants often exhibit accelerated growth and maturation in aeroponics systems. These features have made aeroponics not only a popular research tool for scientists studying root growth and plant nutrient uptake but also a viable method for commercial cultivation of high value crops, circumventing many of the difficulties associated with soil cultivation. Molitor and Fischer (1999) also reported that aeroponic system ensures an optimum supply of nutrients, water and oxygen. The closed irrigation system prevents ground water pollution and the media – free cultivation lowers the running costs and the waste problem.

The data also showed that in the container system increasing the substrate depth from 10 to 20cm reduced N uptake which reduced the vegetative growth but at the same time, it increased phosphorus uptake which increased number of flowers than NFT system and horizontal bag system.

The water use efficiency was the highest under aeroponic system followed by NFT and the lowest water under container system. This could be because of the minimized evaporation in aeroponic and NFT systems. El-Shinawy *et al.* (1996) in their study on lettuce got similar results. Fascella and Zizzo (2005) stated that rose plants differed in their water consumption according to substrate type; plants grown in pure perlite consumed more water than those grown in perlite mixture with coconut dust.

Conclusion

The study showed that aeroponics system can be used easily for producing carnations with high yield, flower quality and water use efficiency. It was more suitable soilless system for producing carnations in comparison to nutrient film technique (NFT), shallow perlite containers, deep perlite containers and horizontal bag filled with perlite..

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6. Enhancing climate resilience of farming in arid regions of north-west India

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Abstract

Arid regions constitute 12% of total geographical area of India ranging from cold arid areas in northern parts to hot arid areas in western and southern parts of the country. Climatic stresses (drought, extreme temperatures, sand blasting), edaphic factors (sandy soil with low organic carbon content and poor water holding capacity), and relatively higher biotic pressure (human and livestock population) in these areas are major contributing factors to degradation of natural resources and lower productivity resulting in greater risk of farming *per se*. Enhancing stress resilience of farming system, therefore, remains a major challenge in these regions. Several interventions in crop management, water conservation, and alternate land use have been evaluated across diverse farming systems to mitigate effects of stresses on crops and livestock and to develop appropriate contingency plans to curtail the losses. Water harvesting, moisture conservation, and choice of water-efficient crops, cultivars and cropping system have been, and continue to be, key components to enhance water use efficiency and to achieve the objective of "per drop, more crop". Identification and utilization of stress-adapted crop germplasm has resulted in development of stress tolerant cultivars providing stable yields across a range of stress environment. Several models of integrated farming system have been developed with variable proportion of crops, horticulture, grasses, trees and shrubs in order to fulfill the need of food, fodder, fuel and fruits and to minimize the risk associated with farming in the arid regions. Up-scaling of new technologies has met with variable success. The paper discusses lessons learnt from the past, challenges and future strategies to make farming in arid regions more profitable and resilient to climatic stress.

Keywords: Climate resilience, Cold and Hot arid regions, Farming systems, Stress tolerant cultivars

1. Introduction

About 18.8% of the total land area of the world is arid. The arid regions face severe edapho-climatic conditions due to low rainfall compared to the potential evapotranspiration (aridity index <0.20), usually accompanied with high inter-annual variability of rainfall. High wind and solar regimes further accentuate the effect of rainfall variability resulting in a very fragile ecosystem. In general, pastoralism is predominant practice in arid regions and arable farming receives less importance with few exceptions (Malhotra, 1984).

Arid regions cover about 12% geographical area of India, comprising 31.7 m ha hot arid and 7.0 m ha cold arid region. Nearly 90% of hot arid region of India lies in northwestern states of Rajasthan (19.6 m ha), Gujarat (6.22 m ha) and Haryana and Punjab (2.75 m ha). Some small pockets (3.13 m ha) of hot arid zone are in southern states of Andhra Pradesh, Maharashtra and

Karnataka. The cold arid region is spread in northern states of Jammu and Kashmir and Himachal Pradesh.

The arid region of northwest India constitutes the major part of the Great Indian Desert or the Thar Desert (Figure 1). About 85% of the Thar Desert lies in northwest India and the remaining part is in southeast Pakistan. It is biogeographically the eastern edge of the Saharan-Arabian Desert zone and, like these deserts, it is a mid-latitude desert that lies in subsidence zone. Compared to other deserts of the world, it is relatively small and ranks 17th in size. This desert is drier in the northwestern side and relatively less dry in the southeastern part that boarders with semi-arid regions.

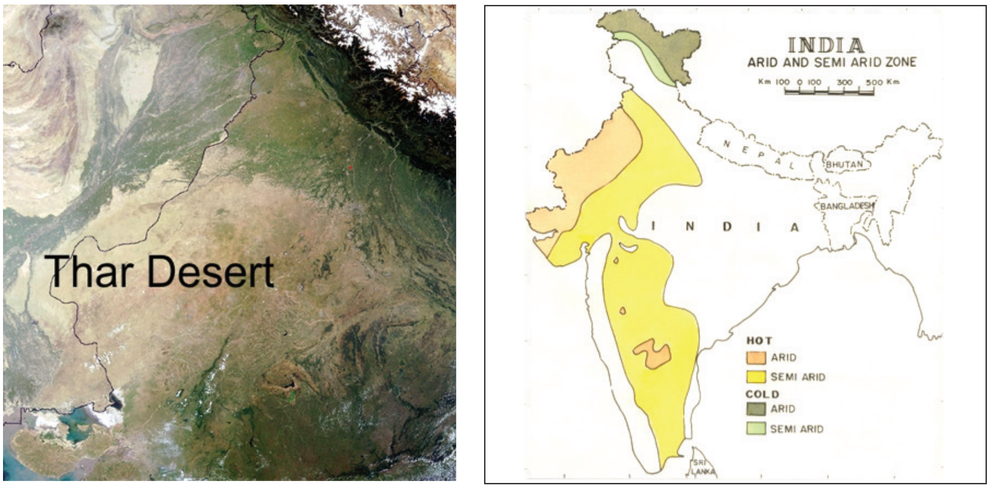


Figure1. Satellite image (NASA) of the Thar Desert, with superimposed Indo–Pakistan border (left), arid and semi-arid regions in India (right).

2. Agro-climatic and edaphic features of Indian arid zone

The climate of hot arid regions is characterized by low and erratic rainfall, high potential evapotranspiration, wide diurnal and annual temperature range, high solar radiation, low relative humidity and high wind velocity. The annual rainfall ranges from about 100 mm in extreme west to 500 mm in the east and southeast side (Figure 2; Rao, 2008), while the potential evapotranspiration is about 1650 mm in the east that increases to over 2000 mm in the west. The coefficient of variation of annual rainfall varies from 35% in the east to 65% in the west. Most of the rainfall (80-85%) is received during the southwest monsoon season (June-September) of the Indian sub-continent. However, monsoon rains start in the first week of July and usually withdraw by September beginning in the hot arid zone of northwest India.

The region experiences extremes of temperatures. Air temperature increases sharply from April and peaks during May to mid-June. Maximum temperatures during summer season vary from 36 to 43°C in the eastern and 39 to 45°C in the western parts but occasionally may reach up to 50°C. During winter season, the maximum air temperature varies from 24°C in the east to about 26°C in the west. Sub-zero temperature is not uncommon and minimum temperature during winter may be as low as -5°C in sandy terrains. Soil temperature fluctuations reflect the diurnal and annual cycles of the air temperature.

Soils are coarse textured, mostly sandy or sandy loam, inherently low in soil organic carbon and water holding capacity. Majority of soils belongs to Aridisol and Entisol orders. Soils are alkaline in nature with high calcium carbonate and gypsum content. These are deficient in soil organic carbon (SOC) as well as N content (Joshi, 1993). Mean SOC ranges from 0.05 to 0.2% in coarse textured soils. These soils are very susceptible to wind and water erosion due to poor aggregate structure. Wind erosion is very high from March to June as the wind velocity starts increasing from the month of March and peaks in May and June. Rainfall sometimes comes in intense bursts, resulting in surface runoff and uncontrolled rill and gully erosion. Soil salinity and alkalinity, and impermeable sub-surface soil layer are other constraints in some pockets. Widespread deficiency of macronutrients (mainly N and P) and micronutrients (Zn and Fe, particularly under irrigated conditions) occurs due to loss of nutrients through soil erosion and inadequate nutrient application. Groundwater is deep (up to 150m) and is saline/brackish in almost 80% area.

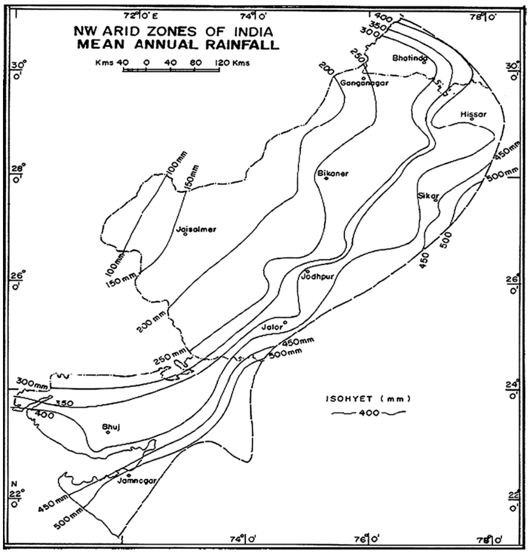


Figure 2. Mean annual rainfall (mm) in northwest arid region of India.

Natural vegetation in the region is sparse and is comprised of perennial and annual grasses, other herbaceous plants, shrubs and small trees. Shrubs and trees are slow growing in nature, while the annual grasses are fast growing and complete their life cycle in a short span of favorable rainy season. Most of the vegetation cover is degraded due to over exploitation. The degraded grasslands are able to produce only 10-20% herbage yield compared to that of protected grasslands.

The fragile arid ecosystem is not very conducive for agriculture *per se* but high human and livestock population density (human density in arid Rajasthan varies from 44 to 270 km^{-2} and livestock density from 10 to 160 km^{-2}) necessitates cultivation of crops in order to produce food grain for human consumption and fodder for livestock. The productivity is low mainly due to aberrant weather conditions and poor soil fertility.

The use of inputs like fertilizers and chemicals is low due to poor resource base of farmers due to high probability of crop failure. The risk of crop failure and poor yields always influ-
.ences farmers' decision on investing on new technologies and level of input use

3. Enhancing climate resilience of farming

The selection of farming system enterprises depends on factors like soil and climatic features; availability of land, labour, capital and other resources; present level of utilization of farm re-.sources; market prices; farmers' skills and preferences

3.1 Adopting integrated farming system approach

Integrated farming system (IFS) consisting of variable proportions of crops, grasses, shrubs, trees and livestock makes best use of available resources and minimizes the risk of weather vagaries. Several farming systems involving trees, fruits, grasses and crops have been studied for their suitability in arid agro-ecosystem and compatibility of selected farming system components in agroforestry, silvi-pasture, agri-silvi-pasture, agri-horticulture, and horti-pastoral systems. It has been observed that the areas falling in <250 mm rainfall zone have predominance of grasses and shrubs (Figure 3); hence range/pasture development with livestock rearing is the major proposition for such areas. Areas in 250-350 mm rainfall zone are suitable for agroforestry and mixed farming; while areas receiving more than 300 mm rainfall are suitable for agroforestry, arable crops, crop diversification and livestock rearing.

Prosopis cineraria has been found as the most prominent tree in agri-silviculture or silvi-pastoral systems. *P. cineraria,* being a leguminous crop, provides benefits to the companion crops particularly pearl millet and grasses. Trees like *Acacia tortilis, Acacia lebbeck, Acacia senegal, Acacia indica, Hardwickia binate* and *Colophospermum mopane*, with proper canopy management, were found to be compatible with arid grasses. In agri-horti and horti-pastoral systems, intercropping of legumes like clusterbean (*Cyamopsis tetragonolobis)*, green gram (*Vigna radiata*), dew gram/moth bean (*Vigna aconitifoliaor),* pasture grasses like *Cenchrus ciliaris, C. setigerus* with *Ziziphus mauritiana* (grafted jujube) has been established as more remunerative compared to sole cropping of legumes, cereals or grasses. Besides, these systems provide year-round employment and resilience to the system in erratic rainfall conditions.

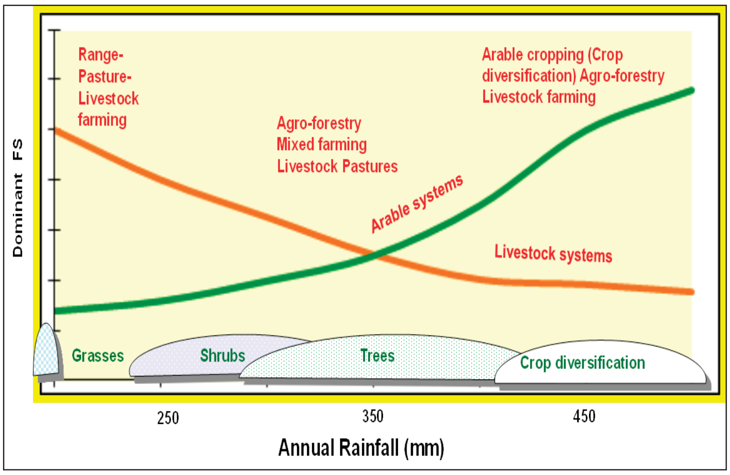
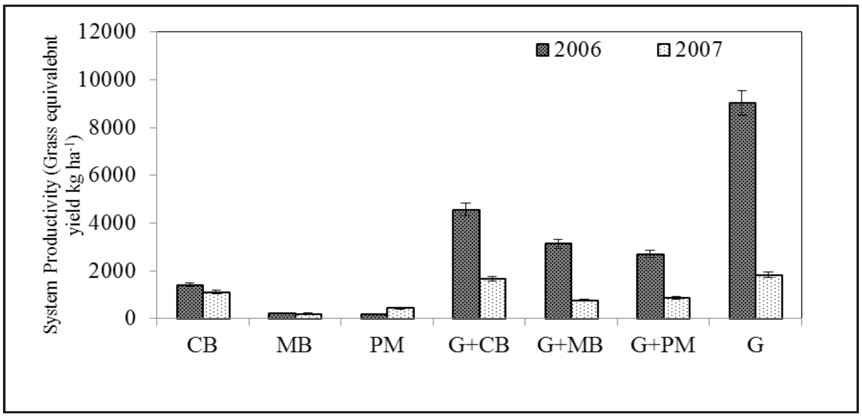


Figure 3. Predominant farming systems vis-à-vis annual rainfall in the dry areas of India.

In traditional farming system, trees like *Prosopis cineraria* and *Acacia tortilis* are retained in the field while mixed cropping of pearl millet, clusterbean, green gram, dew gram, sesame etc.

is common practice. Mixed cropping of rainfed crops, however, hampers mechanization of farm operations. Intercropping or strip cropping of crops or crops and grasses gives all the benefits of mixed cropping and facilitates the use of farm machinery for inter-culture operations. Strip cultivation of grasses like *Cenchrus ciliaris, Cenchrus setigerus* and *Dichanthium anulatum* is compatible with crops (Daulay and Bhati, 1989). The strip cropping of crops and grasses in agri-pasture system provides fodder for livestock without adversely affecting crop yields. Soni *et al*. (2013) observed the higher total system productivity in strip cropping system of *Cenchrus ciliaris* and clusterbean in 5m:15m strips (Figure 4). Strip cropping of C*enchrus ciliaris* with rainy season (*kharif*) crops significantly reduced the soil loss also in comparison to sole cropping of crops. Bhati *et al.* (2008) also recorded the highest benefit: cost ratio of 1.87 in strip-cropping system of grass and crops.

Under limited water availability, agri-horti systems are becoming more remunerative. Fruit crops are given irrigation while compatible arid crops may be taken as rainfed intercrops. In one such system tested under Bikaner (Rajasthan) conditions, highest seed yields of green gram (471.3 kg ha^{-1}) and clusterbean (419.8 kg ha^{-1}) were recorded with *Citrus aurontifolia*, which were 50.8 and 84.8; 54.2 and 184% higher over their yields in intercropping with *Dalbergia sissoo* and *Colophospermum mopane*, respectively (Yadava *et al*., 2013). Thus, *C. mopane* and *D. sissoo* showed more competitive effect on intercrops than *C. aurontifolia*. Similarly, highest fruit yield of citrus (248.3 kg ha^{-1}) was obtained when dew gram was taken as intercrop which was 13.8 and 55.4% higher than the yield obtained with intercropping of clusterbean and *Cassia angustifolia*, respectively. It is, therefore, important that the compatibility of trees and crops needs to be considered while selecting various farming system components.



B = Clusterbean; MB = Moth bean; PM = Pearl millet; G = Grass (*Cenchrus ciliaris*)

Figure 4. Grass equivalent yield in sole and strip cropping systems.

3.2 Selecting appropriate crops, cultivars and cropping systems

It is very important that water requirement of selected crops, cultivars and cropping systems should match the rainfall pattern of the region. Several crop cultivars suitable for different agro-climatic conditions have been developed. Improved varieties of arid legumes like green gram (*Vigna radiata*), dew gram or moth bean (*Vigna aconitifolia)*, cowpea (*Vigna unguiculata*), clusterbean (*Cyamopsis tetragonolobis)*; oilseed crops like sesame, rapeseed and mustard, and pearl millet having different length of growing period, are available. Relatively long duration varieties are recommended for medium to heavy textured soils if onset of rains is timely. Short duration varieties are preferred when onset of rainfall is delayed. Choice of crops also varies depending upon timing of rainfall in the season. Under delayed sowing beyond the third week of July, pearl millet is seldom preferred as it gives poor yield but legumes like clusterbean and dew gram perform well. With the availability of canal water and groundwater for irrigation in some areas of arid regions, the traditional cropping systems in such areas are shifting towards high value, but unfortunately high water requiring, crops like groundnut, cotton, chilies, castor, wheat etc.

3.3 Conserving soil and water

Soil and water are two basic resources for crop production and both the resources have severe limitations in arid ecosystem, necessitating the need for their conservation and efficient management. Various physical and biological measures have been developed for soil and water conservation. Field and contour bunding, trenching, ridging, conservation furrows, contour cultivation, etc. have been found to reduce runoff and soil erosion. Contour farming and contour cultivation are particularly important for undulated sandy terrain. Vegetative barriers, windbreaks and shelterbelts, and stubble mulching are effective biological measures for moisture conservation and soil erosion control. Singh (1992) suggested the vegetative barriers of arid grasses like *Lasiurus sindicus, Cenchrus ciliaris, Cenchrus setigerus*, *Dichanthium anulatum* and *Panicum antidotale* to check soil erosion and conserve soil moisture. Shelterbelts were found effective in reducing wind erosion and create favorable micro-climate for crop growth. Mertia *et al*. (2006) studied the effect of *Acacia tortilis, Eucalyptus camaldulensis, Dalbergia sissoo, Tecomella undulata* shelterbelts on wind regime and found that the maximum reduction in wind speed (21.5 to 36.0%) was at a distance of 2H (H is average height of shelterbelt). The reduction was pronounced up to 10H and then slowly reduced up to 20H.

Mulches are very effective in moisture conservation mainly during initial stage of crop growth when crop foliage development is less and evaporation losses from bare soil surface are high. Gupta and Gupta (1983) reported almost double yields of green gram, (*Vigna radiata*) dew gram (*Vigna aconitifolia*) and clusterbean (*Cyamopsis tetragonolobis*) with the application of 6 t ha^{-1} grass mulch. The beneficial effects of mulching were attributed to reduction in evaporation, better soil thermal regime and suppression of weeds.

3.4 Water harvesting and irrigation water management

3.4.1 In-situ rain water harvesting: *In-situ* water harvesting and rain water conservation can substantially increase the resilience of arid agriculture to climate variability. Inter-plot water harvesting from a 1.5 m wide catchment area with 5% slope is optimum for a cropped area of 3 m width (Figure 5). Surface sealing of catchment area with pond silt can also be quite effective in generating runoff (Singh, 1988). This technique was particularly beneficial in low rainfall condition when pearl millet yield with inter-plot water harvesting was 1240 kg ha^{-1} compared to 400 kg ha^{-1} in untreated control.

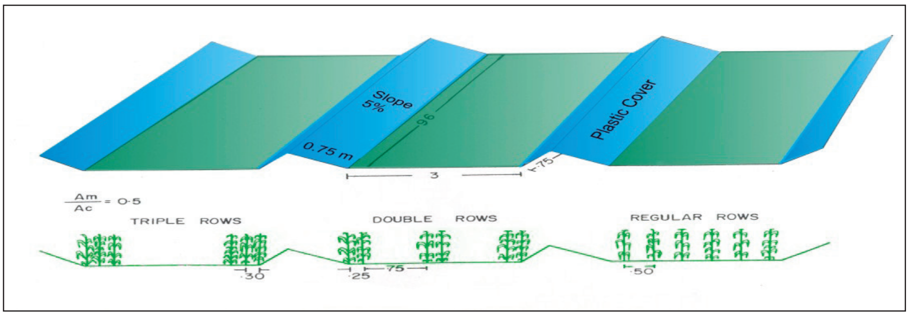


Figure 5. Inter-plot water harvesting system.

Several types of micro-catchment designs have been tried and found effective for establishment of forestry trees and horticultural plants like jujube, pomegranate, date palm etc. In micro-catchment based cropping, rainwater is concentrated in a small portion of the cultivated area. Circular catchments of 1.5 m diameter with 5% inward slope were found appropriate for jujube trees (Sharma *et al*., 1986).

3.4.2 Ex-situ rainwater harvesting: Owing to low rainfall, the scope of *ex-situ* water harvesting is limited in arid zone. However, the runoff water collected from fields during heavy rainfall events and harvested water from farm buildings may be very beneficial for establishment of fruit and tree plants, kitchen gardening or giving lifesaving irrigation, preferably in conjunction with poor quality groundwater, at critical growth stage of crops.

Khadin system, a traditional method of water harvesting, has been practiced since ages in fields surrounded by some sort of natural catchment zone. In the *khadin* system, runoff from upland and rocky surfaces is collected in the downstream fields by making a long earthen embankment. Provision is made to drain excess water. The ratio of farmland to catchment areas is regulated to be about 1:6 to 1:18, so that a suitable moisture supply is uniformly maintained. The soils in *khadins* are enriched through silt deposition. Usually, winter season crops like wheat, gram (*Cicer arietinum*) and mustard are taken on conserved soil moisture. The institute developed a *khadin* of 20 ha areas in Baorali-Bambore watershed near Jodhpur (Rajasthan), which converted .(the water-erosion prone area to a very productive farmland (Narain and Goyal, 2005

3.4.3 Efficient irrigation water management: Maximizing water productivity, rather than the land productivity, should be the major target when irrigation water is limited. Pressurized irrigation systems like drip and sprinkler reduce the conveyance losses, apply water uniformly and in desired quantity, thus increasing the water use efficiency. Sprinkler system is suitable for undulated terrain of arid lands and saves about 30% water compared to conventional check-basin method. But prevalent high wind velocity and saline groundwater (>4 dS m^{-1}) restrict its utility. Drip system is very efficient which can be used to give irrigation to trees, vegetables and widely spaced field crops. It applies water, and, if need be, fertilizer (fertigation), near the root zone. Drip irrigation is particularly suitable for hot arid zones where soils are sandy, and evaporational as well as deep percolation losses are high. Since the irrigation can be given at desired interval to replenish the moisture lost from the root zone, the yield levels are usually high as the soil water status in the root zoon remains favorable. Compared to surface irrigation, about 10-50% higher yields of vegetables were obtained with drip irrigation (Figure 5). Some modification in planting geometry can reduce the number of laterals required per unit area and thus cost of drip system. Paired row planting of cabbage, tomato, turnip and cauliflower and using one lateral between each pair of rows provided almost as much yields as regular planting and using single lateral for each row (Singh, 1978).

Timely weeding, use of mulch, appropriate and timely tillage operations including inter-culture are some of the techniques that minimize wasteful water loss, conserve moisture and increase the amount of water available to crops. Extensive irrigation approach, which focuses on applying limited irrigation water (deficit irrigation) to larger land area and obtaining maximum productivity per unit of water rather than per unit of land, is more appropriate in arid zone as irrigation water is often very limited.

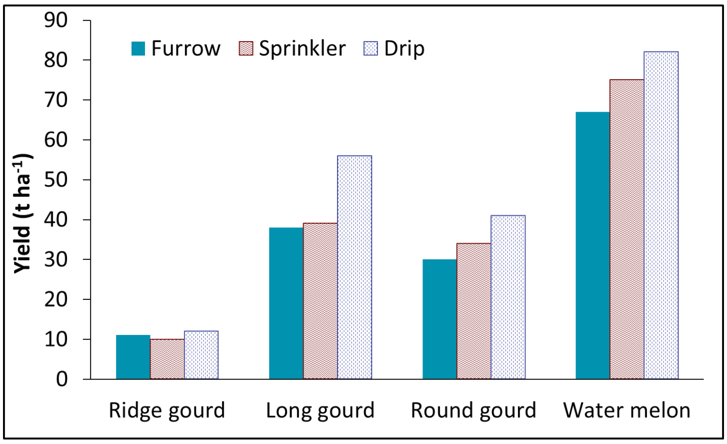


Figure 6. Yield of four crops with three irrigation methods.

3.5 Crop management

Crop and field management strategies need to focus on maximizing use of rainwater by alleviating other yield limiting factors to crop production. Maintenance of adequate and uniform plant stand is crucial for efficient use of rainwater and other inputs. Quality seed of suitable improved varieties, proper seedbed preparation and use of suitable planting equipment ensure desired and uniform stand in the field. Improved cultivars of all the arid crops are available that are responsive to nutrient inputs and resistant to pests and diseases. Kathju *et al*. (2001) reported a twofold difference in the water use efficiency (WUE) of pearl millet genotypes mainly under low rainfall condition. The difference in their maturity period could be the major reason for such high difference in WUE. Similarly, early maturing genotypes of moth bean (RMO-40 and RMO-257) and pearl millet (HHB 67 and CZP 9802) consumed less soil moisture during vegetative stage making it available during the critical flowering stage. Consequently, early maturing genotypes produced higher seed yield and exhibited greater WUE than late maturing types. Higher photosynthetic rates and better metabolic efficiency of early genotypes under water stress led to significantly less reduction in their seed yield and dry matter production as compared to late flowering genotypes (Garg *et al*., 2004).

Nitrogen is low in native arid zone soils and crops suffer from both moisture and nutrient stresses. Applying even modest amount of appropriate fertilizers improves plant vigor as it results in efficient enzyme activity and higher chlorophyll content in crops. N-fertilization improved plant vigor and yield in pearl millet (Garg and Burman, 2011). About 50% of applied N is lost through gaseous emission or leaching and the nutrient use efficiency is very low. To some extent, this can be reduced by reducing solubility, through urease or nitrification inhibitors and use of urea derivatives. N-use efficiency could be increased by sulphur mixed urea that reduced the loss due to ammonia volatilization by 50% (Aggarwal *et al.*, 1987). Possibility of alleviation of water stress effects by P nutrition in clusterbean, at least up to moderate stress level, also exits (Burman *et al*., 2009). Integrated nutrient management involving organic and inorganic sources has been found to be a viable option for pearl millet cultivation, which resulted in high nitrogen use efficiency (Praveen-Kumar *et al*., 1998).

Heat stress is usually associated with water stress as the temperature rises by 2-5°C in the absence of rains. Adverse effects of high temperature on pearl millet, clusterbean and wheat could be partially alleviated by application of iron and zinc through their effect on membrane stability index, nitrate reductase activity and total chlorophyll content in leaves (Garg and Burman, 2011). Use of anti-transpirants, reduction in plant stand by removing alternate or every third row, spray of thiourea and urea and timely weed management have been found effective to reduce the impact of mid-term drought stress on arid crops.

3.6 Using decision support tools

Both long range forecast and numerical weather prediction outputs can be used for informed-decision-making in agriculture. Short and medium range weather forecasts are important for farmers to plan the farm operations like land preparation, planting, thinning, fertilizer application, irrigation, weeding, pest and disease control, management of grazing lands, harvesting, on-farm post-harvest processing and transport of produce (Das *et al*., 2010).

In India, weather forecast-based agromet advisory services (AAS) are being implemented successfully through collective efforts of India Meteorological Department, Indian Council of Agricultural Research institutes, State Agricultural Universities, NGOs and private partners. The AAS bulletins include medium range weather forecast and advice by experts to farmers on ‘what to do’ or ‘what not to do’ for maximizing the advantages of likely favourable conditions and minimizing the losses in production due to adverse weather conditions. At present, the AAS bulletins are issued at district, state and national levels, which are disseminated through newspapers, television, radio, internet, SMS, personal contacts etc. There are plans to issue bulletins at block level (smaller administrative unit) in near future and SMS (text, audio, and video) will be used extensively to reach to maximum number of farmers directly.

3.7 Enhancing farmers’ income through value addition and product diversification

A large number of products or byproducts of arid agriculture are underutilized, but have potential to fetch good income with some value addition. Most of the horticultural produce, milk, meat, mushrooms, hair and wool, etc. are sold directly in the market. Farmers have been traditionally using the pods, fruits or seeds of *Prosopis cineraria, Cordia myxa, Acacia senegal, Ziziphus nummularia*, Z. *rotundifolia, Salvadora oleoides* for livestock or human needs, but not as a source of income generation. Several products have been developed from arid fruits and underutilized plants, which can be prepared at individual farm level, in small cooperatives or self-help groups to augment farmers' income. Wide range of products like juice, pulp, jam, jelly, dehydrated products, powder, candy and tutti-frutti have been prepared from *Ziziphus mauritiana* fruits. Similarly, squash, jelly and *anardana* (dehydrated arils) from pomegranate; squash, carbonated juice, candy and jam from *Emblica officinalis*; pickles from *Cordia myxa* and *Capparis decidua*; and squash, jam, candy, toffee and powder from *Aegle marmelos* fruits can be prepared. Simply drying the pods of *Prosopis cineraria* and fruits of *Capparis decidua* and *Cucumis callosus* can be a source of good income.

There are several naturally growing gum exuding trees like *Acacia senegal, A. jacquimontii, A. tortilis, A. nilotica* and *A. leucocepholea,* which can yield up to 500 g gum per tree after ethaphone injection compared to 20-30 g per tree in natural condition. *Prosopis juliflora* pods-based low cost cattle feed can be prepared easily at small scale. Neem (*Azadirachta indica*) seed cake, oil and pallets have good demand.

Woolen shawls, blankets, carpets etc. may be prepared from wool and hair while handicraft items can be made from cured skin of dead animals. Even farm wastes can be put to good use for mushrooms cultivation or preparation of vermin-compost. Enhanced income of farmers provides good scope for additional investment for technological adoption in order to reduce the risk to farming system.

3.8 Managing livestock to alleviate environmental stress

Livestock is an integral part of arid farming system as it plays crucial role in risk-aversion mechanism for sustaining farm families, when the crops fail due to climatic stresses (Misra *et al*., 2006). Major environmental stresses include heat stress (due to direct effects of high temperature and solar radiation on animals) and nutritional stress (due to drought-induced reduced quantity and quality of feed).

3.8.1 Minimizing effects of heat stress: The livestock employ behavioral changes complemented by physiological mechanisms to counter the heat stress. For example, buffaloes wallow during summer to reduce thermal load and maintain thermal equilibrium. The adverse effects of heat can be reduced by adopting simple and basic rules of animal shed design (shape, orientation and thermo-physical properties of construction material, ventilation, etc.). The environmental modifications attempt to reduce heat stress by reducing the solar radiation and temperature around the animal. The provision of shade (natural or artificial) is one of the simplest and cost-effective methods to minimize heat stress. Trees provide shade to animals and have cooling effect due to transpiration of water from their leaves. The silvi-pasture system or plantation of fodder trees in grazing area provides feed as well as shelter during summer (Sastry et al., 2012). Artificial shades have been used with success for heat-stressed animals in confinement or in intensive situations. Major design considerations like orientation, space, height and roof construction must be taken into account for shade structures. East-west orientation is most suitable design of shed under hot arid condition (CAZRI, 2012).

3.8.2 Improving nutritional management: Scarcity of feed is one of the primary constraints to improve livestock production in arid lands. Livestock diets, usually dominated by crop residues and other low-quality feeds, require inclusion of more energy-rich feeds to increase productivity. Various feeding strategies have been tried to alleviate the adverse effect of heat stress with varying degrees of success. Under extreme climate conditions of Jaisalmer, maintaining grazing sheep exclusively on pasture of *Lasiurus sindicus* reduced animal production, which could be mitigated by adopting scientific feeding and health management practices (Mathur *et al*., 2016). Concentrate @ 200 g/animal/day and health care resulted in increase in live body weight and wool yield of sheep under same grazing condition.

Most of the community grazing resources (CGRs) are degraded. Local governing bodies of the villages need be involved in their improvement as the CGRs are common resources. Improvement of CGRs may involve adoption of soil and water conservation measures, sowing/planting of grasses, shrubs and trees and restriction on grazing during establishment stage. Once established properly, CGR may be subjected to continuous grazing or deferred grazing or rotational grazing or deferred and rotational grazing as per requirement and condition of CGR. In the arid grazing land situation, Das and Paroda (1980) observed a 22% increase in dry matter yield of *Cenchrus* sp. under deferred rotational grazing compared to only 6.3% under continuous grazing. In a *Lasiurus sindicus* dominated grassland in western Rajasthan, deferred rotational grazing gave higher body weight gains of heifers compared to continuous grazing system.

Inclusion of alternate feed resources in livestock feed could be a useful strategy to minimize nutritional stress during lean period. Feeding of cactus pear to livestock reduced their water requirement and increased nutrient digestibility without affecting health of the calves (Mathur and Misra, 2014). Similarly, feeding Blepharis indica and Anabaena azollae also holds promise to provide feed as well as water to animals during feed-scarce summer season (Sahoo et al., 2013). Inclusion of Prosopis juliflora pods in concentrate mixture or feed blocks improved the production and reproduction of animals during summer without any adverse effect on health (CAZRI, 2014).

3.8.3 Livestock species diversification: Maintaining multi-species and multi-breed herd is a strategy adopted by many traditional livestock farmers to buffer against climatic and economic adversities. Such traditional diversification practices are useful to increase climate resilience. The small farms in developing countries are therefore more climate resilient because of their diverse species portfolios, the ease with which they can shift between species and diversify, and their reliance on goats and sheep.

The nature has endowed arid areas of India with some of the best breeds of cattle (Tharparkar, Kankrej, Rathi, etc.), sheep (Marwari, Jaiselmeri, Chokla, Magra, etc.), goats (Sirohi, Marwari, Kutchi, etc.) and other species of livestock (Misra et al., 2012). There are clear genetic differences among breeds in resistance to heat stress, as tropically-adapted breeds maintain lower body temperature during heat stress than non-adapted breeds. High heat tolerance of local breeds is generally correlated with their small size, low-production level and some special morphological traits (properties of the skin or hair, sweating capacity, tissue insulation, special appendages) compared to exotic breeds and crossbred lines. The cattle breeds of drylands of India (Tharparkar, Red Sindhi, etc.) have higher number of sweat glands per unit skin area and larger sweat gland perimeter resulting in higher sweating response compared to crossbred/exotic breeds (Govindaiah et al., 1980). Indigenous breeds, well adapted to the arid environment, are not only heat tolerant but are able to survive, grow and reproduce even with poor seasonal nutrition, and high parasite and disease pressure.

4. The way forward

An array of technologies have been developed and tested to cope with climate variability. Several of them have been successfully demonstrated. As a short-term strategy, there is need to upscale and out scale their adoption through state government departments, *Krishi Vigyan Kendras* (Farm Science Centres), and other extension agencies. Government of India has initiated a program to reach maximum number of farmers through mobile telephony. The platform will be used extensively to reach to the farmers with information related to expected weather vagaries including drought early warning, along with suggestions for appropriate corrective measures to enhance climate resilience at individual farm level.

Heat stress causes several morpho-anatomical, physiological and biochemical changes in plants. A thorough understanding of biochemical and physiological responses of plants to high temperature and mechanisms of heat tolerance will be imperative to develop strategies for improving their thermo-tolerance. Changes in planting dates and plant spacing, fertilizer placement in lower moist soil zones, etc. may be required to reduce the adverse impacts of changes in some climatic parameters as a short-term to medium-term strategy.

As a long-term strategy, major focus should be on development of heat and drought tolerant genotypes suitable for adverse agro-climatic conditions and diversification of farming systems. Emphasis on natural resource management and desertification control, soil and water conservation and maximization of water productivity will always be there for sustainable resource management.

The arid regions are niche to several medicinal and aromatic plants, some of which are hitherto underutilized while some are overexploited. Similarly, there are arid fruits like *Capparis decidua*, *Ziziphus numularia*, *Salvadora oleoides*, *Cordia gharaf*, *Cordia myxa*, which have remained underutilized. Naturally growing, well adapted native trees, fruits, vegetables, and medicinal and aromatic plants may be used to diversify the farming systems in different agro-climatic zones of the hot arid zone.

Livestock, particularly goat and sheep, have been reared on grazing in rangelands. Semi-intensive and intensive management systems, including feeding, housing and healthcare needs to be developed. Conservation and improvement of local breeds of livestock also need consideration.

Modern tools of biotechnology and genetic engineering have a great potential to augment conventional breeding programs to develop and design climate resilient crops. Collaborations with national and international organizations to share experience and expertise hold a great promise to develop climate resilient arid farming.

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Theme 4. Soil health and land use constraints for agricultural productivity in dry areas and their management

1. Evaluation of soil quality under organic agriculture systems in irrigated arid lands

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Abstract

Evaluation of soil quality or soil health is complicated because many physical, chemical, and biological processes and their interactions in time, especially at different cultivation periods affect the quality. The present work aimed to study the effect of organic farming for different periods on soil quality indicators (i.e. physical, chemical and biological) in selected organic farms. The study sites were selected to represent different farms with different organic cultivation periods and different management practices. The selected sites represent two different great soil groups, torripasamment and torrerts. The principal component analysis (PCA) was used to obtain the minimum data set needed for soil quality evaluation. The PCA of the standardized values was used for the measured 27 soil variables for different periods of organic cultivation and the same for uncultivated soil. Results indicated that organic farming improved most of the studied soil quality indicators of both soil groups i.e. organic carbon content, CEC, bulk density, porosity, aggregation state, structure factor (Sf), soil salinity, available macro and micronutrients level, SAR, ESP%, total N %, OM%, C/N ratio, soil respiration, microbial biomass (MBC), and microbial quotient (MQ). Results indicated that soil respiration, MBC, MQ, organic matter, and physical aspects of soil quality are the most sensitive indicators of soil quality evaluation. In torripasamment soil the score of Soil Quality Index (SQI) depended mainly on soil biological properties, but in torrerts soil the score of SQI depended on soil physical indicators. The best score for SQI was at the fourth cultivation periods in torripasamment (13 years organically managed) and at the third cultivation period in torrerts (17 years organically managed).

Keywords: Organic agriculture, Soil quality index, PCA, MDS, Soil organic matter, Arid lands.

Introduction

Soil quality is defined as the capacity of a soil to function within an ecosystem and land-use boundaries, to sustain biological activity, maintain environmental quality, and promote plant, animal, and human health (Doran and Parkin, 1994). Doran *et al*. (2000) defined soil health to indicate more integrative nature of the soil similar to that of a functioning living system that focuses more on sustaining biological production and maintaining the health of the environment. The assessment of soil quality or soil health and direction of change with time are considered as the primary indicators of sustainable land management (Doran *et al*., 2000).

Soil quality indices are considered the most common methods for soil quality evaluation because of the ease in use, flexibility and quantification. These indices represent the cumulative effects of different soil properties (physical, chemical and biological) as an index based on the role of each indicator in soil quality (Drury *et al.,* 2003; Singh and Khera, 2009).

In organic farming systems, plant production mainly depends on nutrient transformation in soil because only a limited amount of fertilizer is used. According to IFOAM (2009) organic agriculture is a production system that sustains the health of soils, ecosystems and people. Soil quality indicators may be qualitative (e.g. fast drainage) or quantitative (infiltration= 2.5 in/hr). Many of investigators have discussed this issue. Carter *et al.* (2004) reported that an important feature of soil quality is the differentiation between inherent and dynamic soil properties. Qi *et al.* (2009) suggested soil quality indices to evaluate agricultural soil quality in Zhangjiagang as an important county of China. They used the principal component analysis (PCA) for selecting minimum data set (MDS) from nineteen physical, chemical and biological soil properties as the total data set (TDS) under different planting patterns and soil types. They concluded that the selected MDS had a good efficiency in representing TDS.

The main objective of this work was to determine MDS for evaluating soil quality of organic farming system using multivariate analysis, evaluating the importance of cultivation periods on the improvement of soil quality and developing scoring function for soil quality assessment of some organic farming systems in Egypt.

Materials and methods

The study sites were selected to represent irrigated farms under different cultivation periods and management practices in two great soil groups dominating in arid lands (i.e. Torripasamment and Haplotorrerts). Torripasamment soil was selected to represent sandy textured soils at Nubaria area located west of the Delta region (Figure 1). The selected farms were located at an elevation of 20 masl with arid climate conditions (precipitation 94 mm/year, temperature range 14.3-28.1^{o}C). Four farms were chosen to represent organic cultivation periods of 2, 6, 10 and 13 years plus uncultivated soil. Haplotorrerts soil was selected to represent clay-textured soils located in Faiyum governorate (Figure 1). The selected farms were located at an elevation of 28.30 masl with arid climate conditions (precipitation about 13.7 mm, temperature range 14.5-29.5^{o}C). Three farms were chosen to represent organic farming periods of 5, 10 and 17 years plus uncultivated soil.

A brief description of the farming practices, source of irrigation water; irrigation system, pest control management and cropping pattern in the study sites are given in Table 1. The selected soil profiles were described in the field, and then 42 representative samples were collected according to the morphological variations in the studied profiles. Collected samples were prepared for physical, chemical and microbiological analyses following the standard procedures. Undisturbed soil samples were collected by cylinder (5 cm height and 5 cm diameter) after removing gravels from soil surface and prepared for bulk density and total porosity measurements according to Page *et al* (1982). Structure factor (s_f) was calculated after El-Sarangawy (1986). Soil physical and chemical properties were evaluated according to Page *et al.* (1982) and Rhoades (1982). Representative sub-samples were extracted by DTPA (diethylene triamine penta acetic acid) according to Johnson (1992) for available micronutrients determinations. Extractable Fe, Mn, Cu and Zn were measured using atomic absorption spectrometry (AAS) according to Ure (1991). Available phosphorus was extracted by $NaHCO_3$ method and determined using ascorbic acid as a reducing agent according to Anonymous (1994). Available K was extracted and measured using flame photometer.

Figure 1. Location of the sites: Om-El- moemineen farm (Lat 30˚ 1544.39 ’” and Long 30º 5’ 56.85” 2) and El- Esh (Lat 29˚ 1814.31 ’” and Long 30º 51’ 16.05”).

Table 1. The selected soil profiles and the applied agriculture management systems in the studied farms

Governorate and District	Profile No.	Farming system		Irrigation		Crop at sampling time	Fertilizers	Pest control
		Type	Age years	Source	Method			
El-Behera El- Nubariya	1	organic	2	Blended water	Drip	Tomato	Compost 10-15 m^3+(rock phosphate+ natural potassium + EM and natural Nitrogen (Algazon)) with recommended dose	-Insecticidal soap -Micronized sulfur . -Natural oil
	3		6	Blended water	Drip	Snap bean		
	5		10	Blended water	Drip	Pepper		
	7		13	Blended water	Drip	Asparagus		
El- Faiyum Ebshiway	9	organic	5	Well (coming from the Nile)	Surface	Calendula	Compost 12 m^3	-Insecticidal soap -Micronized sulfur . -Natural oil
	11		10		Surface	wheat	Compost 12 m^3	
	13		17		Surface	Mint	Compost 12 m^3	

Representative sub-samples from each layer were prepared and analyzed for some biological properties by the standards methods described by Anderson and Domsch, (1978).

The obtained data was statistically analyzed according to SPSS (2002) and soil quality index (SQI) was obtained as follows: a) Selection of a minimum data set (MDS) of indicators that best represent soil function; b) Scoring the MDS indicators based on performance of soil functions; and c) Integrating the indicator scores into a comparative index of soil quality. The selected indicators were converted to score values (between 0 and 1) using the non-linear scoring functions. The scored values were integrated into indices using additive model (Eq. 1), where SQI = soil quality index, Si = score values for individual indicators and, n = number of indicators used:

$$SQI = \left[\sum_{i=1}^{n} \underline{Si} \right] * 10 \qquad \text{Eq. 1}$$

Results and discussion

1. Physical soil quality indicators

Regarding torripasamment soil, data in Table 2 indicated that fine sand, and silt +clay content was relatively higher in organically cultivated soil than the uncultivated soil .The variation in soil texture under the organic farming systems are related mainly to the variability in soil formations and not to the management practices in the farm. Organic farmed soils were higher in soil aggregation state than the uncultivated soils, and the aggregation state increased with depth. Soil structure factor data indicated a similar trend.

Bronick and Lal (2005) reported that soil structure is often expressed as the degree of stability of aggregates and addition of organic amendment was associated with a significant improvement of the structural stability of the soil. Also, data in Table 2 showed that the soil bulk density for the surface layer decreased as the period of cultivation increased. The total porosity % (Table 2). showed an opposite trend.

For haplotorrerts soils, data in Table 3 indicated clay texture and the clay percentage was higher in soil under organic farming than in the uncultivated soil. The higher percent was found in profile No.9 followed by profile No. 13. The difference in clay, silt and sand fractions of the soil was mainly related to the addition of these constituents to the soil either by human action or by wind action. All organic cultivated soil profiles were lower in soil bulk density, and higher in total porosity, aggregation state, and structure factor than the profiles of uncultivated soils. Jastrow and Miller (1998) showed that there are positive feedback cycles between SOC, its accumulation in macro-aggregates and enhanced aggregate stability. It appears from these data that organic cultivation improved soil physical properties, which in turn enhanced other soil properties and soil behavior.

2. Chemical soil quality indicators

Data of torripasamment soils, (Table 4) indicated relatively lower soil pH and ECe in the cultivated soils compared with the uncultivated soil. Organic farming soils had higher CEC values than the uncultivated soils. The highest level was found in soils organically cultivated for 6 years, followed by 13 years cultivation periods. The available N, P, K and SOM were higher under

Table 2. Soil physical indicators for the studied soil profiles samples, Om El-moemineen farm (Nubariya site)

Pro. No.	Farming period & Age	Depth cm	Sand (%)		Silt %	Clay %	Textural Class	Bulk density (Mg/m^3	Total porosity (%)	Aggregation state (%)	Structure factor (Sf) %
			Coarse	Fine							
1	Tomato (2years)	0-30	21.5	65.0	6.20	7.30	Sand	1.53	42.2	4.41	8.21
		30-60	21.0	68.0	3.50	7.50	Sand	1.54	41.8	4.30	10.6
		60-90	15.5	73.5	2.50	8.50	Sand	1.58	40.3	4.81	8.23
2	Uncultivated soil (2years)	0-30	28.5	65.0	3.20	3.30	Sand	1.63	38.4	2.60	4.06
		30-60	22.5	70.0	3.50	4.00	Sand	1.64	38.1	1.59	4.13
		60-90	16.5	75.4	3.50	4.60	Sand	1.64	38.1	2.23	3.92
3	Snap bean (6years)	0-30	9.00	79.5	3.00	8.50	Sand	1.47	44.5	6.15	9.00
		30-60	7.50	79.5	4.00	9.00	Sand	1.51	43.0	9.04	9.31
		60-90	6.80	80.0	4.00	9.20	Sand	1.51	43.0	9.00	9.00
4	Uncultivated soil (6years)	0-30	18.0	77.5	2.00	2.50	Sand	1.58	40.3	1.54	3.55
		30-60	16.0	80.0	1.50	2.50	Sand	1.60	39.6	1.53	3.90
		60-90	14.0	82.0	1.70	2.30	Sand	1.65	37.7	1.45	3.52
5	Pepper (10years)	0-30	15.0	72.3	3.50	9.20	Sand	1.50	43.3	7.32	9.33
		30-60	7.00	80.4	3.10	9.50	Sand	1.52	42.6	9.89	9.87
		60-90	7.60	80.0	3.10	9.30	Sand	1.52	42.6	9.92	10.0
6	Uncultivated soil (10years)	0-30	12.0	79.0	4.50	4.50	Sand	1.59	40.0	2.67	4.30
		30-60	14.4	75.5	6.50	3.60	Sand	1.63	38.4	2.49	4.00
		60-90	19.0	71.2	6.50	3.30	Sand	1.65	37.7	2.40	3.79
7	Asparagus (13years)	0-30	6.50	82.0	5.50	6.00	Sand	1.48	44.1	5.95	8.64
		30-60	4.50	83.5	5.50	6.50	Sand	1.49	43.7	7.56	9.58
		60-90	3.80	84.0	5.60	6.70	Sand	1.50	43.3	8.00	10.0
8	Uncultivated soil (13years)	0-30	11.0	79.5	5.50	4.00	Sand	1.60	39.6	3.00	2.65
		30-60	10.5	81.0	5.50	3.00	Sand	1.64	38.1	2.34	2.50
		60-90	11.7	80.0	5.50	2.80	Sand	1.65	37.7	2.20	2.42

Table 3. Soil physical indicators for the studied soil profiles samples , EL-Esh farm (Ebshiway site).

Pro. No.	Farming periods& Age	Depth cm	Sand (%)		Silt %	Clay %	Textural Class	Bulk density (Mg/m3)	Total porosity (%)	Aggregation state (%)	Structure factor (Sf) %
			Coarse	Fine							
9	Calandula **(5 years)**	0 - 20	5.00	10.0	20.0	65.0	Clay	1.11	58.1	20.2	18.5
		20 - 45	3.00	10.0	21.5	65.5	Clay	1.20	54.7	21.4	21.5
		45-75	2.50	10.5	22.5	64.5	Clay	1.20	54.7	21.4	23.2
10	**Uncultivated soil (5 years)**	0-20	11.0	18.0	25.0	46.0	Clay	1.35	49.0	30.0	10.3
		20-45	10.0	18.0	25.0	47.0	Clay	1.37	48.3	30.6	11.3
		45-75	10.0	20.0	23.0	47.0	Clay	1.40	47.1	31.5	11.3
11	**Wheat (10 years)**	0-20	5.00	10.0	35.0	50.0	Clay	1.06	60.0	21.8	20.0
		20-45	2.50	9.00	36.4	52.1	Clay	1.09	58.8	19.4	26.3
		45-75	2.00	9.50	36.0	52.5	Clay	1.18	55.4	20.4	25.0
12	**Uncultivated soil (10 years)**	0-20	9.80	18.0	27.0	45.2	Clay	1.31	50.5	29.0	11.9
		20-45	12.0	20.0	25.0	43.0	Clay	1.32	50.1	32.0	9.32
		45-75	10.0	20.0	26.0	44.0	Clay	1.39	47.5	32.0	8.13
13	**Mint (17 years)**	0-20	3.50	11.5	25.5	59.5	Clay	1.16	56.2	18.7	20.4
		20-45	6.00	10.0	24.0	60.0	Clay	1.20	54.7	20.2	22.0
		45-75	3.50	10.0	26.5	60.0	Clay	1.22	53.9	19.3	21.1
14	**Uncultivated soil (17 years)**	0- 20	12.0	21.0	22.5	44.5	Clay	1.36	48.6	33.0	10.4
		20-45	7.00	21.0	27.0	45.0	Clay	1.36	48.6	29.0	10.3
		45-75	8.00	22.0	26.0	44.0	Clay	1.40	47.1	30.0	9.27

Table 4. Some chemical indicators of the studied soil samples from the organic farming site, Om Elmoemineen farm (Nubariya site).

Pro. No.	Farming periods& Age	Depth cm	pH at 1:2.5	ECe (dS m^{-1})	O.M %	$CaCO_3$ %	(cmol/kg)			ESP %	CEC cmol/ kg	Nt (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
							Ca^{++}	Mg^{++}	Na^{+}					
1	Tomato (2years)	0-30	7.65	0.٤١	3.97	0.88	5.79	0.٥١	0.16	1.93	8.28	0.26	8.98	366
		30-60	7.51	0.55	1.40	1.00	5.60	0.48	0.16	2.00	8.00	0.08	14.6	350
		60-90	7.74	0.31	1.19	0.80	5.32	0.4٦	0.15	1.97	7.60	0.06	9.80	336
2	Uncultivated soil (2years)	0-30	7.81	0.32	0.39	1.10	2.55	0.23	0.12	3.08	3.90	0.02	9.98	109
		30-60	7.85	0.25	0.2٨	0.89	2.66	0.23	0.08	2.11	3.80	0.01	8.26	172
		60-90	7.90	0.22	0.1٤	0.82	2.45	0.21	0.07	2.00	3.50	0.01	11.6	172
3	Snap bean (6years)	0-30	7.60	0.51	3.28	2.60	6.79	0.58	0.19	1.96	9.70	0.21	11.1	382
		30-60	7.66	0.55	2.80	2.82	6.37	0.55	0.18	1.98	9.10	0.18	10.8	344
		60-90	7.68	0.56	2.40	2.85	6.50	0.51	0.18	2.00	9.00	0.15	9.80	344
4	uncultivated soil (6years)	0-30	7.62	1.17	0.34	2.81	3.99	0.34	0.11	1.93	5.70	0.02	11.6	172
		30-60	7.82	1.00	0.19	2.91	3.71	0.32	0.11	2.08	5.30	0.01	9.68	148
		60-90	7.83	1.10	0.15	2.98	3.80	0.34	0.11	2.10	5.00	0.01	8.20	148
5	Pepper (10years)	0-30	7.82	0.85	3.83	1.74	5.95	0.51	0.17	2.00	8.50	0.25	11.7	272
		30-60	7.85	0.93	3.40	1.85	5.95	0.51	0.17	2.00	8.50	0.22	11.8	234
		60-90	7.85	0.95	3.10	1.93	5.90	0.53	0.16	1.86	8.60	0.19	11.0	195
6	uncultivated soil (10years)	0-30	8.10	3.06	1.03	13.0	2.94	0.25	0.08	1.90	4.20	0.05	14.2	210
		30-60	8.00	3.11	0.60	13.1	3.36	0.29	0.11	2.29	4.80	0.03	11.5	202
		60-90	8.00	3.14	0.34	13.4	3.53	0.30	0.11	2.44	4.50	0.01	11.0	172
7	Asparagus (13years)	0-30	7.46	0.55	4.15	0.87	6.51	0.56	0.19	2.04	9.30	0.25	8.78	312
		3060	7.5	0.60	2.99	0.85	6.44	0.55	0.18	1.96	9.20	0.19	8.52	272
		60-90	7.5	0.60	2.90	0.86	6.43	0.55	0.18	2.00	9.20	0.18	8.50	272
8	uncultivated soil (13years)	0-30	7.85	1.67	0.28	1.92	2.73	0.23	0.08	2.05	3.90	0.01	15.0	179
		30-60	7.87	1.81	0.26	2.11	2.52	0.22	0.07	1.94	3.60	0.01	11.2	179
		60-90	7.87	1.82	0.24	2.81	2.52	0.22	0.06	1.82	3.30	0.01	11.2	156

Table 5 . Some chemical indicators of the studied soil samples from the organic farming site, EL-Esh farm (Ebshiway site)

Pro. No.	Farming periods& Age	Depth cm	pH at 1:2.5	ECe (dS m- 1)	O.M %	CaCO3 %	(cmol/kg)			ESP	CEC cmol/ kg	Nt (%)	Available P (mg kg-1)	Available K (mg kg-1)
							Ca++	Mg++	Na+	%				
9	Calendula (5 years)	0-20	7.96	4.69	4.20	9.81	33.3	5.23	1.42	2.98	47.6	0.24	30.2	985
		20-45	8.10	5.10	4.10	6.91	33.8	5.32	1.91	3.94	48.4	0.22	15.4	993
		45-75	8.20	5.02	3.80	12.2	33.0	5.19	2.1	4.44	47.2	0.19	11.0	1329
10	Uncultivated soil (5 years)	0-20	8.11	15.3	2.90	9.11	24.4	3.83	2.14	6.13	34.9	0.12	25.4	1008
		20-45	8.21	15.1	2.50	9.51	23.9	3.76	2.25	6.57	34.2	0.12	30.8	985
		45-75	8.00	14.2	2.50	8.33	22.3	3.50	2.52	7.89	31.9	0.11	28.1	914
11	Wheat (10 years)	0-20	7.90	3.76	4.40	7.12	28.9	4.55	1.38	3.33	41.4	0.25	57.9	1180
		20-45	7.85	3.47	4.01	8.52	28.1	4.42	1.51	3.75	40.2	0.22	41.3	1149
		45-75	7.79	3.17	3.70	6.95	30.8	4.84	1.76	4.00	44.0	0.18	40.0	1251
12	Uncultivated soil (10 years)	0-20	8.09	9.38	2.60	9.88	25.4	4.00	2.9	7.96	36.4	0.12	43.2	1047
		20-45	8.10	9.62	2.32	10.1	24.7	3.88	2.5	7.08	35.3	0.11	38.4	1016
		45-75	8.11	9.58	2.20	10.5	25.8	4.05	2.5	6.77	36.9	0.11	25.3	1055
13	Mint (17 years)	0-20	7.88	2.91	4.80	6.33	33.4	5.25	2.24	4.68	47.8	0.25	55.2	1352
		20-45	7.89	3.02	4.60	7.22	33.3	5.23	2.45	5.14	47.6	0.23	51.1	1360
		45-75	7.91	2.56	4.00	7.55	34.1	5.36	2.1	4.30	48.8	0.20	48.4	1368
14	Uncultivated soil (17 years)	0-20	8.12	6.44	2.40	8.22	22.8	3.59	1.7	7.78	34.7	0.11	47.3	946
		20-45	8.15	6.61	1.92	9.13	21.8	3.43	1.8	8.43	33.2	0.09	43.1	899
		45-75	8.00	6.82	1.80	9.87	21.5	3.38	1.8	8.80	31.8	0.07	40.0	891

organic farming than in uncultivated soils. The highest level of organic carbon, total nitrogen contents and SOM content was obtained under 13 years organic farming followed by 10 and 2 years.

Data of haplotorrerts soils (Table 5) showed that soils under organic farming generally had low soil pH and relatively high ECe values. Also, soil CEC values and exchangeable Ca^{++}, Mg^{++}, and Na^{+} were relatively higher in the organic farmed soils. The studied soils had very high contents of available K and organic farmed soils had relatively higher available K than uncultivated soils. In general the high K levels in these clayey soils could be related to the type of parent materials from which these soils were developed and to the management practices. Total N, OC and SOM contents were higher in the cultivated soils than those of the uncultivated soils. Also, the highest level was obtained under the organic farming period of 17 years followed by 10 years. These results are in good agreement with those of Kaschl *et al.* (2002).

Data of torripasamment and haplotorrerts soils revealed that the contents and distribution of $CaCO_3$ in the studied soils were more related to the soil forming processes under the prevailing arid climate conditions. It seems also that $CaCO_3$ content and its distribution with depth was not a clear dynamic indicator for soil quality evaluation.

3. Biological soil quality indicators

For torripasamment (Figure 2 & 3) soil basal respiration in laboratory assays, as well as soil microbial biomass C (SMBC), were enhanced by the organic farming for different years with different crops as compared to the uncultivated soils. This effect was evident especially for soils 10 and 13 years under organic cultivation and surface layer had relatively higher values than deep layers. Microbial quotient (MQ, Figure 4) was decreased by organic farming as compared to the uncultivated soils. MQ was relatively lower in surface than deep layers, which may be related to increased OC or decreased SMBC in the surface layer. Data of haplotorrerts (Figure 5) showed that the highest soil respiration rate was found in the soils under organic farming for 17 years. The rate of soil respiration had the following ascending trend 5 years 10 < years 17 < years. Figure 6 showed that the SMBC content displayed similar trend to that obtained for soil respiration rates. MQ (Figure 7) of haplotorrerts showed quite different trend to that obtained for torripasamment soil.

4. Principal Component Analysis (PCA) for soil properties

The PCA output for the physical, chemical, and biological characters indicated that only PCs with eigenvalues > 1 explained that at least 5% of total variance were retained for interpretation. The first component was marked by high loadings for some attributes.

In torripasamment soil, the first component was determined by soil respiration, MBC, MQ, total porosity, bulk density ,%Silt +Clay, %OM, %SOC, CEC, NT, available NO_3 content and available Fe, Mn, Zn, and Cu. The second component was determined by structure factor (Sf), %$CaCO_3$, available P, Mn, Zn, and Cu, pH, and ECe. The third component was determined by SAR and available K content. The obtained results are directly related to the organic farming management systems. Also, it can be concluded that soil physical, chemical, and biological condition increased

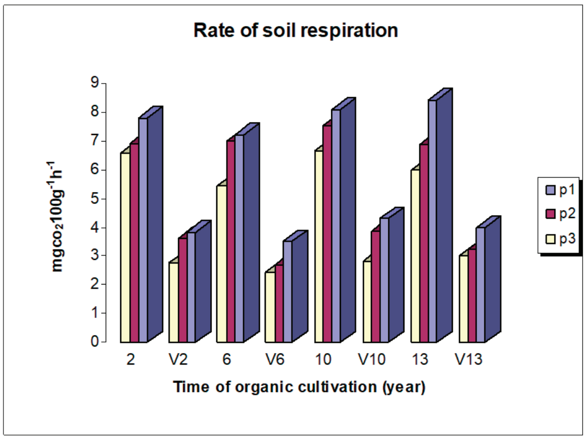

Figure 2. CO2 concentrations at different soil depths taken from the organic farming , (Nubariya site). P1 0-30 cm, P2 =30-60 cm, P3 =60-90 cm.

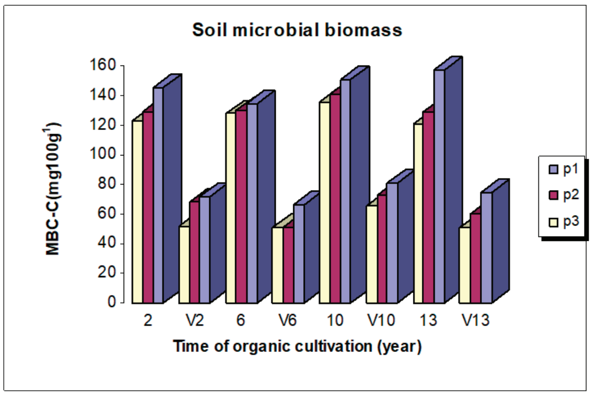

Figure 3. Microbial biomass C at different soil depths taken from the organic farming , Om El-moemineen farm (Nubariya site). P1 =0- 30 cm , P2 =30--60 cm, P3=60-90 cm.

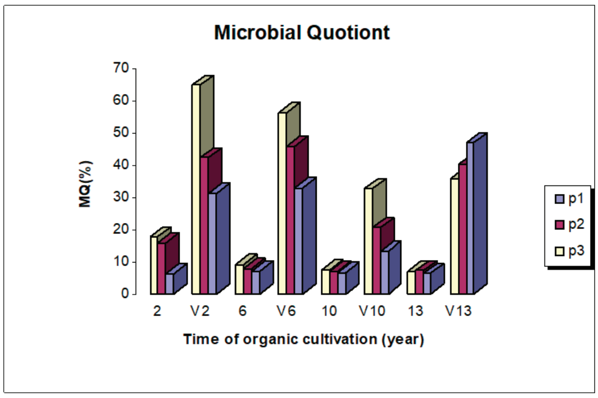

Figure 4. Microbial quotient (%) at different soil depths taken from the organic farming , (Nubariya site). P1 =0- 30 cm , P2 =30--60 cm, P3=60-90 cm.

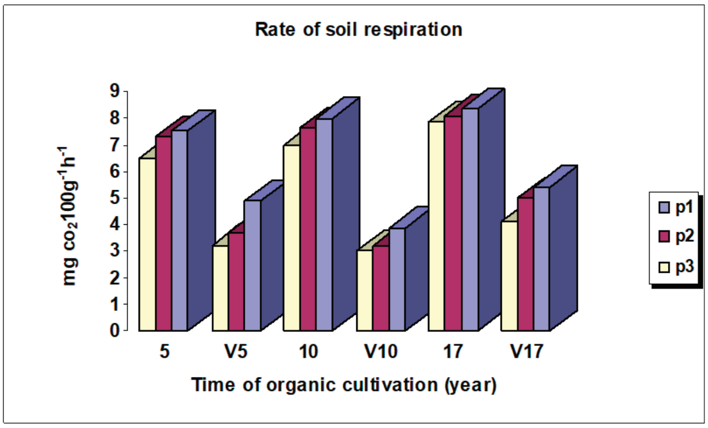

Figure 5. CO_2 concentrations at different soil depths taken from the organic farming, (El-Faiyum site **).** P1 =0- 30 cm , P2 =30--60 cm, P3=60-90 cm.

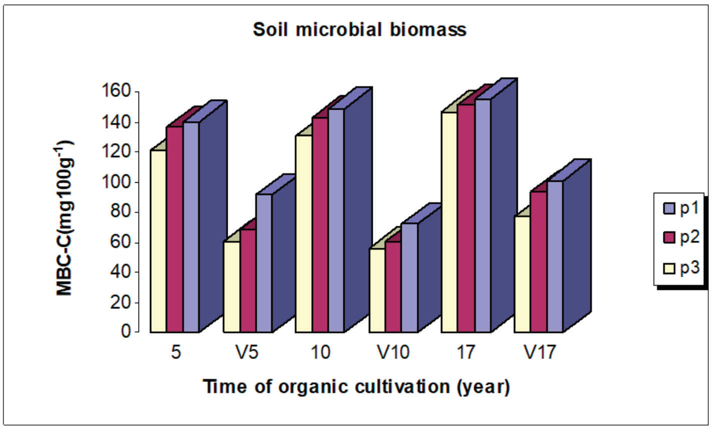

Figure 6. Microbial biomass C at different soil depths taken from the organic farming, (El-Faiyum). P1 =0- 30 cm , P2 =30--60 cm, P3=60-90 cm.

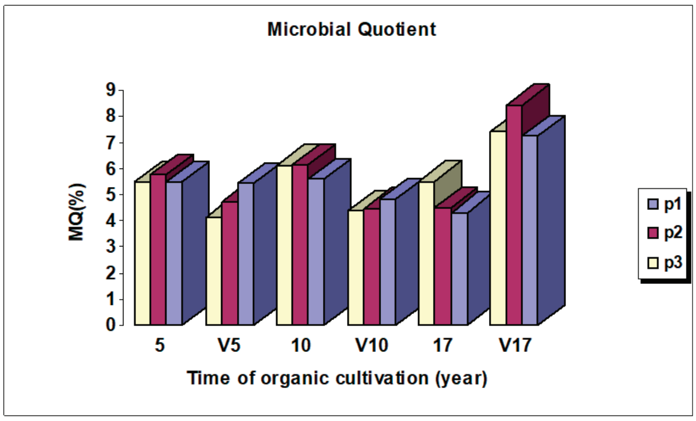

Figure 7. Microbial quotient (%) at different soil depths taken from the organic farming (El-Faiyum). P1 =0- 30 cm , P2 =30--60 cm, P3=60-90 cm.

with PC1 scores. PC1 represented in physical SQI in the following order of cultivation periods 2 year > 6 years >10 years >13year. The SQI for chemical variables had similar order, but biological SQI was quite different and showed the following order: 2 years >13 years > 6 years >10 years. The results indicate that soil respiration, MBC, MQ, OM, and physical aspects of soil quality were the most sensitive indicators of the soil quality of the farming system.

Data of haplotorrerts showed that the first component was determined by soil aggregate state, bulk density, %silt + clay, Sf and some chemical indicators e.g. % ESP, SAR, available NH_4, available Cu, pH, and ECe. The second component was determined by soil respiration, MBC, MQ, CEC, %$CaCO_3$ and available Fe. The third component was determined by soil respiration and % clay. Results indicated that soil respiration, MBC, MQ , OM, and physical aspects of soil quality are the most sensitive indicators of the soil quality evaluation. Thus in torripasamment soil the score of SQI were depending mainly on soil biological indicators, but in haplotorrerts soil, the score of SQI were depending on soil physical indicators. Also, the best score for SQI was under13 years organic farming period with torripasamment and 17 years organic farming with haplotorrerts. The SQI was calculated using weighting factors for each scored MDS variable according to the following formula where s is the score for the subscript variable and the coefficients are the weighting factors derived from the PCA:

$$SQI = \left[\sum_{i=1}^{n} Si \right] * 10$$

Weights were determined by the percent of variation in the data set explained by the PC that contributed the indicated variable divided by the total percentage of variation explained by all PCs with eigenvectors>1.The retained components consist of weighted sum of original variables :in the following mathematical model

PCi1 = Ai1X1 + Ai2X2+ · --- + Ai nXn, where: PC = principal component, X = the explicative variable, n = number of variables, i = 1, 2, 3,… , n.

For torripasamment, the highest SQI was found under 13 years of organically managed soil (**Σ**SQI= 145.9) and lowest in uncultivated soil (**Σ**SQI=123.2). Also, in haplotorrerts, the highest SQI was found under 17 years of organically managed soil (**Σ**SQI= 106) and lowest with uncultivated soil (**Σ**SQI=35.5).

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2. Testing and up-scaling sustainable technologies for soil salinity management in irrigated semi-arid lands of Taveta sub-county, Kenya

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Abstract

Soil salinity is a constraint to land productivity in semi-arid Taveta irrigation schemes. It affects over 82,000 farm families in over 800 hectares of land. Research was conducted to evaluate the use of *Mavuno* NP fertilizer (at 60 kg P_2O_5 ha^{-1}), 20 t ha^{-1} FYM (cattle manure), 40 t ha^{-1} trash incorporation, meeting100% gypsum requirement, rotational crop of Rhodes grass, rotational crop of Sudan grass and control (farmers' practice) for salinity management for raising maize (*Zea mays* L.) crop. Mean maize grain yield and TDM were measured. The treatments involving application of 20 t ha^{-1} FYM + *Mavuno* NP fertilizer and *Mavuno* NP fertilizer alone significantly ($p \leq 0.05$) increased maize yield compared to farmers' practice. However, after three consecutive years of experimentation, mean yields of maize grain, stover and cobs dry weight and TDM were significantly ($p \leq 0.05$) increased over the farmers' practice by residual effects of trash plus *Mavuno* NP fertilizer, meeting 100% gypsum requirement, and trash incorporation alone. Grass treatments were dropped after the initial year as there was no farmer preference for them. It was concluded that 20 t ha^{-1} FYM + Mavuno NP fertilizer (at 60 kg P_2O_5 ha^{-1}) can be recommended for use by farmers in moderately saline-sodic soils of Taveta sub county and trash incorporation with Mavuno NP fertilizer at 60 kg P_2O_5 ha^{-1}, 100% gypsum requirement plus Mavuno NP fertilizer and trash incorporation alone can be suitable technologies in the long run in sodic-moderately saline soils. Use of 20 t ha^{-1} FYM plus 60 kg P_2O_5 ha^{-1} is recommended for up-scaling in sodic-moderately saline soils while more research is required on the other treatments used in this study.

Keywords: Salinity management, Irrigation schemes, Cattle manure, *Mavuno* fertilizer, Trash incorporation, Gypsum requirement

1. Introduction

Soils become saline if they contain large amounts of soluble salts to interfere with plant uptake of water from soil and its growth (Ayers and Westcot, 1994; Richards, 1954; Chhabra, 1996). A saline soil has ECe > 4dS.m^{-1}, pHe < 8.3, ESP < 15. The soils are massive, lack structural B horizon and contain very little organic matter (org. C% < 1). The soluble salts mainly consist of chlorides and sulphates of sodium, calcium and magnesium. Bicarbonates may be present or not and Ece soil increases as exchangeable calcium increases in the soil (Chhabra, 1996; Kathuli *et al.,* 2013). Crop yields start declining at ECw >0.8dS.m^{-1} or soil ECe >1dS.m^{-1} (Ayers and Westcot, 1994). Severity of salinity increases with desiccation of the soil and affects crops depending on degree of salinity at the critical stages of growth, resulting in reduced yield and in severe cases, total loss of yield (Rasel *et al.,* 2013; Ali, 2009).

Soil salinization is a major constraint to optimal utilization of land resources in all irrigated areas worldwide (Michael and Lauchli, 2002; ICID, 2009). Some 20-50% of all irrigated lands are salt-affected. The situation is severe in the arid and semi-arid regions (Rasel *et al.,* 2013), which comprise of approximately 43 million ha of salt-affected soils (Dregne *et al.,* 1991) with Kenya accounting for 26 million of these soils (Mugai, 2004). Water logging and salt accumulation, resulting from the use of low quality irrigation water, leads to salinization. Low rainfall (250-500 mm) in the semi-arid lands is partially responsible for salinization because of to high evaporation rates (2500 mm per annum) (Mugai, 2004).

In Taveta irrigation schemes, soil salinization is a constraint to crop production and is aggravated by the use of low quality water used for irrigation (Itabari and Kizito, 2004). In this sub-county, about 15-20% of once non-saline arable land has been rendered waste land by salinization and about 800 ha of land in Taveta irrigation schemes is saline (Sijali *et al.,* 2003). It is estimated that another 5-10% of the arable land will be affected by salinity if urgent and appropriate interventions are not taken (Sijali *et al.,* 2003).

The extent of soil salinization in Taveta sub-county has been attributed to accumulation of soluble calcium salts and chlorides from irrigation waters and external salt intrusion (Kathuli *et al.,* 2013). The problem is wide spread in all the irrigation schemes in the sub-county with *Kimoringoh/Kamleza* and *Kimala* irrigation schemes being significantly more saline (Kathuli *et al.,* 2013). Farmers have been abandoning agricultural lands once they become economically unfeasible to continue being cultivated (Rasel *et al.,* 2013; Sijali *et al.,* 2003). This implies that unless measures are put in place to mitigate the impact of soil salinization in this sub-county, agricultural production will decrease and hence also the food insecurity. This will in turn contribute to increased poverty for over 82,000 persons living in this sub-county (Census, 2009). In order to ensure sustainable food production and land use in the salt-affected soils of Taveta sub-county, it was found prudent to develop and scale up farmer-affordable technological packages for soil salinity management in the irrigation schemes.

2. Materials and methods

2.1 Study sites

The study involved five selected major irrigation schemes: Njukini (37°35.97’55”E, 9.6°48.3’53”N), Kasokoni (37°35.7’56.7”E, 9.6°32.09’7”N), Challa (37°36.05’54”E, 9.6°40.1’24”N), Kamleza (37°35.44’89”E, 9.6°14.9’40”N)-Kimoringoh (37°35.52’44”E, 9.6°15.17’7”N) and Kimala Blocks A and B (37°35.61’03”E, 9.6°25.17’9”N) in Taveta sub-county. Three representative schemes were chosen from the above schemes, based on soil salinity gradient and severity of damage to crops, using farmer information and ground trothing, for evaluating salinity management technologies. These sites were Kimala block A (Madicha site), Kamleza-Kimoringoh (Eldoro site) and Njukini (Gideon Ndolo site). Kamleza-Kimorigoh irrigation scheme represented the most salt affected soils while Njukini irrigation scheme represented fairly saline soils. Njukini and Kimala sites had been under cultivation for over ten years while Eldoro site was newly cultivated. The three irrigation schemes represented soil salinity encountered in whole of Taveta sub-county. In the field, some areas in the study sites exhibited salt accumulation on the soil surface (Plate 1) and others were bare and abandoned due to soil salinity (Plate 2).

Plate 1. Salt formation on top most soil in Kimala irrigation site (2011).

Plate 2. Abandoned field before the salinity management trials started (2011) at Kimala showing degraded lands due to soil salinization.

The soils in Njukini are moderately well drained, very deep, dark reddish brown to dark brown, firm, strongly calcareous, slightly saline and moderately sodic with slightly cracking clay and are classified as vertic luvisols, saline-sodic phase (FAO, 1988). The soils in Kimala block A and B are eutric fluvisols (FAO, 1988). The soils are well drained to imperfectly drained, very deep, and brown to dark brown, friable, slightly calcareous, sandy loam to clay loam. The soils are hard when dry and slake on wetting and are dispersed as seen from turbidity when irrigating. The soils crack on drying but do not have vertic properties. They have high base saturation and clay content increases with depth hence the classification (FAO, 1988). Table I summarizes the chemical and physical characterization of the initial soils from the sites.

The analysis shows that soils in Taveta irrigation schemes are sodic (*Njukini* and *Kimala)* to strongly saline–sodic (*Eldoro)* (ESP > 15) with large amounts of soluble calcium salts (26-134 meq/100 g soil). The salinity of the soils was classified according to USDA salinity classification (Richards, 1954).The soils are poorly drained and low in organic matter. The very high pH means micronutrients are likely to be deficient and will affect crop growth and yield.

Table 1. Characteristics of soils from three representative irrigation schemes in Taveta sub-county (2011)

Site	Depth (cm)	pH	ECe	% C	T	CEC	eCa	eMg	eK	eNa	BS	ESP
Eldoro P. Mare	0 -20	8.4	11.5	1.6	1	27.0	88	3.0	4.2	28.4	100	105.2
	20 -30	8.3	4.1	1.3	1	26.8	134	3.2	5.2	27.4	100	102.2
Kimala Madicha	0 -20	9.0	1.2	0.9	3	16.0	81	2.5	1.7	3.1	100	19.6
	20 -30	9.0	0.9	0.8	1	14.2	26.8	1.8	0.9	3.1	100	22.1
Njukini G. Ndolo	0 -20	8.0	0.6	3.0	3	34.6	133	2.9	4.4	6.1	100	17.6
	20 -30	8.2	0.3	1.4	2	29.2	25.7	3.2	3.2	4.6	100	15.8

Notes: pH (soil pH-H_2O(1:2.5)); ECe (electrical conductivity, mS/cm); % C (% organic carbon); T (texture):1 (clay); 2 (sandy clay); 3 (sand clay loam); CEC (cation exchange capacity, cmol kg^{-1}); eCa, (exchangeable calcium, cmol kg^{-1}); eMg (exchangeable magnesium, cmol kg^{-1}); eK (exchangeable potassium, cmol kg^{-1}); eNa (exchangeable sodium, cmol kg^{-1}); BS (% base saturation); ESP (exchangeable sodium %).

Kimala is located in a valley bottom or in a bottomland where soils have been deposited over time. Kimoringoh-Kamleza irrigation scheme lies in a bottom land with alluvial soils formed from undifferentiated basement system rocks. Drainage is strongly impeded and soils are fine textured with no natural drainage ways. The soils are saline-sodic with a shallow ground water table (70-170 cm depth). Kimala and Kamleza-Kimoringoh schemes lie on a slope of 1.5% at an elevation of 730 masl while Njukini site is on a slope of 3% at an elevation of 980 masl (Mugai *et al.,* 1976).

The irrigation schemes lie in agro-ecological zones IV-V (Jaetzold and Schmidt, 1983) which are semi-arid. The area has a bimodal rainfall with long rains in March - May with an average mean season rainfall of 319 mm and a short rain season in October – December with a mean season rainfall of 169 mm. The potential evaporation stands at 2179 mm/year and mean annual daily temperatures are 22-25^{o}C (Jaetzold and Schmidt, 1983; Mugai *et al.,* 1976).

The inhabitants are small-scale farmers who grow cotton, banana, maize, beans, citrus, mangoes and a variety of vegetables under furrow irrigation. Crop production is constrained by soil salinization from both soil and irrigation waters (Mugai *et al.,* 1976).

2.2 Experimental treatments and design

The treatments were: 1. *Mavuno* NP fertilizer (at 60 kg P_2O_5 ha^{-1}), 2. Cattle manure (FYM) 20 t/ha, 3. Trash incorporation 40 t/ha, 4. 100% Gypsum Requirement, 5. Rhodes grass rotation, 6. Sudan grass rotation and 7. Nil or farmer practice which represented the way farmers were growing their crops. Combinations of Mavuno NP fertilizer with FYM or trash incorporation were also tested in some seasons. The experiment was laid out in a completely randomized block design (CRD), with four replications, with plots measuring 3.5 m x 3.5 m. The plots accommodated 6 lines of maize (*Zea mays* L.), 'Duma 43', spaced at 75 cm x 25 cm. The trials were initiated in 2011. A total of nine trials were carried out with farmers using the host farmers to provide the learning farmer field schools. In the first experimentation (2011/2012), all the seven treatments were included. However, treatments testing grasses were dropped in the experimentation in 2012/2013 because they did not require the grasses. Farmers were given best-bet treatments to compare with their practice after completing experimentation in 2014.

Maize was irrigated using level basin irrigation in Kimala and Njukini while in Kiwalwa, cambered beds were used, whereby a furrow irrigated two adjacent rows of maize. The irrigation was carried out more frequently at the beginning of the trials and at least once a week or when crop showed signs of water stress. Nitrogen was applied at 30kg $N.ha^{-1}$ as sulphate of ammonia as a topdressing in all plots except farmer practice. Topdressing was applied one month after germination. The trials were hand weeded while 'bull dock star' was used for control of stem borer. Only data involving basin irrigation was obtained in this research.

2.3 Data collection and analysis

Soil and water characterization: Top (0-20 cm depth) and sub (20-30 cm depth) soil samples were taken from each experimental site at 3-5 sampling points representing the whole farm. The soil samples from these sampling points were composited and resampled to give a representative soil sample for analysis. The soils were analysed for pH, electrical conductivity of the saturated extract (Ece), organic carbon (C), texture, cation exchange capacity (CEC), exchangeable calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), percent base saturation (BS) and exchangeable sodium percent (ESP), following the procedures described by Hinga *et al.* (1980).. Water samples were obtained from all available water sources (Njukini, Kasokoni, Challa, Njoro *Kubwa* and Rama springs, Kimala, Grogan and Kitogito canals and Njukini shallow wells) at the sources, at conveyance canals, shallow wells and at farm inlet points. The samples were analysed for electrical conductivity (ECw), sodium concentration (Na^+), sodium adsorption ratio (SAR), sulphates ($SO_4^=$), chlorides (Cl^-) and bicarbonates(HCO_3^-) concentrations following procedures described by Hinga *et al.* (1980).

***Plant sampling and analysis*:** The data collected included grain yields, stover weight, weight of grains plus cobs, and total dry matter (TDM) yield. The whole experimental plot was harvested. Stover weight was taken in the field and corrected for dry weight after carrying out moisture analysis. Maize cobs with grains were obtained in the field during harvest. A few cobs were taken randomly for moisture analysis while shelled grains were also sampled for moisture analysis.

Data analysis: ANOVA was carried out on all obtained data using statistical analysis software (SAS) by running general linear model. Means were separated out using Duncan multiple comparison tests.

3. Results

3.1 Water quality

The results of analysis of the water used for irrigation from different sources in Taveta irrigation schemes are shown in Table 2. Water from Rama springs in Njukini and at Kimala canal inlet from Lumi river were significantly ($p \leq 0.05$) more saline than other water sources. Salinity of Kasokoni springs water was not significantly ($p \leq 0.05$) different from salinity of water source in Kimala canal sampled at inlet from Lumi river. Challa springs, Lumi source, Grogan springs and Grogan canal had significantly ($p \leq 0.05$) lower water salinity and would not lead to soil salinization if used for irrigation. Kasokoni springs, Rama springs and Kimala canal water sources had significantly ($p \leq 0.05$) high concentrations of sodium and would lead to increased levels of sodium in the soil irrigated with this water source. Same trend was observed for sodium adsorption ratio showing potential for water sources from these sources to add more sodium to the soil in rcomparison to calcium and magnesium leading to high levels of exchangeable sodium percent and hence chances of soil sodicity. Similarly, same water sources had significantly ($p \leq 0.05$) higher concentrations of sulphates, chlorides and bicarbonates which would lead to soil salinization.

Table 2. Characteristics of irrigation waters from Taveta irrigation schemes (2011)

Water sources	EC µS/cm	Na^+ me/l	SAR	$SO_4^=$ me/l	Cl^- me/l	HCO_3^- me/l	Elev. Masl
Njukini springs	279.2^c	0.66^b	0.50^b	1.76^b	2.72^b	3.18^b	981^a
Kasokoni springs and *Lumi* joining point	1119^b	3.92^a	2.01^a	29.19^a	9.42^a	7.85^a	$784d^e$
Challa springs and farm inlet point	386^c	1.16^b	0.75^b	3.58^b	2.95^b	3.40^b	952^b
Rama springs in *Njukini*	1363.75^a	5.95^a	2.32^a	29.37^a	14.93^a	8.07^a	922^c
Kimala canal and inlet from *Lumi*	1328.67^{ab}	4.59^a	1.79^a	32.60^a	13.64^a	6.76^a	788^d
Njoro Kubwa source, *Kamleza, Kitogito* inlets	244.4^c	0.63^b	0.39^b	1.46^b	2.78^b	2.95^b	763^{ef}
Lumi source	207^c	0.39^b	0.24^b	0.73^b	0.93^b	3.88^b	983^a
Grogan springs, *Grogan* canal	377^c	0.73^b	0.27^b	0.51^b	1.17^b	2.35^b	751^f
Lsd ($p \leq 0.05$)	228.17	2.34	0.97	20.23	9.12	1.47	22.14
Grand mean	667.5	2.32	1.06	12.6	6.4	4.8	685
CV%	18.99	56	50	89	79	16.8	1.42

Means in the same column followed by same letter are not significantly ($p \leq 0.05$) different, according to Duncan Multiple Comparison test.

These results of analysis of irrigation waters further indicates that the water used to irrigate Kimala soil was significantly ($p \leq 0.05$) more saline than water used for irrigation on Eldoro and Njukini sites. Njukini site was irrigated with water from Njukini springs while Eldoro site was irrigated with water of low salinity from Njoro Kubwa. Kimala site was irrigated with significantly ($p \leq 0.05$) more saline water from Kimala canal.

3.2 Effects of salinity management technologies on yield of maize in 2012, 2013 and 2014

In 2012 (Figure 1), application of FYM+ *Mavuno* NP fertilizer increased mean maize grain yield by 3.275 t ha^{-1} compared to the control. Trash incorporation + *Mavuno* NP fertilizer similarly increased mean maize grain yield by 1.525t ha^{-1}. Gypsum application alone at 100% requirement increased the mean maize grain yield by 0.925t ha^{-1}. Rhodes grass (treatment 5) and Sudan grass (treatment 6) where grown for rotation but became unpopular with the farmers because they preferred food crop, not feed. These treatments are therefore not shown in Figure 1.

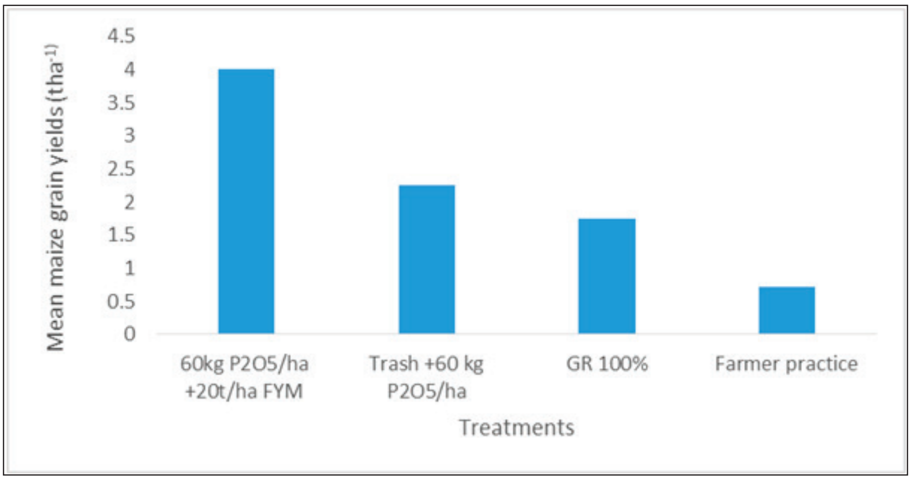

Figure 1. Effects of salinity management technologies on grain yield of maize planted on saline soils of Kimala, Taveta sub-county (2012).

In 2013, maize yield data was obtained from a field in Kimala next to the field planted in 2011 and harvested in 2012. This field had been abandoned due to soil salinity (Plate 2). The maize crop planted early in 2012 in this field was lost to animals and the site was replanted in 2012 and harvested in 2013. The treatments remained the same except that Rhodes grass and Sudan grasses were rotated with a maize crop to see if the grasses took up salts from the soil. The results (Figure 2) showed that application of FYM + *Mavuno* NP fertilizer significantly ($p \leq 0.05$) increased maize grain yield, stover weight and cobs plus grains over the farmer practice This treatment was however not significantly ($p \leq 0.05$) different from fertilizer alone and gypsum plus fertilizer (Figure 2).

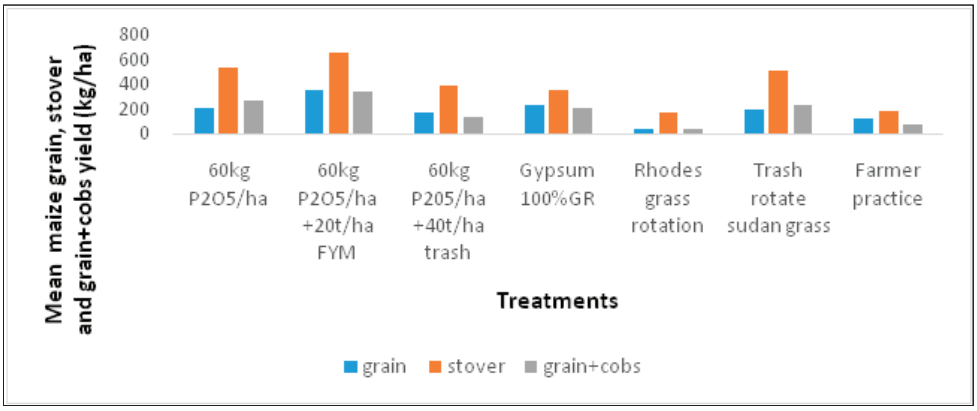

Figure 2. Effect of soil salinity management technologies on mean maize yield components (kg/ha) in Taveta Kimala irrigation scheme (2013).

The Rhodes grass rotation planted with Mavuno NP fertilizer had the least mean maize grain yield. Trash incorporation + Mavuno NP fertilizer rotated with Sudan grass had mean grain yield which was not significantly ($p \leq 0.05$) different from Mavuno NP fertilizer alone. Mavuno NP fertilizer + FYM and gypsum + fertilizer resulted in slight yield improvement over farmer practice.

In 2014, the use of Mavuno NP fertilizer + FYM significantly ($p \leq 0.05$) increased maize grains, cobs, stover and total dry matter (TDM) yield at Kimala site. This treatment was however not significantly different from use of Mavuno NP fertilizer alone, incorporation of trash + Mavuno NP fertilizer and planting with gypsum (100% GR) + Mavuno NP fertilizer (Table 3).

The trash alone treatment was not significantly different from the control. FYM alone increased mean maize yield over the control but it was not significantly ($p \leq 0.05$) different from Mavuno fertilizer alone, trash + Mavuno fertilizer, and 100% GR+ plus Mavuno fertilizer treatments. The experiment shows that use of 20 t ha^{-1} FYM+ Mavuno NP fertilizer (@60 kg P_2O_5 ha^{-1} was the best technology for improving maize yield in a saline-sodic soil. This was followed by Mavuno NP fertilizer, and trash + Mavuno NP fertilizer combination in mitigating the effects of soil salinity.

Table 3. Effect of soil salinity amendments on mean maize yield on a saline-sodic soil of Kimala irrigation scheme (2014)

Treatments	Mean maize yields (kg ha-1)			
	Grains	**Cobs**	**Stover**	**TDM**
Mavuno fertilizer	1706ab	429ab	3490ab	5429ab
Mavuno fertilizer + FYM	2405a	633a	4276a	7122a
Mavuno fertilizer + Trash	1123abc	418ab	2806abc	4327abc
Mavunofertilizer + 100% GR	1716ab	469ab	3153ab	5225ab
Trash	218c	153b	541c	878c
FYM	416bc	151b	1616bc	2184bc
Control (farmer practice)	269c	104b	1402bc	1776bc

Means followed by the same letter in the same column are not significantly different ($p \leq 0.05$)

3.3 Residual effect of salinity management treatments on soil salinity reduction

The mean maize grain, stover, cobs, and total dry matter yields obtained from plots testing residual effects of trash incorporation at 40 t ha^{-1} + Mavuno NP fertilizer and FYM+ Mavuno NP fertilizer were significantly ($p \leq 0.05$) different from maize yields obtained from plots with residual effect of farmer practice (Table 4) in 2011/2012 and 2013 in Kimala irrigation scheme.

Table 4. Residual effect of soil salinity management technologies on yield of maize (kg ha^{-1}) in Taveta -Kimala irrigation scheme (2014)

Treatments	Grain	Stover	Cobs	TDM
Mavuno fertilizer	1433ab	2992a	323ab	4750a
Mavuno fertilizer + FYM	1470ab	2963b	343ab	4777a
Mavuno fertilizer +Trash	1690a	4556a	396a	5141a
Mavuno fertilizer +100%GR	1575ab	2757b	396a	4727a
Trash	1553ab	2523b	386a	4461ab
FYM	1073ab	2041b	286ab	3354ab
Control	688b	1641b	243b	2573b

Means in the same column followed by the same letter are not significantly different $p \leq 0.05$).

The residual effect of Trash incorporation + Mavuno fertilizer resulted in the significantly highest maize grain yield. This was the third cropping cycle of the field and it indicated that the soils had been rehabilitated as seen from increased grass and weeds, which were not there before the experiment started (Plate 3). The rehabilitated (vegetated) land was part of the denuded land behind, which is bare.

Plate 3. A rehabilitated field after three seasons of cropping in Kimala Taveta, 2014.

3.4 Farmer participatory technology evaluation

The two treatments were compared by farmers, 20 t ha^{-1} FYM+ Mavuno fertilizer (@60 kg P_2O_5.ha^{-1}) and Mavuno fertilizer (@60 kg P_2O_5.ha^{-1}), against farmer practice for soil salinity reduction in Njukini using maize as the test crop. Results indicated that all 19 farmers (15 male and 4 female) in this evaluation program scored the treatment 20 t ha^{-1} FYM + Mavuno fertilizer (60 kg P_2O_5 ha^{-1}) as better soil salinity management technology than the other treatments (Plate 4 and Table 5).

Plate 4. Farmers' participatory evaluation of maize performance using 2 best technologies for soil salinity reduction in Njukini (2014).

Table 5. Farmer participatory evaluation of the two best technologies for soil salinity reduction in Njukini irrigation scheme (2014). Score: 1=best, 2=moderate, 3=poorest

Treatment	Score
Farmer practice	3
FYM + Mavuno fertilizer	1
Mavuno fertilizer	2

4. Discussion

The use of 20 t ha^{-1} FYM + Mavuno fertilizer (@60 kg P_2O_5 ha^{-1}) increased mean maize grain yield by 3.275, 275 and 2136 kg ha^{-1}, in 2011/12, 2012/13 and 2013/14 respectively, when compared to control. This is attributed to reactions of manure in the soil in the presence of an acidifying fertilizer. Manure in presence of inorganic fertilizer decomposed and produced organic and inorganic acids that might have liberated calcium from the soil exchange complex to replace exchangeable sodium. Lowering the soil exchangeable sodium percent (ESP) and the soil electrical conductivity would have increased the availability of other nutrients in the soil (Benbouali *et al.,* 2013). Trace elements and phosphorus will not be available at pH > 8.0 (Tisdale *et al.,* 1984). This effect of manure in presence of inorganic fertilizer corroborates the findings of Suriyan and Kirdmanee (2011) and Wang *et al.* (2014). Rasel *et al*. (2013) reported that saline soils affect crop growth depending on degree of desiccation and salt concentration at critical stages of growth. Application of manure at 4 g C kg^{-1} soil in a saline soil of Algeria resulted in improved soil water infiltration, reduced ECe, decreased ESP and pH, and increased microbial carbon (Benbouali *et al*., 2013). The inorganic fertilizer used in our study contained 7% sulphur and additional micronutrients that could have led to faster manure decomposition, improving soil quality and hence the increased crop yield.

Use of inorganic fertilizer (containing 7% sulphur) alone also showed significant increase in maize yield. This is attributed to acidifying effect of the fertilizer, which might have improved the availability of trace elements that are deficient in high pH (> 8.0) soils (Tisdale *et al.,* 1984). However, when gypsum was used along with inorganic fertilizer (containing 7% sulphur) the improvement was better when compared to manure alone. The increased amount of sulphur would have more acidifying effect on soil leading to better amelioration of saline-sodic soil by converting exchangeable sodium to water soluble salts that get leached from the soil leading to improved soil structure, water retention and increased plant growth and yield as observed in this study.

The treatment receiving gypsum at 100% gypsum requirement was better than the farmer practice in saline-sodic soil of Kimala. Gypsum should have reacted with some exchangeable sodium decreasing the ESP leading to improved soil physical properties and hence the increased yield over the control. Sodic soils are dispersed and do not permit water infiltration readily (Hillel, 1980); also, due to their high pH, phosphorus and micronutrients are not available to plants (Tisdale *et al.,*1984). When gypsum is added, it reacts with sodium in the exchange complex producing soluble sodium sulphate which is leached along with sodium thus decreasing exchangeable sodium and soil ESP. Soil pH is decreased and phosphorus and micronutrients become available. Soil structure is improved because of increased flocculation of soil particles, and water retention of the soil is also improved (Hillel, 1980). Hence, there was increased maize yields in this study when gypsum was applied as compared to farmer practice. The high maize yield in Figure 1 was attributed to the fact that this site had been under cultivation for over 10 years with crop residue incorporation by the host farmer. This finding corroborates the finding of Shaaban *et al.* (2013) on paddy rice in *Multan,* Pakistan.

Trash, consisting of crop residues, weeds and dry grass material found in the field, when incorporated at 40 t ha^{-1} along with inorganic fertilizer led to increased maize grain yield in all the three years in saline-sodic soils of Kimala. Wang *et al.* (2014) found that when green waste compost mixed with sedge peat and furfural residue were incorporated into a coastal saline soil in north China it led to increase in plant growth, improved soil structure and nutrients and reduced salt content, ECe, ESP and exchangeable Na. Wong *et al.* (2009) reported that addition of organic substances into sodic and saline soils led to increased soil microbial biomass and organic carbon. Arshadullah *et al.* (2012) found that incorporation of 5 t h^{-1}a wheat straw + 90 kg N.ha^{-1} in a saline sodic soil (ECe, 5.32 dS.m^{-1}, pH 8.57, SAR = 18.38) increased significantly the yield of rice. Trash alone depressed the maize yield in our study (Table 3). Since it consisted of dry grass there could have been nutrient immobilization and delayed decomposition due to large C/N ratio leading to poor nutrient supply and little reaction with sodium in the saline-sodic soil studied. Same was true of application of FYM alone (Table 3). For trash or manure to be effective, their quality is important as this will affect their decomposition rate and reactions of the decomposition products in the soil. Organic amendments will require at least 60 days in the soil to be effective (Zubair *et al.,* 2012).

Residual effect of trash plus inorganic fertilizer was significantly ($p < 0.05$) superior to that of other treatments as it increased mean maize grain yields from 688 kg ha^{-1} to 1690 kg ha^{-1}. This was closely followed by 100% gypsum requirement + inorganic fertilizer treatment, which in turn was followed by trash alone treatment. Manure +inorganic fertilizer treatment was the fourth in residual effect on increasing maize grain yield. This was studied in the third cropping cycle after applying the treatments twice. Each cycle was of 4 months and it provided adequate time for trash decomposition, which led to soil improved soil structure and fertility and thus the increased maize yield. This mechanism should also apply to residue effect of manure (Table 4). These results corroborate the observations of Zubair *et al.* (2012) that organic amendments on saline soils requires time to decompose and produce reactive substances such as organic and inorganic acids Freshly applied trash or manure had insignificant effect on maize yield (Table 3) due to limited decomposition.

Farmers confirmed the suitability of use of 20 t ha^{-1} manure + inorganic fertilizer (@ 60 kg P_2O_5 ha^{-1}) as the best technology for use in crop production in these sodic-saline soils of Njukini (Table 5). Hence, this technology is recommended for use in saline-sodic soils of Taveta and should be up-scaled. The residual effect of trash and manure in saline-sodic soils needs further research. There is need to analyze the soils and quantify changes in soil quality due to these treatments.

Conclusions and recommendations

The soils in Taveta irrigation schemes were found to be slightly saline (Ece < 1.2 dS m^{-1}) and sodic (ESP> 15) (Njukini, Challa, and Kimala) to strongly saline–sodic (Kamleza-Kimoringoh) with Ece > 4 dS m^{-1} and ESP > than 100. The quality of irrigation water sources showed high salinity (Rama springs, Njukini shallow well, Kasokoni springs and Kimala canal) and low salinity (Njoro *Kubwa*, Lumi river, Grogan and Challa springs). It emerged that water sources that irrigate the most saline-sodic Kamleza-Kimoringoh irrigation schemes are not saline and can provide an opportunity to leach the salts out of the soil profile. Productivity of maize in the slightly saline-sodic irrigation schemes like Kimala block A and B can be increased through use of 20 t ha^{-1} manure + 60 kg P_2O_5.ha^{-1} (from *Mavuno* fertilizer) plus a topdressing of 30 kg N ha^{-1} (as sulphate of ammonia). Use of trash incorporation at 40 t ha^{-1} + 60 kg P_2O_5.ha^{-1} (from *Mavuno* fertilizer) and 100% GR + 60 kg P_2O_5.ha^{-1} (from mavuno fertilizer) seems to be potential fertilizer sources for these saline-sodic soils due to their significant good residual value after three cropping cycles. However, soil changes due to these treatments need to be quantified and related to maize yield.

Acknowledgements

The authors are grateful to the Centre Director, KALRO-Katumani, for project logistics, KAPAP for funding the project and Director of Agriculture in Taveta sub-County, for facilitation in the County. We are also grateful to the collaborating farmers and all those who contributed to the success of the study.

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3. Impacts of land reclamation and urbanization on agriculture land use in Egypt

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Abstract

Egypt has a total area of about one million Km^2 under arid to hyper arid climatic conditions. It is a densely populated country with more than 90 million inhabitants, mainly concentrated on a small territory (about 5%) around the Nile Valley and Delta with regional disparities. This has led to environmental problems causing serious public concern, particularly the encroachment on the old agricultural lands. Land reclamation and development is considered one of the solutions for alleviating these problems and more efforts are needed to better redistribute the population in promising desert areas. Data indicated that more than 3 million Feddans were reclaimed and developed since 1950. The study presents the land reclamation and development since 1952 till date and the future plans. Results of monitoring urbanization, using satellite data, for the Nile valley, Delta and fringes in 1985 to 2007 and 2007 to 2010 years indicated different land use changes during that period (i.e. agriculture, urban, traffic ways, water bodies including northern lakes and others). Results indicated that total agricultural areas increased while informal urbanization dominated the patterns of urbanization encroachment. It showed that urbanization denatured the unique alluvium soils and the annual agricultural land use loss was 31.0 thousand Feddan / year in the period 1985-2007. Also, the annual loss in the period from 2007-2010 was about 41.0 thousands Feddan/year. If this urbanization rate were to ceaselessly continuous, the integrated loss of the remaining cultivated soil will result in a catastrophic loss of the Nile alluvium soils. The study reflected also that carful new land expansion and development in the desert could be a solution for many of the serious environmental problems facing Egypt.

Keywords: Old agricultural land, Land degradation, Reclamation, Urbanization

4. Assessing the aftermath of informal irrigation practices under the arid climate east of Suez canal using Hyperion and multispectral remote sensing data

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Abstract

The study was conducted in El Qantrasharq District of Ismailia Governorate, east of Suez Canal, covering an area of almost 14,355ha (34,165feddans) as a representative of vast cultivated area in Egypt that is informally irrigated under arid climate. In this study, for getting more accurate mapping results, Hyperion (EO-1) and multispectral (TM8) remote sensing data were used, both acquired in January 2016. Normalized Difference Vegetation Index (NDVI) was extracted from the two types of data for mapping the land cover features. NDVI values of the cropped area with irrigated trees, dominated by mango, under slightly saline soils ranged from 0.22 to 0.43 by EO-1 but from 0.24 to 0.35 by TM8. For the annual cropped area with surface irrigated herbaceous crops, dominated by clover, in slightly saline soils, the values ranged from 0.44 to 0.53 by EO-1 but from 0.35 to 0.43 by TM8. The values of the waterlogged area with extremely saline soils ranged from 0.01 to 0.03 by EO-1, while byTM8 they ranged from 0.07 to 0.1. Pearson's Correlation between the processed NDVI values from TM8 and EO-1 was 0.89 showing strong correlation. For setting up that correlation, the pixel values of TM8 were selected to fit the same sites as of spectral signatures of EO-1 that reflected within ranges of NDVI values. It is concluded that use of spectral data from TM8 within those adapted ranges can produce more valid and accurate results concerning the cultivated and deteriorated land. Also, these adapted NDVI values can be manipulated to serve an extrapolation process for lateron scanning of other managed land. The frequent availability of TM8 data versus the scarcity and costs of other ones in order to monitor the land degradation within proper systemized dates is an added advantage for the former.

Keywords: Land degradation, Land cover, Hyperion data (EO1), NDVI (TM8).

Introduction

Cultivated land of high economical value in certain areas in Egypt is recently getting degraded under uncontrolled planning because of the lack of adequate information about the use. This requires correcting the approach to land conservation to realize its profitable function. The State commits itself to protect the land under cultivation according to the Constitution (*Destor*) of Egypt. However, it has to be strictly implemented, otherwise the crises will accentuate (Afify *et al.,* 2013). The informal irrigation practices have resulted in a wide spread deterioration of land quality. Most of these deteriorated areas in Egypt have good potential. Profiting from this situations mostly depends on developing a good network of infrastructure that ensures an easy access to markets near highly populated regions (Afify *et al.,* 2008).

The area covered in this study is partly cultivated in its western portion, near Ismaeilia city, which is a good market to be accessed. Most of the non cultivated area here is in the eastern part, which should to be assessed as a new promising area for agriculuture based on good land management and irrigation practices. The surface types of the study area were studied using. Land cover assessment was considered important for defining the spatial distributions of the surface types According to Kavzoglu and Colkesen (2009) land cover is very important in for the assessment of natural resources. At local and regional scale, knowledge of land cover forms a basic dimension of recourses available for use. Castillejo-Gonza´lez *et al.,* (2009) stated that on a wide scale, land cover information is of main importance in determining the broad patterns of climate and vegetation, which form the environmental framework for human activities. Furthermore, land cover maps are a valuable contribution in the development of policies, particularly for ecologically protected areas and the restoration of native environments, as well as for monitoring of desertification and land degradation in a region. According to Mathur and Foody (2008), a huge range of procedures have been developed to achieve this purpose with image classification being more widely used.

The current study aimed at setting up a revised methodological scheme for getting more effective verification and validation of the surface type attributes as well as their spatial magnitude. For that reason, the study area was scanned by very recent remote sensing data of Hyperspectral sensors, acquired by the EO-1 Hyperion instrument. According to Xu *et al.* (2008), these hyperspectral data are able to register reflected light from land surface elements in many narrow continuous spectral bands, from the visible to the shortwave infrared parts of the electromagnetic spectrum The study area also was scanned by rather advanced remote sensing data of TM8, which has radiometric quantification (12-bits) of the OLI and TIRS. Such dada provide significant improvement in detecting surface type changes. They are freely available for down loading. Normalised Difference Vegetation Index (NDVI) is considered in this study as a master index based on tests to realize its ability of discriminating the multiple surface types. Dwivedi and Sreeniwas (2002) used this index for separating the vegetated land from waterlogged areas using the formula: NDVI = (NIR – Red) / NIR+ Red).

The main objective of this study was to produce a land cover map for an area east of Suez Canal in order to assess the level of land degradation as aftermath of informal irrigation practices under an arid climate and to predict the magnitude of the problem. Also, it aimed at finding out a collective master index which will be suitable for different surface types.

Materials and methods

The study area was located in El Qantrasharq District of Ismailia Governorate, east of Suez Canal. It covers almost 16,3527 ha representing the newly reclaimed land for agriculture land use. In the upper left corner, the coordinates are latitude of 30º38ˀ20” North and a longitude of 32 º23ˀ20” East, while the lower right corner is coordinated as latitude of 30 º30ˀ0” North and longitude of 32 º28ˀ20” East (Figure 1).

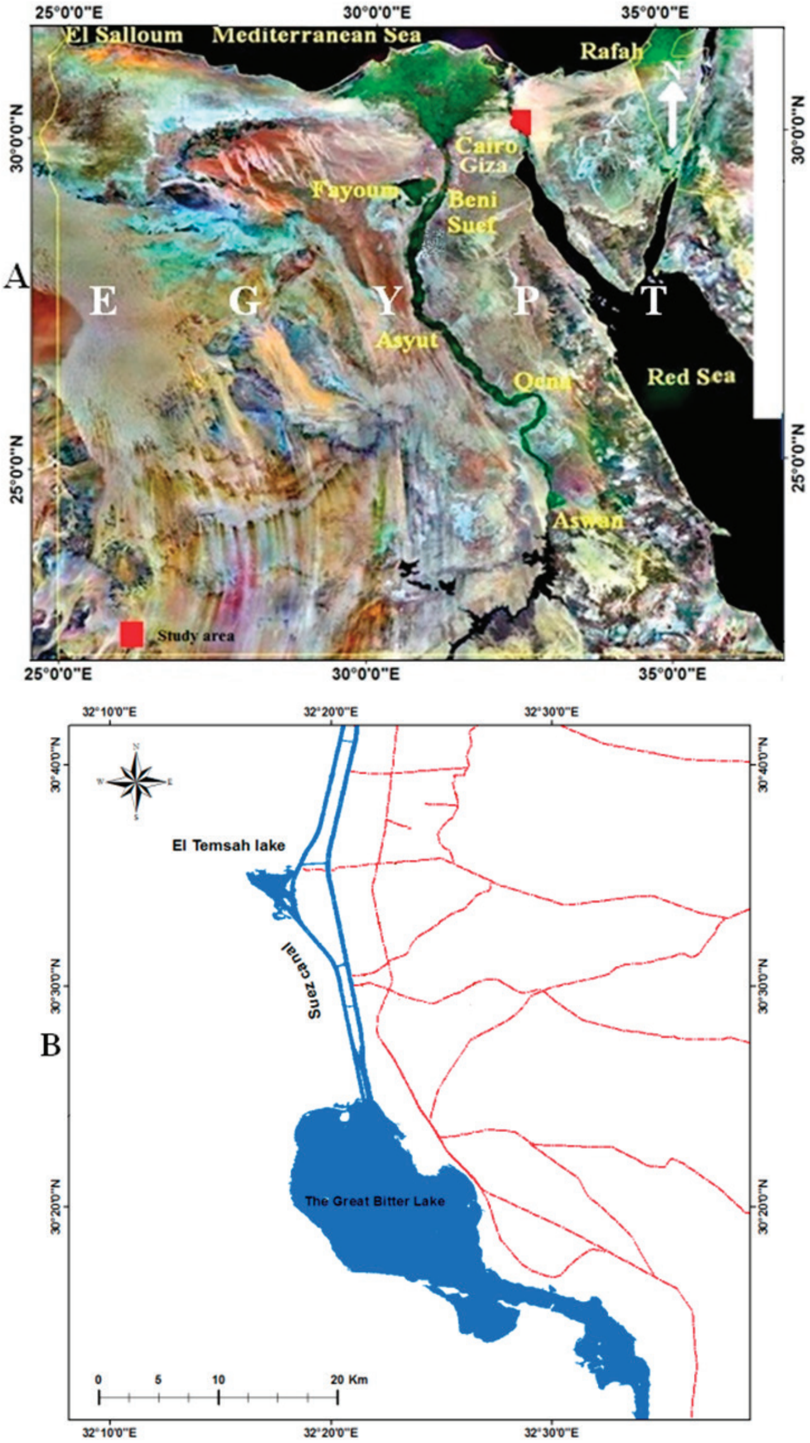

Figure 1. Location map of the study area (A: map of Egypt, B: study area).

The Hyperion data for selected projection (Figure 2) were acquired on January 9, 2016. The imagery was received from the National Aeronautical Space Agency (NASA) Earth Observer (EO)-1. According to Datt *et al.* (2003), the non-calibrated bands of the Hyperion imagery (namely bands 1–7, 58–76, and 225–242) were removed. The Hyperion visible and near-infrared (VNIR) spectrometer has 70 bands, only 50 of which are calibrated, while the short wave infrared (SWIR) spectrometer has 172 bands of which only 148 are calibrated. The residual 198 calibrated bands cover the entire spectrum from 426 to 2395 nm. Therefore, the Hyperion bands sensitive to water absorption (i.e., bands 120–132, 165–182, 185–187, and 221–224) were extracted so as to reduce the influence of atmospheric scattering and water vapor absorption caused by mixed gasses to the data (Beck, 2003). Bands 77 and 78 were also eliminated because they had a low signal to noise value, and overlapped with bands 56 and 57.

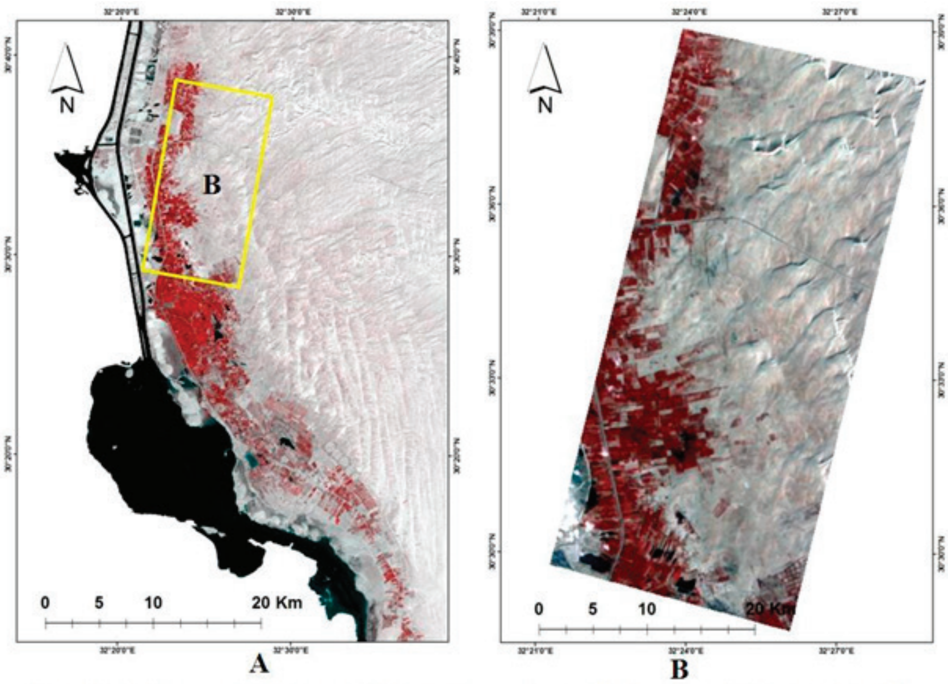

Figure 2. Sub scene of TM8 image (A) superimposed by slected frame of Hyperton data (B)

TM8 data were recorded by Operational Land Imager (OLI) during the year 2016 within the path 176 and row 40. The data having radiometric quantization (12-bits) of the OLI and TIRS is higher value than the ones from previous Landsat instruments (8-bit for TM and ETM+). The multispectral bands have spatial resolution of 30 meters and spectral resolutions of Green (530-590 nm), Red (640-670 nm), and Near-Infrared (850-880 nm).

In the study area, ENVI's Fast Line-of-sight Atmospheric Analysis of Spectral Hyper-cubes (FLAASH) module was applied on Hyperion data for atmospheric correction. FLAASH requires input image in BIL format and ASCII file of scale factors number. The scale factors for the VNIR and SWIR bands are 400 and 800 nm. FLAASH were selected and other parameters were defined based on metadata of the Hyperion image file.

Geometric correction was carried out for both Hyperion (EO-1) and multispectral (TM8) remote sensing data using 40-ground control points (GCP's) obtained from a digital topographic map at a scale of 1:50,000 and Landsat ETM+ using the image- to-image technique. The geometric model used in the rectification process was three-order polynomial and the resembling method is the nearest neighbor method, following the method of Tucker *et al.* (2004). The image was projected with Transverse Mercator projection in WGS-84 spheroid and datum. Finally, the root-mean-square error (RMSE) images were obtained as less than 0.4 pixels, which are acceptable.

Normalised Difference Vegetation Index (NDVI) values were calculated according to Dwivedi and Sreeniwas (2002) using the equation NDVI = (NIR - RED) / (NIR + RED).

Normalized Difference Water Index (NDWI) values were calculated according to Xu (2006) as NDWI = (GREEN - NIR) / (GREEN + NIR). Normalized Difference Moisture Index (NDMI) was calculated according to Wilson and Sader (2002) using the equation NDMI = (NIR -MIR) / (NIR + MIR).

Normalized Difference Soil Index (NDSI) was based on the equation of Takeuchi and Yasuoka (2004) formulating the shortwave infrared (SWIR) as NDSI=(SWIR-NIR)/(SWIR+NIR).

Ground observations were located to represent the land cover classes using the Global Positioning System (GPS). Fifteen soil profiles were dug and were described using the nomenclature of the Soil Survey Manual (USDA 2003). Six of them were considered as representative soil profiles. Samples of soil layers were collected for the requiered soil analysis.

Particle size distribution was carried out using the pipette method as described by Jackson (1969). Calcium carbonate was measured using the calcimeter (Black *et al.,* 1965). Gypsum content was determined by precipitation with acetone. In soil paste extract, electrical conductivity (EC) was measured.

Accuracy assessment of land cover classes was based on Anderson *et al.* (1976), using 280 ground control points distributed with in the different land cover classes and located by GCPs.

Results

The ranges of measured values extracted from hyperion data related to each index that cover the multiple surface types in the study area are shown in Table 1.

Table 1. The values of indices from Hyperion data and correlation coefficient to NDVI

Index	Averaged values	Correlation coefficient (r) to NDVI	Correlation
NDVI	0.034 to 0.612	--	--
NDWI	0.203 to 0.734	0.95	strong
NDMI	0.110 to 0.707	0.75	strong
NDSI	0.003 to 0.376	0.82	strong

The magnitude of correlation coefficients indicated that NDVI is highly correlated to NDWI, NDMI and NDSI as the **c**orrelation coefficient were 0.95, 0.75 and 0.82, respectively (Table2).

The Coefficient of Determination (R2) between NDVI and other indices are shown in Figure 3. It is concluded that NDVI index is highly correlated with other indices each of them is successefully scanning certain land type with specified bands. Accordingly, NDVI index can be considered in this study as a master index that can be used for identification of the multiple land cover .features and their distributions

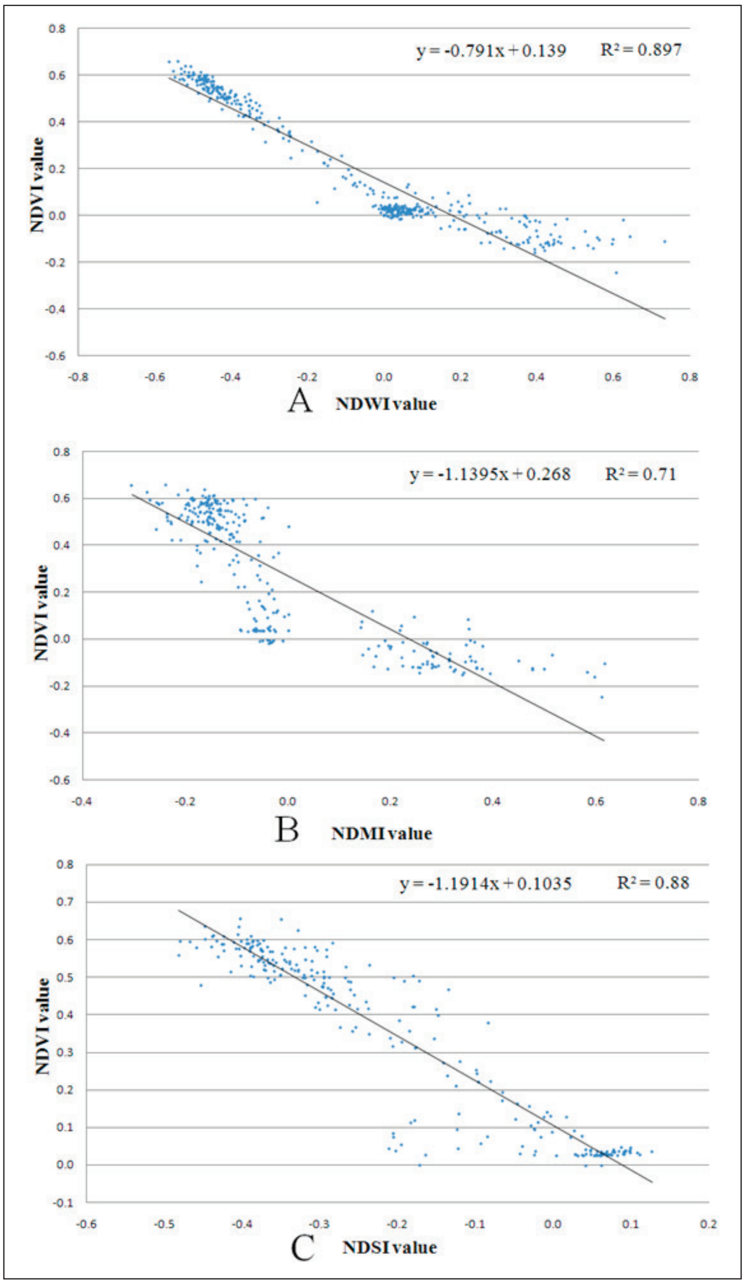

Figure 3. Validity assessment of NDVI based on NDWI (A), NDMI (B) and NDSI (C).

In a selected projection (14,355 hactares) the land cover classes were assessed by sorting NDVI values extracted from Hyperion data These land cover classes are descibed in Table 2.

Table 2. Land cover classes based on Hyperion data (EO-1) in the selected projection

Land cover class	Area (ha)
Trees mainly mango	2,888
Annual crops mainly clover	230
Other crops	1,081
Bare area (stony soils)	415
Bare area (shifting sands)	9,224
Main roads	211
Waterlogged area	176
Submerged area	131
Total area	14,355

The correlation between the two covariance of NDVI from Hyperion data and NDVI from TM8 data (Table 3) for the land cover of vegetated areas, bare areas of shifting sands, and submerged areas was strong. The correlation was moderate for the bare area of stony soils and water logged areas.

Table 3. NDVI values of Hyperion and TM8 data versus land cover classes

Land cover classes	NDVI from Hyperion data	NDVI from TM8 data	Correlation coefficient (r)
Trees mainly mango	0.381 to 0 .612	0.463 to 0.541	0.76
Annual crops mainly clover	0.343 to 0.381	0.386 to 0.463	0.83
Other crops	0.34 to 0.150	0.127 to 0.179	0.83
Bare area (stony soils)	-0.119 to 0.081	0.050 to 0.076	0.57
Bare area (shifting sands)	-0.081 to -0.004	0.076 to 0.127	0.72
Waterlogged area	-0.235to -0.119	-0.024 to -0.050	0.52
Submerged area	-0.620 to -0.235	-0.285 to -0.001	0.87

Land cover distribution in the study area based on NDVI of TM8 data was the main target of this study. After confirming the high validity of NDVI extracted from TM8 data in correlation with that of Hyperion data, a satisfactory land cover map was possible. The distributed values of NDVI as custom tone map were sorted in range values with the help of ground control points representing the land cover classes These land cover classes are included in Table 4.

Table 4. Land cover classes in the study area based on TM8 data

Land cover class	Area (ha)
Trees mainly mango	13,304
Annual crops mainly clover	878
Other crops	7,079
Bare area (stony soils)	25,236
Bare area (shifting sans)	86,547
Urban area	310
Main Roads	4,351
Waterlogged area	1384
Submerged area	1095
Artificial water body (lakes and Suez Canal)	23,343
Total area	163,527

Table 5. Particle size distribution and modified texture classes of representative soil profiles

Land cover class	Profile No	Depth (cm)	Gravel %	Particle size distribution%			Modified texture class
				Sand	Silt	Clay	
Cultivated areas	1	0-30	10	77.3	15.5	7.2	SGLS
		30-70	5	72.9	17.3	9.8	SGSL
		70-90	10	81.7	10.2	8.1	SGLS
		90-130	10	82.7	8.2	9.1	SGLS
Bare area (stony soils)	**2**	0-25	20	79.4	9.8	10.8	GSL
		25-70	25	80.0	9.1	9.9	GLS
		70-150	30	78.8	11	10.2	GSL
Bare area (shifting sands)	**3**	0-30	-	95.8	3.3	0.9	S
		30-65	-	92.1	6.2	1.7	S
		65-150	-	92.3	3.1	4.6	S
Waterlogged areas	4	0-20	15	82.6	8.8	8.6	GLS
		20-45	20	83.3	9.2	7.5	GLS
	5	0-20	10	86.6	8.8	4.6	SGLS
		20-35	10	85.3	10.2	4.5	SGLS
		35-50	15	76.7	10.5	12.8	GSL
	6	0-15	10	80.5	9.8	9.7	SGLS
		15-30	10	75.3	10.2	14.5	SGSL
		30-50	20	76.6	10.5	12.9	GSL

SL= sandy loam, LS= loamy sand, S= sand, SG= slightly gravelly, G= gravelly

Table 5 gives the particle size distribution and modified texture classes of representative soil profiles of the studied area. Cultivated land in the study area is managed under surface irrigation on sandy soils of different elevations and slope directions. The spatial distributions of soil deterioration were proportionally affected by those factors. The irrigation water is vertically draining within sandy strata of the cultivated areas and mostly seeped eastwards and south eastwards following descending slopes to the depressed areas. Land cover units of relatively high elevations are not waterlogged, while the lower bare areas of relatively low elevations are affected by the fluctuations of waterlogging. This mechanism can be illustrated from the Digital Elevation Model (DEM) with the gross slope flow direction in Figure 4. The water seepage creates spots of submerged areas and waterlogged ones that are very poorly and poorly drained soils, respectively.

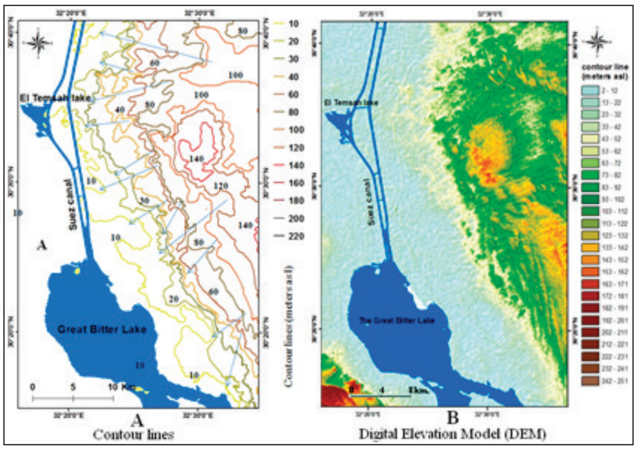

Figure 4. Gross flow directions of drainable water (A) within landscape configuration (B)

Soil moisture and temperature regimes in the study area were interpreted from the climatic data of WMO (2016**)**. The soils in the study area, as normal environment should be, are dry for more than half of the growing season and moist for less than 90 consecutive days (arid moisture regime). The mean annual temperature is 22.1° C (expected to be higher below soil surface) and the difference between mean summer and mean winter temperature is 9 ° C (hyperthermic temperature regime). As the soil become wet, that dry regime changed to be aquic moisture regime. According to the key of Soil Taxonomy **(**USDA, 2014) and using soil characteristics in Tables 5 :and 6, the soils were classified as follows

- ***Gypsi-aquisalids, sandy, hyperthermic****:* These soils occurred in the waterlogged areas, expressing the degree of land degradation. They are currently having aquic moisture regime superimposed by hyperthermic temperature regime. Under hyperthermic temperature, aquatic status is frequently subjected to evaporation that accelerates salt accumulation in soil strata to be extremely saline (30.3 to 81.9 dS/m). The soils have salic and gypsic horizons resulting in more areas of salt affected soils.
- ***Typic Haplocalcids, sandy, hypertermic*****:** These soils of calcic horizon occurred in the cultivated areas of slightly saline soils (2.1 to 3.9 ds/m)and the bare areas of stony soils that are moderately saline (4.2 to 7.8 ds/m).
- ***Typic Torripsamments, hypertermic****.:* These soils occurred in the bare areas of shifting sands that include recent soils.

Submerged areas have isolated water spots representing the extreme case of land degradation in the study area. They are soils with persistent internal free water and the soils are frequently ponded.

Table 6. Required soil analyses for formulating the current land degradation

Land cover class	Profile No	Depth (cm)	EC	$CaCO_3$%	Gypsum %
Cultivated areas	1	0-30	3.8	9.3	4.9
		30-70	2.5	13.8	5.4
		70-90	3.9	8.6	3.5
		90-130	2,1	7.9	1.3
Bare area (stony soils)	**2**	0-25	5.8.0	9.68	0.63
		25-70	7.8	14.5	0.92
		70-150	4.2	3.68	2.04
Bare area (shifting sands)	**3**	0-30	3.2	1.83	0.16
		30-65	2.6	1.23	0.12
		65-150	3.9	2.82	0.22
Water logged areas (Deteriolated land)	4	0-20	70.9	12.8	7.5
		20-45	30.3	9.8	6.9
	5	0-20	80.8	8.8	8.3
		20-35	32.3	11.8	6.9
		35-50	65.9	12.2	4.1
	6	0-15	81.9	14.8	8.3
		15-30	35.4	13.8	3.9
		30-50	67.7	10.2	4.1

EC= Electrical conductivity (ds/m)

The study area will be negatively affected by long-term use of surface irrigation on sandy soils. These cultivated areas are currently distributed on a wide range of elevations from 10 to 50 meters above sea level. It is most probably the extra bare areas eastwads on elevations higher than 50 meters above sea level that will be put for agricultural land use. By analyzing slope gradients, the contour line of 30 meters above sea level is considered as the line of break slope. Following the slope gradient classes of FOA (2006), this line separates the slope gradient of nearly level areas (0.4 to 1.0 % slope) westwards from those of gently sloping to sloping (2.5 to 5.0 % slope) east of that contour line. The detectable extension of the land degradation based on tracing the contour line at elevation 30 meter above sea for delineating an area is descending westwards. This area will most probably be affected by the seepage of drained water to spread over 35,303 ha. Partly, the deterioration will cover about 10,997 ha of the cultivated land, while the bare areas of the stony soils may negatively affect an area of 14,055 ha (Figure 5).

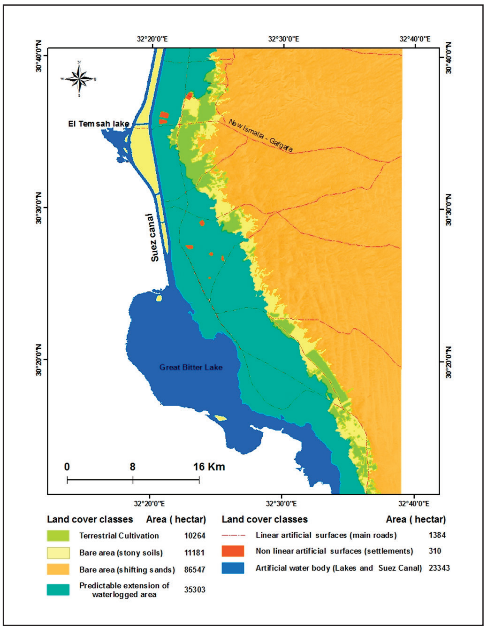

Figure 5. Predictable extension of land deterioration in the study area.

Classification accuracy of land cover classes (Tables 7) was assessed based on the equation of Anderson *et al.* (1976). A total of 280 ground control points (GCPs) were used for accuracy assessment. These point were 109 within trees mainly mango, 35 within the annual crop mainly clover, 30 within the other crops, 25 within stony soils, 80 within the shifting sands, 17 within waterlogged area and 13 within the submerged area. The accuracy ranged a from 80% to 100% for the individual classes. The overall classification accuracy was 94%.

Table 7. Confusion matrix for land cover classes

Land cover classes	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**Total**
Unclassified	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**
A Trees, mainly Mango	78	1	0	0	0	0	0	79
B Annual crops, mainly Clover	1	34	0	0	0	0	0	35
C Other crops	4	2	24	0	0	0	0	30
D Bare area (stony soils)	0	2	0	20	3	0	0	25
E Bare area (shifting sands)	2	0	0	0	78	0	0	80
F Waterlogged area	0	0	0	0	0	16	1	17
G Submerged area	0	0	0	0	0	0	13	13
Total	85	39	24	20	82	16	14	280

Recommendations

Monitoring land cover changes is required to assess the aftermath of informal irrigation practices under an arid climate to correct the land use conservation for realizing its profitable function. Without solution, the crises will still be there, as the waterlogged areas under the arid climate are subjected to high rate of evaporation leading to an expansion of salt affected areas.

Predicting the extension of land degradation is required for tracing areas that will be negatively affected by long-term use of surface irrigation on sandy soils

NDVI index is highly correlated with other indices (NDI, NDMI and NDSI), each of them is successfully reflecting the nature of certain surface type with specified bands. Accordingly, NDVI index can be considered as a master index that can be used for a well identification of multiple land cover features. Hyperspectral data is able to register reflected radiations from surface elements in many narrow continuous spectral bands.

NDVI values extracted from TM8 data are highly correlated with Hyperspectral data. Based on that correlation, NDVI index ofTM8 data is highly valid for defining the spatial distribution of cultivated and bare areas as well as the deteriorated land. Also, these NDVI values can be manipulated to serve an extrapolation process for later on scanning of other managed land. The easy availability of TM8 data is an additional advantage.

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5. Rainfed agriculture impact on the hydrological system of Wadi El Raml in the North Western Coast, Egypt

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Abstract

As a result of the increasing demand for food and water, people tend to alter the land cover and soil in their surrounding environment. For instance, in the northwestern coast of Egypt tremendous reduction at the pastoral grazing lands has occurred in the last 60 years due to increasing livestock numbers, rain-fed agriculture expansion, and large urban development. One of the big challenges is to determine the impact of these changes on the biological processes associated with the land cover changes such as plant and animal biodiversity, the hydrological and geochemical processes. The hydrological processes are highly impacted by the land cover changes including the evapotranspiration, surface and subsurface flow, soil moisture and erosion. Rain-fed agriculture in the North Western Coast of Egypt provides the food security for the majority of the local Bedouins. As a result of the limited resources, local Bedouins alter their lands to move from rangelands to rain-fed agriculture. The downstream impact of changing land cover in the upstream of Wadi El Raml was simulated using the semi distributed KINEROS2 model. Three scenarios were tested which include, 1) converting the rangeland to rain-fed agriculture of winter crops including wheat and barley 2) converting the bare soil to rangelands assuming following rangeland restoration strategy 3) the base simulation which is the current situation of mixture between rangeland natural vegetation and rain-fed crops. Recent high resolution satellite imagery were acquired for the study area and used for distinguishing the land cover types dominating the study area. The supervised classification of the satellite image revealed that there are 5 major land cover classes; urban, orchard, rain-fed crops, rangeland and bare soil. The primarily results revealed that, changing the land cover type from rangelands to rain-fed agriculture increased the surface runoff by 1.14 to 17.69 %. Also, there was an increase in the sediment yield ranged from 13.96 to 26.83% when the land cover was completely changed from rangelands to rain-fed agriculture. These results combined with our field survey and experiences show that the current primitive methods of farming of barley, the extensive grazing of the wild plants by large herds of goats and sheep and by camels, and the indiscriminate cutting of woody plants for fuel have depleted the land of its natural wealth of vegetation and led to serious erosion of the soil. It is highly recommended that a limited area should be converted from rangelands to rain-fed agriculture and rangeland improvement and restoration strategy should take place for the conservation of these valuable ecosystems.

Keywords: Rainfed agriculture, Land cover classes, Satellite imagery, KINEROS2 model

Introduction

In The North Western Coastal Zone of Egypt, which was rich in natural habitats and biodiversity, the vegetation cover was highly degradated as a result of long drought periods, wind erosion and unsustainable land use practices i.e., firewood gathering, over-exploitation of rangelands, and traditional tillage to grow rainfed cereals (mainly barley and wheat). The vegetation cover degradation has resulted in reduced biodiversity and lower animal feed resources. There are also 218 *wadis* in the area running from south to north. Some of these wadis have been developed based on dyke construction to retain both water and arable soil. Main stream of the wadi and its delta is mainly occupied by olive and fig trees, while, the upstream is left for rainfed crops and natural vegetation. No studies in the area have explored the influences of the land cover change on the runoff behavior in the watersheds.

Many studies worldwide have been conducted to predict the change in the hydrological behaviors of different watersheds as a result of the temporal and spatial distribution of land cover (Li *et al.,*2016; Fang *et al.,*2012; Mahmoud and Alazba, 2015). Mahmoud and Alazba (2015) studied the effect of land cover change in the year 2000 as compared to 1990 and its effect on the surface runoff of El Baha Region in Saudi Arabia. Results revealed that there was a decline of the surface runoff in the majority of the area because of the transition from forest and shrub land to irrigated cropland as well as the construction of different water harvesting projects. However, the increase in the surface runoff occurred in a limited area. Masih et al. (2011) examined three scenarios of land cover change i.e., converting rainfed areas to irrigated agriculture, improving soil water availability by rain water harvesting structures and a combination of the two. Soil and Water Assessment Model (SWAT) was used to evaluate the tested scenarios on the flow of Karkheh basin in Iran. The results revealed a 10% reduction in the basin mean annual flow in the first scenario while the second scenario caused a small reduction (2-5%). The third scenario gave similar results to the first.

Hydrologic modeling plays an essential role in assessing the impact of land cover change on the hydrological system of a watershed (Dwarakish and Ganasri, 2015). Recently many physically distributed models were employed to detect the spatial and temporal land cover change on water resources e.g., MIKE SHE (Refsgaard and Storm, 1995; Im *et al.,* 2009), SWAT (Arnold,1998; Pervez and Henebry, 2015), TOPMODEL (Beven and Kirkby, 1979; Gumindoga *et al.,* 2014). Miller *et al.* (2002) applied two hydrological models: SWAT as a continuous simulation model and KINEROS (Smith *et al.,*1995) as an event oriented model through the Automated Geospatial Watershed Assessment Tool (AGWA) to study the hydrologic responses of three watersheds to the land cover changes in four time periods for the Cannosville watershed. The simulation results showed that both models were effective.

The KINEROS hydrological model was chosen for this study for many reasons. 1) It is an event oriented -physically based model and suits the study of single hydrological event. 2) It was developed to study the hydrological processes in arid and semi-arid areas. 3) It is a GIS-based model that has capabilities of geo-visualization for better understanding and comparing different scenarios. The objectives of this study were to investigate the impact of converting the rangeland to rainfed crops and the bare soil to rangelands on the hydrological behavior of Wadi El-Raml, and to evaluate the potentiality of a physically distributed model (i.e. KINEROS) to simulate the hydrology of an arid watershed in response to the land cover change.

Materials and methods

Wadi El-Raml basin is considered as one of the greatest basins in the coastal area of North Western coast of Egypt. It occupies an area of about 144.35 Km^2 west of Matrouh City. It is located between longitudes 27˚04′27″ - 27˚12′30″ E and latitudes 31˚ 09′ 20″ - 31˚ 21′ 58″ N (Figure 1). The area is characterized by a temperate Mediterranean climate. The mean monthly maximum air temperature reaches 30 ºC in August, while the average minimum value reaches 9 ºC in January, with mean annual value of 19 ºC. The maximum relative humidity varies from 73% to 63% (in July and March, respectively). The rainy season is short (November to February). December is the rainiest month with a monthly average of 32 mm. The maximum annual rainfall was recorded in 1989/1990-season (275mm) while the annual mean value reaches 140 mm.

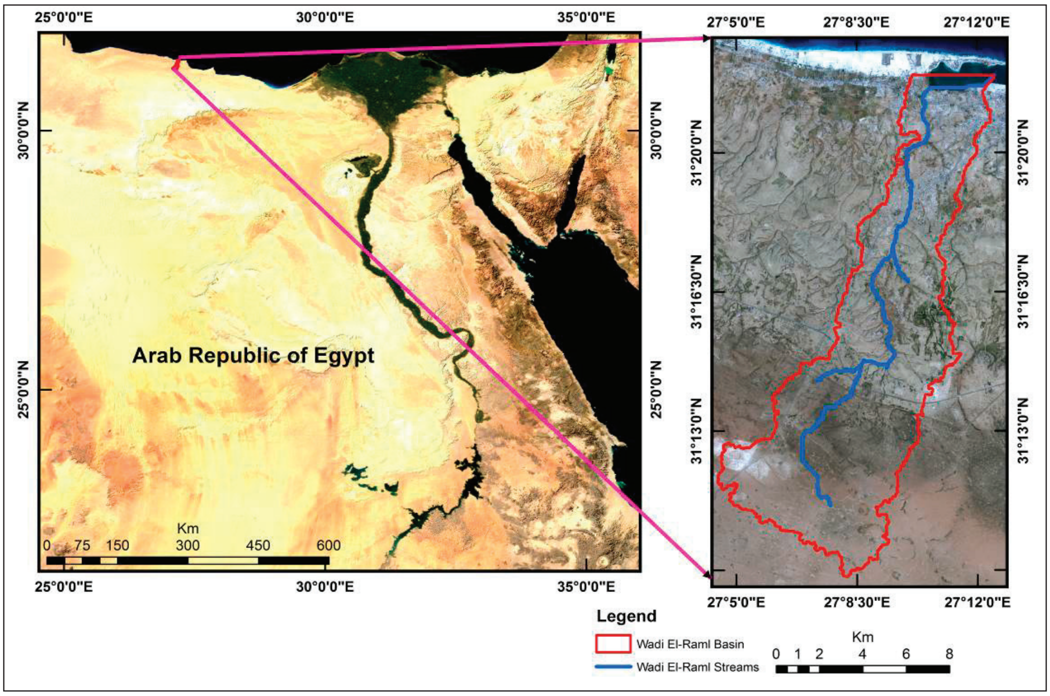

Figure 1. Location map showing the target study area at NWCZ of Egypt.

The geomorphology, geology, and hydrology of western Mediterranean coastal zone have been studied by many authors. (Raslan,1995; Masoud, 2000; Barseem,2006; Mohamed *et al.*, 2011).

Geomorphologically, the western Mediterranean coast is distinguished into four geomorphic units. Each unit has its own characteristic land forms reflecting the dominant geologic structure and Lithologic features. These units were classified according to Raslan (1995) into: coastal plain, piedmont plain, structural plateau and hydrographic basins (Figure 2). The coastal plain is a zone of variable width and elevation. Its width varies from few meters to some kilometers at the approach of headland and along the enclosed gulf, respectively. Its elevation varies from sea level to about l00 m. This unit includes coastal dunes, coastal ridges, and salt marshes. The piedmont plain is developed at the foot slope of the structural plateau. It consists of thick calcareous soil of fine deposit resulting from alluvial deposits of many wadis. This unit includes inland ridges, alluvial fans, and depressions. The structural plateau acts as a major catchment area feeding the drainage line during winter. The plateau structure, from the southward to the piedmont plain northward, has an elevation that varies from 100 to 160 m. The hydrographic basins are differentiated into basins of exterior drainage, of interior drainage, and depressions. The exterior drainage basins drain into the sea, and they are present at the headland area. The topography and structure are the main controlling factors of these wadis. The water flows across with small velocity and heavy load at the start on the plateau surface and high speed on the terminal outlet. The interior drainage basins represent the majority, which do not drain directly into the sea. These wadis cut down their courses on the lowland areas and are characterized by shallower and buried inlet on the surface of the plateau. The depressions are flat areas that are delineated by higher area from one side or from all the sides and they may be suitable for cultivation.

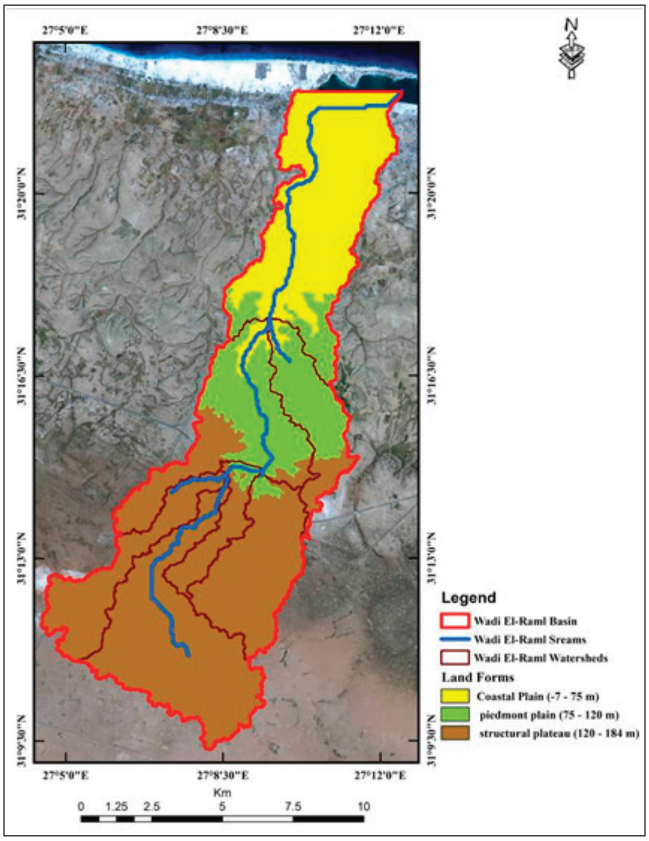

Figure 2. Geomorphologic map of the study area.

Geologically, the stratigraphic sequences of the studied area according to Raslan (1995) are entirely composed of sedimentary origin ranging in age from the Middle Miocene to Quaternary (Figure 3). The Middle Miocene is represented by Marmarica formation covering the whole area of northwestern desert. It forms the structural plateau and part of the piedmont plain. This formation is made up of an upper white limestone fossiliferous member, middle snow-white chalk member, and a lower member of alternating cross-bedded carbonates, shale, and marls. It changes laterally from chalky marl limestone to sandy and clay facies at the approach of headland. The Pleistocene sediments have wide distribution in the area and can be distinguished as Oolitic limestone. It consists of carbonate grains with dispersed quartz grain and fossil allochems, being cemented in different degrees by carbonate. It is cross-bedded with a high degree of primary porosity. The Quaternary deposits, represented by alluvial deposits, act as an alluvial fan or alluvial terraces. These deposits consist essentially of sand, silt, and clay, in addition to being highly calcareous. The structure of northwestern coast zone is dominated by folds and faults. The Middle Miocene rocks in all the studied wadies are fractured in some place and suitable for the occurrence of groundwater. These fractures take different trends such as N–E, E–W, and NE–SW. Non-conformity is found at some place between Miocene and Pleistocene where the Pliocene is missing.

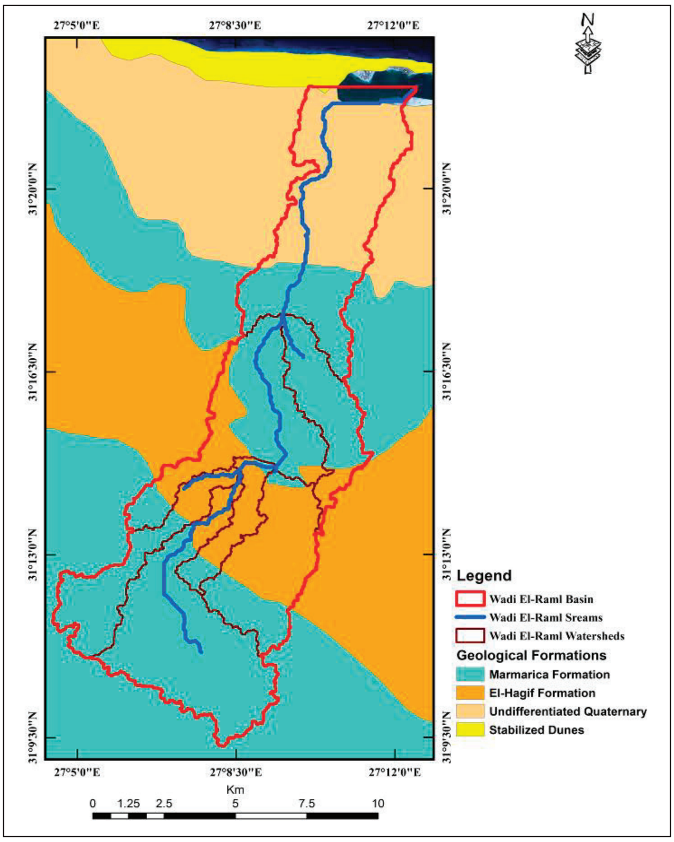

Figure 3. Geological map of the study area.

Hydrogeologically, the aquifers in the study area could be classified according to Raslan (1995) into Pleistocene and Middle. The Pleistocene aquifer is composed of detrial Oolitic limestone. The groundwater belonging to this Oolitic limestone comes either from the direct infiltration of annual rainfall *in situ* or from that falling on the tableland region. The Middle Miocene aquifer is represented by Marmarica limestone aquifer. It consists of alternating beds of limestone and clay. The limestone is highly fissured and jointed in some places, which points to the occurrence of groundwater.

Khalifa and Beshay (2015) have classified the area between El-Qasr and Um El-Rackham areas (including Wadi El-Raml) into six land forms and described their properties. They are: coastal plain (including Oolitic sand beach and Oolitic longitudinal sand dunes, lagoon depression and salt marches, and alluvial fans), Alluvial terraces and interfluves wadis, wadi course, escarpment, piedmont plain, and plateau. Khalifa and Beshay (2015) have described the soils of these landforms in detail.

AGWA interface was used to automate the development of model input. A 5 m digital elevation model (DEM) from the digitizing of 1:25000 topographic map was used. The model uses the DEM to generate information related to the topographic characteristics of the watershed: elevation, watershed boundary, flow path, sub-basin area, slope, and channels elevation. All soil data were obtained from the FAO/UNESCO 2003 Soil Map of the World CD-ROM.

Land cover could be, urban, bare soils, irrigated agricultural and other types of features. Unsupervised and supervised image classification techniques are the two most common approaches used for land cover classification. In the current study, the Sentinel 2A image launched in 2014 was used to define the main land cover types dominating in the study area. Before doing the digital image classification, the SENTINEL-2A image bands were merged to obtain 10 meter pixel resolution. The spatial resolution shown in Figure 4 of SENTINEL-2A is dependent on the particular spectral band.

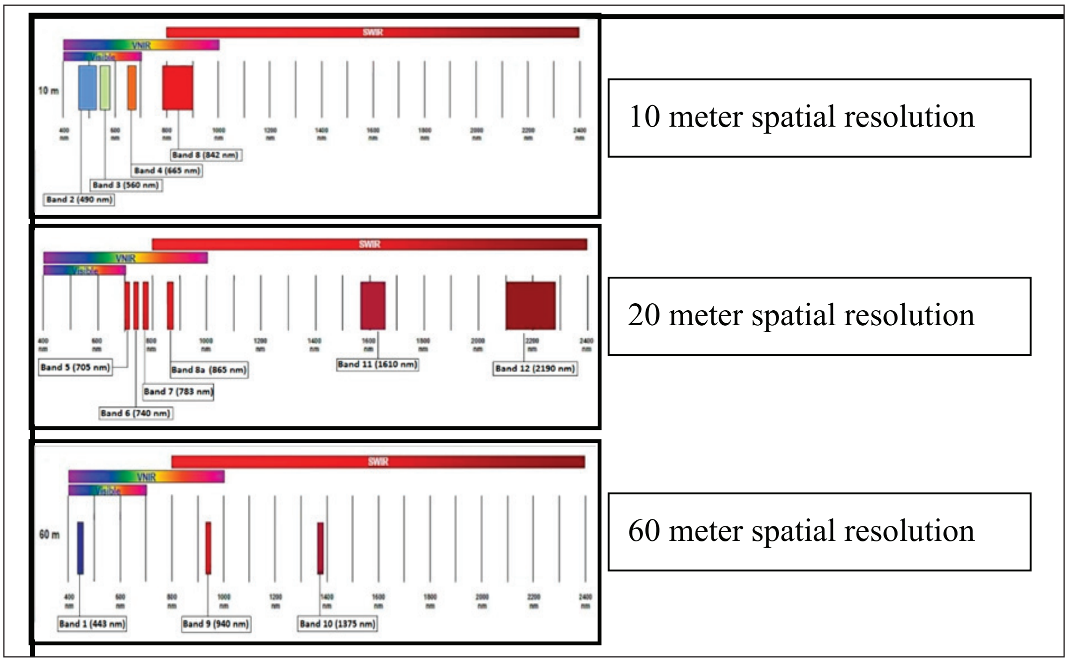

Figure 4. SENTINEL-2A image spatialresolution.

The unsupervised classification was performed using Iso-Cluster as a signature file followed by a Maximum Likelihood Classification, in ArcGIS Desktop 10 by making 742 RGB band combination for Sentinel 2A image data. The classification was assumed to be generally free from user bias. So it is a computer-based system that designates pixels to statistically separable clusters based on the pixel digital number values from several spectral bands. Accordingly, 10 clusters were specified to classify the study area (Figure 5).

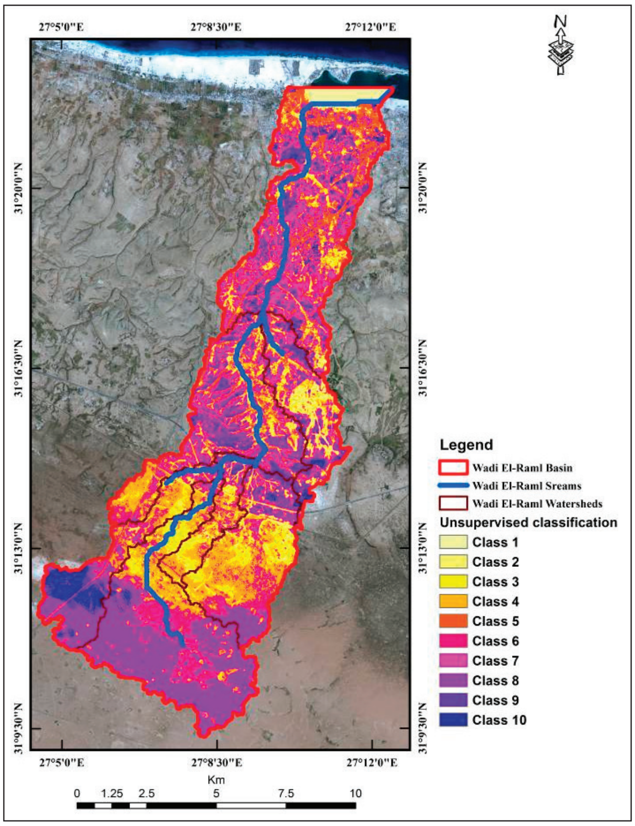

Figure 5. Unsupervised classes based on the spectral signature.

The supervised map was created by digitizing signature file for different surface covers based on the data obtained from the field study. Finally, Maximum Likelihood Classification method was used to run this option using ArcGIS desktop10. Accordingly, the 10 classes resulted from unsupervised classification have been checked and verified in the field. Therefore, they were regrouped based on these field observations. The supervised classification was developed using map units' polygons representing the same spectral units. Finally, the different spectral soil mapping units covering the study area is representing by 6 land cover classes as shown in Figure 6. These classes are: water body, urban land, orchards trees, rain-fed crops, sparsely vegetated rangeland, and bare soils.

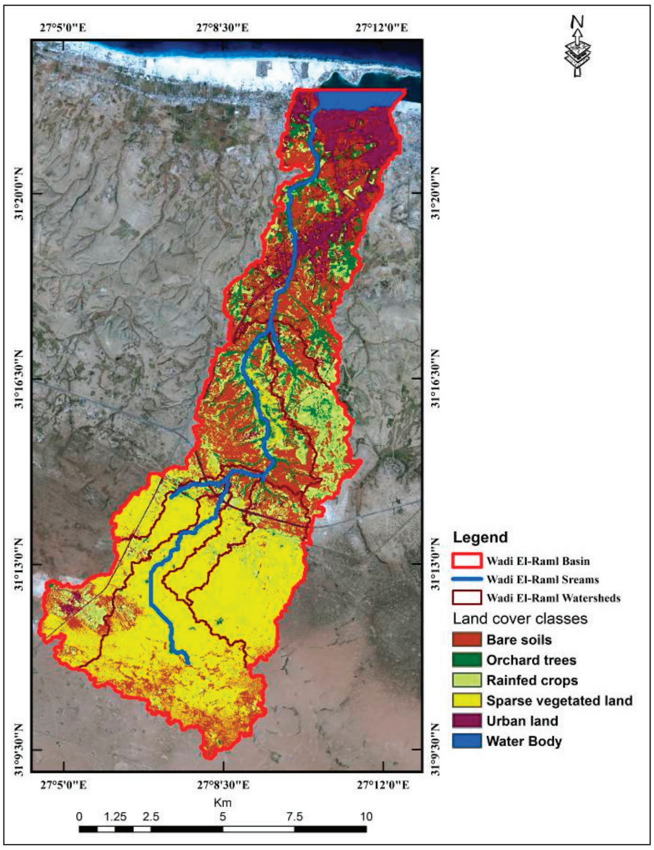

Figure 6. Land cover type based on supervised classification.

Model KINEROS2 (K2) is an event-oriented, distributed, physically-based model developed to simulate the runoff response in basins having predominantly overland flow (Semmens *et al.,* 2008). KINEROS2 has been successfully applied in a number of geographies including the US desert southwest, Western Europe, the Middle East, and Southeast Asia. KINEROS2 is maintained by the USD Agricultural Research Service. The KINEROS2 is a distributed, event-oriented model. The form of the model that we used in this study is part of the AGWA interface (Miller *et al.,*2007). It first calculates the infiltration capacity when rainfall rate < infiltration rate using the Smith-Parlange model (Smith and Parlange, 1978) as follows:

$$f_c(t) = K_s \left\{ 1 + \frac{\alpha}{e^{\alpha F(t) / [(G+h)(\Phi - \theta_i)]}} \right\} \quad (1)$$

where $f_c(t)$ is the infiltration capacity (LT^{-1}), K_s is soil hydraulic conductivity (LT^{-1}), α is the soil parameter, 0 for sand and 1 for well mixed loam, $F(t)$ is the calculated depth of infiltrated water (L), G is the net capillary drive (L), h is the flow depth (L), Φ is the soil porosity (L^3L^{-3}), θ_i is the initial soil water content.

When the rainfall rate exceeds the infiltration capacity, the model uses the kinematic wave equation to calculate the over land flow as follows:

$$\frac{\partial h}{\partial t} + \alpha m h^{m-1} \frac{\partial h}{\partial x} = q(x,t) \quad (2)$$

where t is the time (T), x is the distance along the slope direction (L), q is the lateral flow rate (LT^{-1}), α and m are parameters related to slope, surface roughness and flow regime. After the water reaches the channel the model uses a similar approach to calculate the channel flow as follows:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_c(x,t) \quad (3)$$

where A is the cross sectional area (L^2), Q is the channel discharge (L^3T^{-1}), $q_c(x,t)$ is the net lateral inflow per unit length of channel (LT^{-1}).

Besides calculating the infiltration capacity and surface runoff, the model also calculates the sediment transport which is given by mass-balance equation similar to that for kinematic water flow (Bennett, 1974). Splash erosion was determined using the method described in Meyer and Wischmeier (1969). Hydraulic erosion is modeled as kinetic transfer process and sediment transport capacity is modeled as proposed by Engelund and Hansen (1967). The estimation of these outputs involves parameters that can be adjusted to match the model prediction with the observed reality

Three scenarios were simulated using the KINEROS2 model: 1) baseline simulation of the current condition, 2) converting sparsely vegetated rangelands to rainfed crops, and 3) converting bare soil to sparsely vegetated rangelands. The model was run using the rainfall data of five major events in 2015/2016 rainy season. These events were: 1) 26 Oct. 2015 (27.20 mm), 2) 04 Nov. 2015 (10 mm), 3) 16 Nov 2015 (20 mm), 4) 13 Dec. 2015 (18 mm) and 5) 30 Dec. 2015 (24.80 mm)

Results and discussion

Rangeland ground cover survey

Rangeland vegetation survey indicated that Wadi El Raml is rich in range plants, where 23 range plants were recorded, most of them are palatable (Table 1). These include *Deverra tortousa, Artemisia herba-alba, Gymnocarpos decander, Lycium shawii, Noaea mucronata, Suaeda pruinosa, Lotus polyphyllus, Haloxylon salicornicum, Atractyles carduus* and *Zygophyllum album*. Table 1 shows that total vegetation cover in spring, 2015 was about 28.55 %.

Table 1. Vegetation analysis and rangeland productivity of Wadi El Raml at spring of 2015

Species	Density	Cover %	Frequency	Importance value	Plant height (cm)	Fresh weight (kg/ha)	Productivity (kg dry matter/ha)
Artemisia herba-alba	5.9	1.35	100	19.2	46.0	2.1	1.6
Thymelaea hirsute	4.7	1.79	100	11.9	92.6	21.2	12.3
Oryzopsis miliacea	32.2	1.15	100	37.1	68.1	11.3	7.5
Lygeum spartum	19.1	1.82	100	41.6	57.1	1.6	0.8
Noaea mucronata	6.8	2.3	33.3	3.8	12.3	2.7	1.8
Asparagus stipularis	3.2	1.2	33.3	3.2	16.8	1.2	0.8
Atractylis carduus	0.8	0.3	33.3	3.2	63.3	11.5	6.3
Gymnocarpos decander	10.3	1.7	100	19.6	19.5	13.2	6.8
Deverra tortousa	36	1.28	100	46.4	33.1	13.7	7.9
Reaumuria hirlella	0.1	0	33.3	3.1	18.3	0.6	0.4
Thymus capitatus	2.7	0.75	100	12.5	20.9	0.26	0.21
Suaeda pruinosa	2.3	2.3	33.3	10.1	29.3	0.8	0.3
Centaurea eryngioides	5.3	0.24	33.3	7.0	36.0	3.4	1.7
Lotus polyphyllus	9.3	0.7	66.7	28.8	7.7	6.7	2.8
Ononis vaginalis	1.0	0.5	33.3	17.1	25.7	12.8	7.3
Zygophyllum album	9.2	3.1	33.3	14.6	29.5	14.8	3.9
Helianthemum lippii	80.3	1.27	100	47.4	9.3	3.7	2.9
Haloxylon scoparium	6.7	1.35	100	30.8	16.0	10.9	8.1
Lycium shawii	3.3	3.3	100	13.4	28.0	15.3	8.2
Allium desertarum	0.7	0.2	33.3	3.8	31.0	2.4	1.3
Echium sericeum	0.3	0.45	0	1.0	13.6	0.5	0.2
Asphodelus ramosus	10.3	1.1	66.7	13.8	5.6	8.9	5.3
Fagonia Arabica	0.5	0.4	33.3	0.4	5.2	8.3	4.7

The highest plant cover 3.3 % was recorded by *Lycium shawii* in spring 2015. *Thymelaea hirsute* attained the highest value of height (92.6 cm) while *Fagonia Arabica* showed the lowest value (5.2 cm). Vegetation survey from 2015 showed that the fresh weight and productivity of *Thymelaea hirsute* were the highest in this habitat. This Wadi has faced more land use changes in the last 15 - 20 years where several farmers started to use subsurface water to establish and irrigate small field of vegetable crops. This increased the tillage activity in the area. Total vegetation cover decreased to 28 % in spring of 2015, which indicates vegetation degradation. Overgrazing and land use change has removed the vegetation cover that protects soil from erosion. Connolly *et al*. (1997) reported that when the vegetation cover is less than 30–40%, runoff and soil loss dramatically increase.

KINEROS2 model simulation

A baseline simulation was run to describe the current condition, and it resulted in a runoff volume of 174321, 32744, 116497, 6454, and 19,422 m^3 for the 1st, 2nd, 3rd, 4th and 5th rainfall events, respectively The total sediment yield from the upland area was 1.49, 0.36, 0.90, 0.027 and 0.112 t/ha, for the 1st, 2nd, 3rd, 4th and 5th rainfall events respectively. Lower sediment yield at the outlet as compared to the upstream was observed, and this is due to the nature of the model that some sediments are deposited in the upland and do not reach the outlet.

Impact of converting the range lands to rainfed crops

Table 2 lists the subbasins of Wadi El Raml associated with their land cover types and the dominant land cover in each sub-basin. The impact of the tested scenario on infiltration, surface runoff, sediment yield and peak flow is shown in Table 3.

The impact was notable among the sub-basins, these differences governed by the relative area under the tested scenario. The highest impact was noted for the sub-basins No (42 and 52; Figure 7) in the surface runoff and sediment yield where most of the S1 Scenario is taking place. These two sub-basins showed an increase in the surface runoff by almost 40 % and sediment yield by more than 90 % when compared by the base scenario. However sub-basins No 12 and 13 witnessed comparatively no impact, where the increase in surface runoff and sediment yield is zero. Similar results of increasing the surface runoff by converting the rangelands to rainfed agriculture were obtained by Ghaffari *et al.* (2010), who found that complete removal of the rangelands increased the simulated runoff amount from 7.4 to 38.2 mm/year.

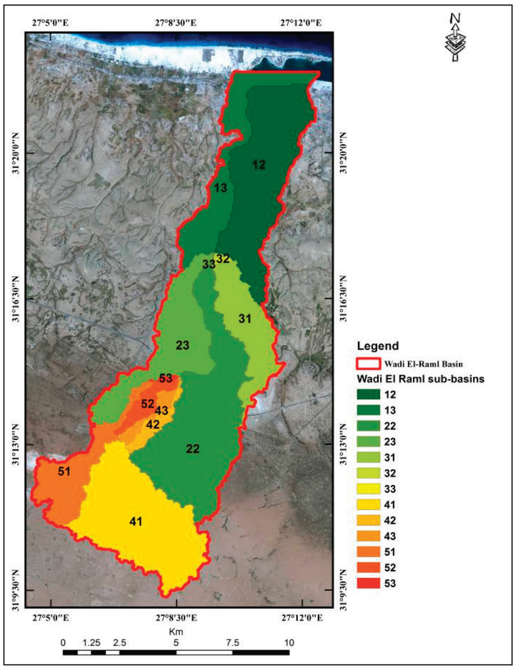

Figure 7 **.**Sub-basins covering Wadi El Raml.

Table 2. Counts and percentages of land cover types of the entire basin and its sub-basins

Main Basin and sub-basins	Land cover type												
	Water Body		Urban land		Orchards trees		Rainfed crops		Sparse vegetated land		Bare soils		Total
	count	%	count	%	count	%	count	%	count	%	count	%	
El Raml Basin	17244	1.51	130637	11.43	119138	10.42	180670	15.80	397923	34.81	297643	26.03	1143255
Sub-basin12	2041	0.96	79765	37.69	40248	19.02	23115	10.92	242	0.11	66250	31.30	211661
Sub-basin13	14312	13.96	24851	24.25	18837	18.38	13847	13.51	198	0.19	30442	29.70	102487
Sub-basin22	0	0.00	6852	2.72	20874	8.28	39599	15.71	139032	55.15	45747	18.15	252104
Sub-basin23	0	0.00	6852	2.72	20874	8.28	39599	15.71	139032	55.15	45747	18.15	252104
Sub-basin31	0	0.00	3435	3.74	15148	16.51	42753	46.61	1285	1.40	29111	31.73	91732
Sub-basin32	0	0.00	309	11.63	606	22.81	519	19.53	10	0.38	1213	45.65	2657
Sub-basin33	0	0.00	1	0.27	226	59.95	25	6.63	1	0.27	124	32.89	377
Sub-basin41	0	0.00	223	0.10	1453	0.67	8273	3.80	154833	71.04	53170	24.40	217952
Sub-basin42	0	0.00	241	1.41	365	2.13	1657	9.66	14270	83.23	612	3.57	17145
Sub-basin43	0	0.00	210	1.60	245	1.87	1414	10.80	10029	76.59	1196	9.13	13094
Sub-basin51	0	0.00	5806	7.23	1765	2.20	18373	22.89	37062	46.17	17263	21.51	80269
Sub-basin52	0	0.00	435	2.13	863	4.22	2318	11.33	15064	73.66	1770	8.66	20450
Sub-basin53	0	0.00	139	6.33	202	9.20	626	28.51	444	20.22	785	35.75	2196

Table 3. Average percent change for various hydrological components under different proposed land use scenarios

Scenarios	Rainfall events	Infiltration (mm)	Surface runoff (mm)	Sediment (mm)	Peak flow (m3/s)
S1	26Oct.2015	-1.98	15.37	36.45	18.11
	04Nov.2015	-2.58	9.47	29.53	12.52
	16Nov.2015	-1.76	10.12	25.67	14.61
	13Dec.2015	-1.15	15.34	27.80	16.00
	30Dec.2015	-0.811	6.39	16.29	10.65
S2	26Oct.2015	-0.72	-10.76	-19.18	-11.21
	04Nov.2015	-1.83	-20.31	-28.74	-18.48
	16Nov.2015	-0.66	-14.37	-22.77	-12.99
	13Dec.2015	-2.02	-12.77	-20.46	-11.89
	30Dec.2015	-1.00	-22.65	-31.48	-18.85

This increase in the surface runoff and sediment yield may likely have a severe negative impact on the environment (Yasouri *et al.,*2012) hence, they found that land use conversion from rangeland to dry farming between 1970-2007 increased the annual sediment yield of the Kardeh basin in Iran to two fold. Thus adoption of S1 requires additional recommendations to avoid excessive erosion and surface runoff, which could be done by using different land management practices e.g. mulching, water harvesting, terracing, contour furrow, conservation tillage........etc. These may help in increasing the crop yield as well as conserve the soil and water resources. Also, increase the farmers awareness related to the connection between soil erosion and their activities.

Impact of converting the bare soil to rangeland

Under the second scenario a reduction in the surface runoff, sediment yield and peak flow was observed for all the tested events (Table 3). The sub-basins responded differently to the land cover change i.e., the highest affected sub-basins were 23, 12, 13, 31, 32 for all the tested events. On contrary, sub-basin number 42 was not affected by the land cover change.

The hydrograph results (Figure 8) show that the peak flow was increased when the land cover was changed from rangelands to rainfed crops. However it was decreased, associated with a delay for the timing of the peak flow, when the land cover was changed from bare soil to rangelands.

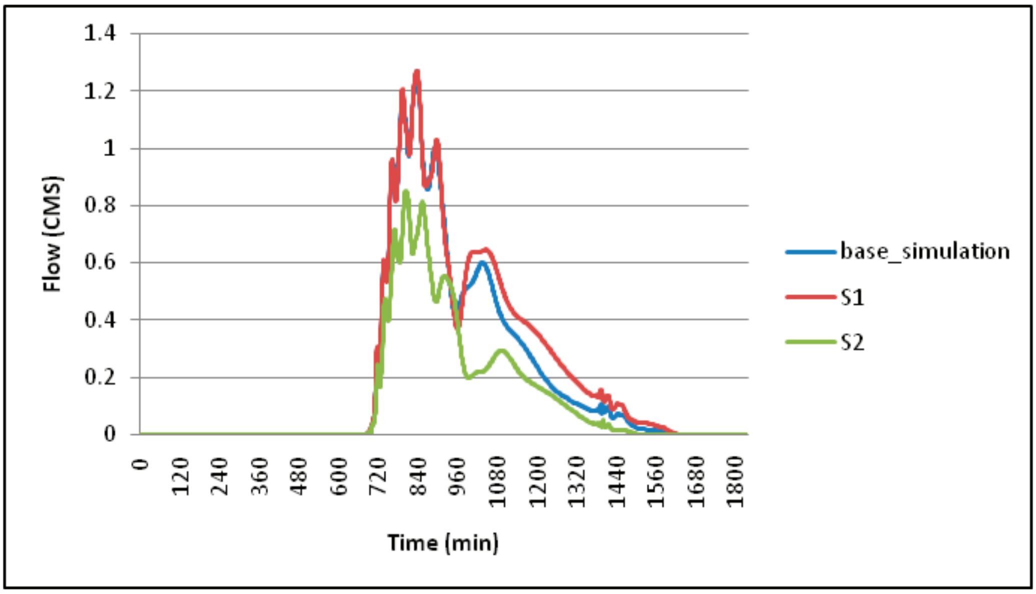

Figure 8. Runoff hydrograph from a single rainfall event (27Oct.2015) under different scenarios

The reduction of the surface runoff and sediment yield is due to the fact that vegetation and ground cover can protect the surface from raindrop splash erosion and slowdown overland flow, moreover vegetation patches can capture runoff, nutrient and sediment (Urgeghe *et al.,*2010). The peak flow is reduced and delayed slightly.

Changes in land cover can have a drastic effect on the storage and movement of water on the landscape. Erosion is a result of the lack of adequate vegetation cover to retain soil and water in the upstream. A strong correlation was found between the biomass on hill slope and the overland flow (Turnbull *et al.,* 2008).

Conclusion

The rapid degradation of natural vegetation caused by human and climate induced factors highly influenced the hydrology of the watershed. In general, converting the rangeland to agriculture increased both the surface runoff and sediment yield, while converting the bare soil to range land decreased the two components of surface runoff and sediment yield. Integrated high resolution landsat images with hydrological models are very helpful to detect the environmental changes and their impact on the hydrology of the watershed. This is also very helpful to evaluate better options for sustainable development of land and water resources.

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6. Using information communication technologies in development and sustainable management of drylands

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Abstract

There are great potentials in developing dryland to help Egypt achieve food safety. Although ICT was sophisticated when introduced to Egyptian farmers 15 years ago in the shape of a Virtual Extension and Research Communication Network (VERCON), it was very successful with farmers by the help of Extension Advisors (EA). VERCON was started in 2002 as an agriculture network, and based on its success, The Rural and Agricultural Development Communication Network (RADCON) was launched in 2006 to help the rural community. In spite of the financial and logistic problems, the Ministry of Agriculture was able to maintain its function until now and VERCON continues to be the second most visited agriculture network in Egypt. These networks also targeted newly reclaimed lands (Nubaria and Ismailia) and got more success than in the old lands because of the nature of farmers in these areas. In 2007, RADCON/VERCON covered 18 governorates and 96 extension centers allover Egypt. In the past 10 years, mobile phones were accepted and used by almost all farmers. Along with many new applications related to dryland development, RADCON/VERCON have the potentials, reputation and experiences to compete well with others in the agriculture knowledge dissemination field. Successful examples include: technical information system of reclaiming and using drylands, agricultural practices information systems, farm management decision support system, farm management expert systems, market information system, locust early warning systems, and tracking systems for clean products. RADCON was funded by the Italian/ Egyptian Debt Swap program and executed by Food and Agriculture Organization (FAO), and implemented by the Central Laboratory for Agricultural Expert Systems (CLAES) with Agricultural Extension & Rural Development Research Institute (AERDRI) and other stakeholders. RADCON consists of two types of modules. The first type focused on improving extension works through expert systems, grower problems, extension documents and intelligent search modules. Expert systems were used in different fields such as variety selection, irrigation and land preparation. 'Variety selection' expert system helps farmers in choosing the best variety according to different parameters such as soil type, water salinity, water quality and weather conditions. The 'Irrigation' expert system provides farmers not only with optimum quantity of water for irrigation but also a complete irrigation schedule including dates and method of irrigation according to parameters provided by farmers. 'Land preparation' expert systems provide the farmers with a list of preparation operations necessary for planting certain crops based on parameters fed by farmers. 'Grower Problems' expert system was developed to provide farmers, through extension officers, solutions to their field and livestock problems. Technical solutions of problems are the responsibility of research institutes and research stations in Agricultural Research Center. 'Extension Documents' system allows farmers to browse an extension document which will help them in managing their crop and livestock. Extension Documents Intelligent Search was developed to facilitate finding specific paragraphs related

to agriculture question. The second type of RADCON modules focused on rural development through Women's corner, Youth, Marketing, NGOs, and Environment modules. 'Women's corner' module supports rural women with education, health and family affaires. Also, it informs them on a set of handicraft items which they can make at home and help themselves in increasing their family income. 'Youth' module tries to solve the youth unemployment problem by improving their capacity and skills, and how they can start up their own work. 'Marketing' module provides agricultural stakeholders with adequate information on exporters, producers, growers, support services, marketing opportunities. Facilitating grower and producers cooperation is done through the 'NGOs' module. 'Environment' module helps in conserving natural resources and produce clean product. It provides information such as practices and recycling of waste .As a result of applying RADCON in 50 villages in 6 governorates, it has helped in improving both the extension agricultural advisory services and rural development.

Keywords: Information technology, Expert Systems, Rural development, Women empowerment

Theme 5. Soil erosion and desertification processes and control

1. Key erodibility factors of dust emissions in the Gobi Desert – findings of the Project Asian Dust, Tottori University

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Abstract

Dust observations were carried out since March 2012 at Tsogt-Ovoo (TsO), Mongolia, in the northern Gobi Desert. An analysis of synoptic data shows the highest frequency of dust occurrence at TsO in East Asia. This suggests that TsO has huge dust sources. Earlier research, using synoptic data, indicated narrow seasonal variations of a threshold wind speed of dust occurrence (TWS) in desert regions including the Gobi Desert. In addition, one can expect that with low precipitation and limited vegetation cover, a narrow seasonal variation of TWS at TsO would exist. However, we found a clear seasonal variation of it. This suggests an aeolian erodibility factor at TsO that strongly control TWS. Drastic changes in TWS were reported from the data of our observation, discussing roles of soil crust and soil freeze-thaw process. Satellite images have captured dust emissions from topographic depressions such as valleys, foothills, and basin in Mongolia. We observed that the amount of sand saltation at a 10 cm-height was 150 to 200 times larger at a topographic depression than that at its surrounding area for March 10 to April 22, 2015. A PM2.5 concentration was 5 to 10 times higher at the topographic depression than that at its surrounding area in a dust event at April 22, 2015. This observation suggests that this topographic depression is the major dust source in TsO. In this presentation, we will discuss role of aeolian erodibility factors on variations of threshold speed.

Keywords: Gobi desert, Aeolian erodibility factor, Saltation of sand

2. Effect of ground surface erosion and deposition distribution on spatial heterogeneity of soil grain size on nebkhas and interdune in the desert-oasis ecotone of northwest China

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Abstract

Plants play a very important role in forming *nebkhas* in arid and semi-arid area. In this paper the regular pattern of ground surface erosion and deposition and their effect on the spatial variation of soil grain size on *Tamarix ramosissima* nebkhas and interdune were investigated in Qira oasis-desert ecotone at the southern rim of the Taklimakan Desert. Our investigation showed that there are different characteristics of surface erosion and deposition in grounds with different vegetation coverage. The surface of nebkhas and interdune is mainly in the process of sand accumulation in the plot where vegetation coverage is about 30%. The nebkhas body and leeward shadow are mainly in the process of sand accumulation, while the interdune is mainly in the process of wind erosion when the vegetation coverage is 10~20%. The surface of both nebkhas and the interdune is mainly in the process of strong wind erosion when vegetation coverage is <5%. The distribution of soil grain size is closely related to distribution of surface erosion and deposition. With the decrease of vegetation cover from 30% to <5%, the average particle size in the 0-10 cm soil layer increased from 74.41μm to 92.71μm, clay disappeared and coarse sand appeared. Under the same vegetation cover, the minimum soil particle size was mainly under the shrubs while the maximum particle size was mainly distributed in the interdune. The quality of the interdune soil was the best while under shrub was the worst, which corresponded to the degree of soil erosion in interdune and the deposition on nebkhas surface. With the decrease of total vegetation cover, the differences of average values of particle diameter between different parts of nabkhas surface are significantly reduced. Viewed from the angle of nebkhas stability, the total vegetation coverage should be maintained at least > 10% in desert-oasis ecotone.

Keywords: Nebkha, Surface erosion, Sand deposition, *Tamarix ramosissima,* Vegetation cover

1. Introduction

Vegetation cover is the key factor in protecting the soil surface from erosive wind (Youssef *et al*., 2012). Most dry lands covered with sparse vegetation are highly susceptible to wind erosion and wind driven redistribution (Field *et al*., 2009), and so land desertification can occur easily (Mc Tainsh *et al*., 1998). With the continuous transport of soil particles by wind, fine materials are winnowed from the surface, causing the ground surface soil to become coarser and less fertile (Larney *et al*., 1998; Field *et al*., 2010). Aeolian activities are known to create spatial heterogeneity in soil properties (Okin and Gillette, 2001). Wind erosion can transport fine grain material with high nutrient content from interdunes to under shrubs, causing significant changes in soil texture (Puigdefábregas, 2005). *Nebkha* dunes develop by trapping sand within the body of a plant (Tengberg, 1995), and under the long-term effects of physical and biological processes, they gradually form so-called 'resource islands', which not only change the spatial pattern of soil resources in desert ecosystems, but also affect the community structure and the ecosystem. Study on the characteristics of its formation and change is significant for understanding the regional environmental change (Titus *et al*., 2002).

There are hundreds of different sized oases distributed at the southern edge of the Taklimakan Desert. The natural vegetation of the transition zones has been the security of oasis civilization over thousands of years. *Tamarix* shrub plants as constructive species are widely distributed in the transition zone, and form different sizes of nebkhas. The climate is extremely arid and windblown sand activity is frequent. The composition of the plant community and the vegetation coverage differ with the different degrees of human activities. Sand erosion reduction depends on vegetation cover, plant morphology and plant distribution (Lancaster and Baas, 1998; Dupont *et al*., 2014). However, little research has examined the combination of surface erosion and deposition under different vegetation conditions and soil characteristics of nebkhas and interdunes. In this study, the distribution patterns of ground surface erosion and deposition was analyzed and their effects on the spatial heterogeneity of soil grains on *T. ramosissima* nebkhas and interdunes were revealed. The results should improve understanding of the interaction of the spatial heterogeneity of soil and the windblown sand environment.

2. Study area and method

2.1 Study area

The study area was located in the Qira desert-oasis ecotone in the southern rim of Tarim Basin, within 80°03′–82°10′E and 35°17′–39°30′N (Figure1). The annual precipitation is 35 mm, the evaporation is 2595.3 mm and the drought index is 20.8, and there is a warm temperate continental desert climate. The average temperature over many years is 11.9 °C, −5.8 °C in January and 25.1 °C in July. There is strong windblown sand activity and this always occurs in spring and summer. The NW and WNW direction winds account for 52.5 and 31.4 % of annual sand transport potential (Wang *et al*., 2011). The annual average wind speed is 1.9 m/s and maximum wind speed is 12.1 m/s. There are about 40 d with more than fresh gale every year. The main soil types in the study area are aeolian sandy and brown desert soils, with light texture and low water content. The natural vegetation types are monotonous and the community structure is simple: *Alhagi sparsifolia*, *Tamarix ramosissima* and *Karelinia caspic* are the main constructive species. *T. ramosissima* is widely distributed and can form nebkhas of different heights. Affected by different degrees of human activities, desertification characterizes the region, mainly shown by reduced areas of transition zones, vegetation with declining trends and even emergence of bare land and mobile sand dunes (Bruelheide *et al.,* 2003), which are a serious threat to the Qira oasis.

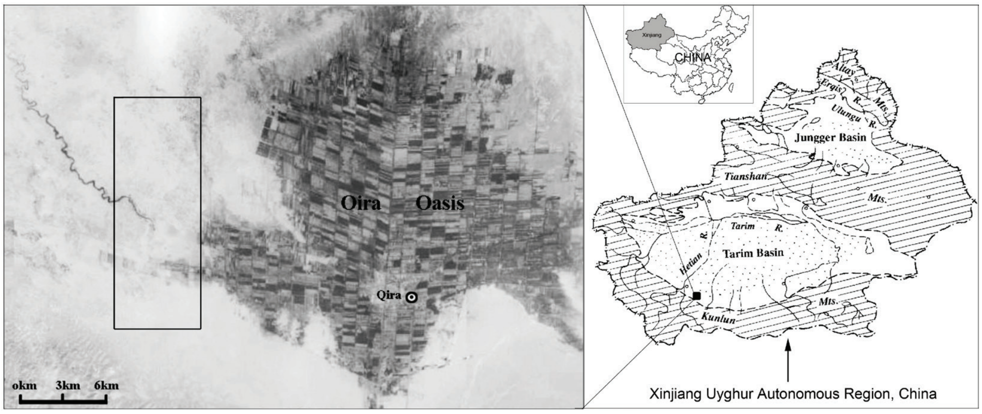

Figure 1. Location of study area.

2.2 Methodology

In the study area, four 100 × 100 m typical plots (plots 1– 4) were selected successively according to the division standard of desertification degree in northern China (Wang, 2003). Plant community structure obviously differed from plot 1 through to plot 4 and the vegetation cover decreased from about 30 % to <5 %, respectively. Plots 1–4 correspond to land with slight, moderate, severe and serious desertification, respectively (Table 1). Four *T. ramosissima* nebkhas and interdune areas were selected for surface erosion and deposition monitoring within the four plots. Nebkha A was located in plot 1 (37°01.337′N, 80°43.249′E) with a length, width and height of 185, 640 and 860 cm, respectively; correspondingly nebkha B was in plot 2 (37°01.115′N, 80°43.189′E) with dimensions of 740, 695 and 147 cm; nebkha C was in plot 3 (37°01.014′N, 80°43.218′E) with dimensions of 860, 640 and 185 cm; and nebkha D was in plot 4 (37°00.922′N, 80°43.142′E) with dimensions of 1205, 870 and 185 cm.

Table 1. Desertification land types and vegetation characteristics in typical plots

Plot number (Land type)	Environmental features description
Plot 1 (Slight desertification land)	Much more flat terrain. Vegetation cover is about 30%. Main constructive species is Alhagi sparsifolia and they distributed uniformly. The shape of Tamarix ramosissima Nebkhas is hemispherical, represent as a sparse distribution.
Plot 2 (Moderate desertification land)	Flat terrain. Vegetation cover is 15~20%. The main constructive species is Alhagi sparsifolia and mainly in contagious distribution. The shape of Tamarix ramosissima Nebkhas is semi-ellipsoid and the density has increased.
Plot 3 (Severe desertification land)	The terrain has a slight fluctuation. Vegetation cover is about 10%. The main constructive species is Tamarix ramosissima. Alhagi sparsifolia and Karelinia caspic are mainly in sparse distribution between Tamarix ramosissima nebkhas. The shape of nebkhas is semi-ellipsoid, some of them with wind shadow.
Plot 4 (Very severe desertification land)	The topographic relief is relatively large. Vegetation cover is <5%. Tamarix ramosissima nebkha form is circular cone with an obvious tail of wind shadow. They are mainly in sparse distribution. There are a lot of wind erosion residual roots exposed in the periphery of Tamarix ramosissima nebkha.

Systematic monitoring of surface wind erosion and deposition was carried out in 2011. Two hundred steel rods were inserted into the ground of the four *T. ramosissima* nebkhas and interdunes uniformly before the end of March, and the exposed height of steel rods was measured. A topographic survey was conducted using morphometry equipment. The steel rods' positions were precisely determined and marked. At the end of October the exposed height of steel rods was again measured and the erosion and deposition thickness of all points calculated by means of D-value of height. Surfer Software was used to draw an erosion and deposition intensity distribution sketch map of the four nebkhas and interdunes in order to analyze the relationship between ground surface change and the spatial variation of soil properties.

Systematic soil sample collection was in November 2011. Based on the main wind direction and distribution of surface erosion and accumulation, every *T. ramosissima* nebkha and its interdune was divided into four parts: under shrub, margin of nebkha, leeward shadow and interdune. The under shrub areas included 5 soil sampling sites; the margin area of nebkhas included 4; the leeward shadow areas included 3; and the interdune areas included 7. A cutting ring with diameter of 50 mm and height of 100 mm was used for taking soil samples. Every soil sample was a mixture of three adjacent samples. A Mastersizer Malvern 2000 Laser Particle Analyzer (particle size 0.02–2000 μm) was used to analyze sample particle size and the method of Folk and Ward (1957) to calculate the grain-size parameters.

3. Results

3.1 Distribution of surface erosion and deposition on nebkhas and interdunes

The distributions of erosion and deposition on *T. ramosissima* nebkhas and interdunes differed in the four plots (Figure 2). The surface of nebkhas and interdunes mainly accumulated sand for plot 1: the cumulative sediment thickness of nebkha A was 0.9 cm on the surface and 1.1 cm on the interdune during whole year. In plot 2, erosion was mainly distributed on the west slope (windward slope) and the peripheral part of nebkha B, with the average wind erosion depth of 1.7 cm and maximum 10.5 cm. The other parts of the nebkha mainly accumulated sand, with average sediment thickness of 1.2 cm and 2.4 cm in the leeward shadow. In plot 3, erosion mainly occurred at the bottom of the west slope of nebkha C and the interdune. The average wind erosion depth was 4.9 cm and the maximum was 13.1 cm. The leeward slope and the nebkha shadow mainly accumulated sand, with average sediment thickness of 1.6 cm and the maximum 4.7 cm. In plot 4, there was a small area of sand accumulation on top of nebkha D, with average sediment thickness of 1.8 cm and the maximum 4.3 cm. The other parts experienced strong wind erosion. Average wind erosion depth for the mid-slope of nebkha D, the periphery and the interdune was 1.7, 5.1 and 5.3 cm, respectively, with a maximum of 24.5 cm. Overall, proceeding from plot 1 through to plot 4, with total vegetation coverage decreasing from 30 to 15–20 to 10 to 5 %, *T. ramosissima* nebkhas and interdunes generally progressed from sediment deposition to wind erosion. With decreased vegetation cover, the wind erosion intensity increased significantly and the area of wind erosion expanded.

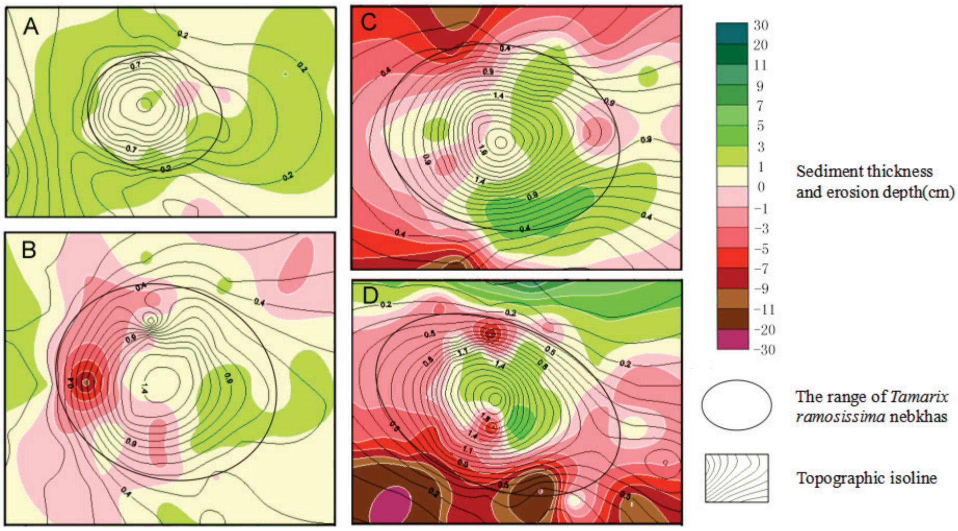

Figure 2. Wind erosion intensity distribution of *Tamarix ramosissima* nebkhas and interdune.

3.2 Various changes in soil grain size

Our investigation showed that the surfaces of nebkhas and interdunes in the four plots were dominated by very fine sand (63–125 μm) (Table 2) with content of 50–60 %, followed by silt (2–63 μm) 20–30 % and fine sand (125–250 μm) 10–20 %. Progressing from plot 1 to plot 4, average contents of very fine sand in the nebkhas were 53.94, 55.61, 59.43 and 52.2 %, respectively; and correspondingly average content of sand was 12.97, 13.29, 19.98 and 18.51 %, and silt content was 33.57, 30.93, 21.81 and 21.85 %. The surface of nebkhas in plot 1 contained 1.25 % clay grains (< 2 μm) but did not contain coarse (500–1000 μm) and medium sand (250–500 μm). In plot 4, there were no clay grains and coarse and medium sand were present. As total vegetation coverage decreased, the surface soil of nebkhas and interdunes gradually coarsened. On the different parts of a single nebkha, fine and very fine sand content of surface soil first increased, and then decreased moving from under shrubs to the nebkha margins, interdunes and leeward shadows. The maximum values of content were mainly from interdunes, while minimum values were mainly under shrubs; however, silt content showed a contrasting rule. With the decrease of the total vegetation cover, grain-size composition differences between each part of nebkhas gradually reduced.

Proceeding from plot 1 through to plot 4, the average particle diameter of surface soil of nebkhas and interdunes was 74.41, 77.28, 86.29 and 92.71 μm, respectively, showing a gradually increasing trend. The corresponding average values of the sorting coefficient were 1.62, 1.56, 1.52 and 1.76, which indicated a good and medium sorting range; the average values of skewness were -0.11, -0.08, -0.07 and 0.09, changing from negative to nearly symmetric. The average values of kurtosis were 1.08, 1.00, 1.02 and 1.24; in addition, nebkhas in plot 4 were of narrow kurtosis, and the other three plots had nebkhas of medium kurtosis, which approximated a normal distribution (Table 3). On a single nebkha, the average values of particle diameter were 76.46, 82.46, 86.08 and 85.69 μm for under shrubs, nebkha margin, interdune and leeward shadow, respectively. The minimum values of particle diameter were mainly from under shrubs, while maximum values

Table 2. Variation of soil grain size in 0-10 cm soil layer at four plots

Soil grain size	Position of nebkhas	Nebkhas			
		Nebkha A Plot 1	**Nebkha B Plot 2**	**Nebkha C Plot 3**	**Nebkha D Plot 4**
Coarse sand (500-1000μm)	U	0.00A	0.00A	0.00A	0.14±1.19bA
	M	0.00B	0.00B	0.00B	4.02±1.56aA
	I	0.00B	0.00B	0.00B	4.88±2.92aA
	L	0.00B	0.00B	0.00B	2.51±2.26abA
Medium sand (250-500μm)	U	0.00A	0.00A	0.00aA	0.40±0.78bA
	M	0.00B	0.00B	0.00aB	3.42±1.26abA
	I	0.00B	0.00B	0.08±0.11aB	4.68±2.40aA
	L	0.00B	0.00B	0.02±0.04aB	3.53±3.34abA
Fine sand (125-250μm)	U	10.83±1.09 bC	12.71±1.25bB	13.41±0.91cB	19.01±1.19aA
	M	11.61±1.50abB	11.71±1.83bB	17.25±3.39bA	20.51±1.56aA
	I	13.32±1.33aC	13.71±1.50 abC	22.55±2.95aA	18.74±2.92aB
	L	12.11±0.28abC	15.04±0.37aB	20.83±1.68abA	21.67±2.26aA
Very fine sand (63-125μm)	U	49.31±1.10cB	52.05±1.57bB	56.04±3.53bA	55.69±1.97aA
	M	52.53±1.93bcBC	56.26±2.13aB	61.18±3.39aA	51.74±1.66abC
	I	57.57±2.60aAB	55.71±2.29aB	60.19±2.09aA	49.79±3.56bC
	L	56.35±3.12abAB	58.41±2.85aA	60.31±0.73aA	51.56±3.35abB
Slit (2-63μm)	U	38.61±1.18aA	35.00±2.37aB	30.05±3.31aC	24.77±2.44aD
	M	35.00±2.68abA	31.60±2.01abA	21.16±6.20bB	20.30±1.95aB
	I	29.11±3.17cA	30.58±2.89bA	17.17±1.83bC	21.59±4.60aB
	L	31.53±3.00bcA	26.56±3.02cAB	18.83±1.1.36bC	20.73±4.56aBC
Clay (<2μm)	U	1.25±0.18aA	0.26±0.57aB	0.50±0.68aB	0.00aB
	M	0.86±0.75aA	0.44±0.76aA	0.40±0.70aA	0.00aA
	I	0.00b	0.00a	0.00b	0.00a
	L	0.00b	0.00a	0.00b	0.00a

Different lowercase letters in the same column indicate significant statistical differences between different parts of the same nebkhas ($P< 0.05$), Different capital letters in the same row indicate significant statistical differences between different nebkhas of the same parts ($P<0.05$). U means Under shrub, M means Margin of nebkha, I means Interdune; L means Leeward shadow. A: Vegetation cover is 30%, B: Vegetation cover is 15~20%, C: Vegetation cover is 10%, D: Vegetation cover is <5%. The same for below.

Table 3. Variation of grain size parameters in 0-10 cm soil layer at four plots

Grain size parameters	Position of nebkhas	Nebkhas			
		Nebkha A Plot 1	**Nebkha B Plot 2**	**Nebkha C Plot 3**	**Nebkha D Plot 4**
Mean (**μm**)	U	69.37 ±1.44cD	74.00 ±2.63cC	77.56 ±3.20cB	84.89 ±2.16bA
	M	73.03±3.29bcC	75.97 ±2.62bcC	85.80 ±6.56bB	95.03 ±4.71abA
	I	78.72 ±2.59aB	77.89 ±2.48abB	92.05 ±3.03aA	95.67 ±9.30aA
	L	76.53±2.08abC	81.26 ±2.11aBC	89.73±1.89abAB	95.25 ±10.76abA
Sorting	U	1.77±0.086aA	1.63±0.065aB	1.59±0.086aB	1.57±0.032bB
	M	1.64±0.062bAB	1.55±0.044bB	1.51±0.080abB	1.79±0.143abA
	I	1.53±0.033cB	1.55±0.033bB	1.49±0.021bB	1.93±0.189aA
	L	1.54±0.042bcB	1.52±0.035bB	1.50±0.010abB	1.75±0.166abA
Skewness	U	-0.195±0.045cB	-0.098±0.050aA	-0.103±0.049bA	-0.052±0.027bA
	M	-0.129±0.053bB	-0.083±0.045aB	-0.086±0.058abB	0.153±0.094aA
	I	-0.061±0.008aB	-0.065±0.016aB	-0.037±0.013aB	0.164±0.107aA
	L	-0.067±0.007aB	-0.058±0.007aB	-0.042±0.009aB	0.104±0.143aA
Kurtosis	U	1.25±0.132aA	1.04±0.104aB	1.05±0.081aB	1.00±0.020bB
	M	1.09±0.092bAB	1.01±0.075aB	1.05±0.106aB	1.32±0.206aA
	I	0.98±0.004bB	0.98±0.009aB	0.98±0.024aB	1.43±0.215aA
	L	0.99±0.002bB	0.98±0.005aB	0.98±0.008aB	1.21±0.193abA

were mainly from interdunes for the four plots. With the decrease of total vegetation cover, the differences in average values of particle diameter among the different parts of nebkhas were significantly weakened. The minimum values of the sorting coefficient were for interdunes in plots 1–3, while maximum values were under shrubs. The soil particles in the interdune showed a good sorting range, while under shrubs had the worst range. However, the pattern in plot 4 was in contrast to this.

Soil probability cumulative grain-size curves showed two modal particles for plots 1–3 (Figure 3): the larger one of about 90 µm and the smaller one of 10 µm. The percentage of smaller modal particles was low, showing different origins of sand. Because the study area was located in the desert–oasis ecotone with some vegetation cover, a part of the suspended load of long-distance transportation subsides due to weakening of wind. The curves also showed that the sorting of larger modal particles of soil was better than for smaller modal particles, which may be related to *in situ* sand transport and sand redistribution under long-term wind action. There were three modal particles of 10, 100 and 500 µm for plot 4, the content of creep particles reached nearly 5 % and the surface composition of the material became coarse. This may be related to the exposure of coarse grains in deeper soil layers due to strong wind erosion or the creep movement of particles from the upwind direction.

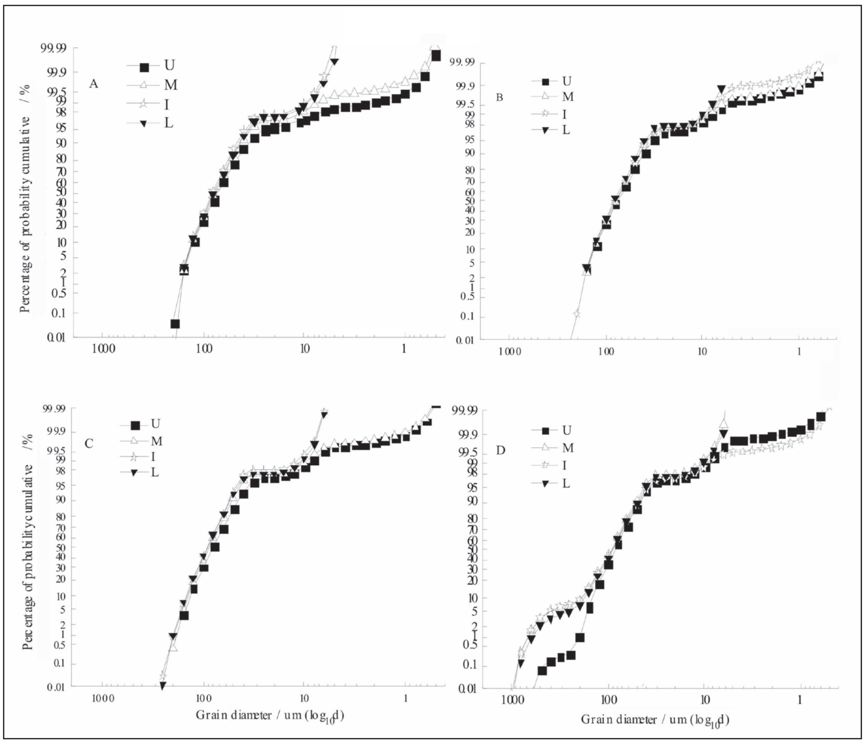

Figure 3. Grain size distribution curves in 0-10 cm soil layer at four plots.

4. Discussion

Vegetation often plays a crucial role in evolution of nebkhas by reducing wind speed and reducing the sand source. These processes can be recorded in the changes in sediment grain size and sorting parameters (Livingstone, 1987). The present study showed that the sand deposition was commonly observed in the plot, with a total of vegetation coverage of 30 %. The existence of clay and silt in the surface soil probably indicates that the high-density vegetation intercepted a considerable part of the suspended material. The material composition with total vegetation coverage of <5 % was generally coarse, and is considered to result from the surface soil being subjected to strong wind erosion and continuous loss of fine material. In the plots with total vegetation coverage of 15–20 and 10 %, there was accumulation of coarse soil in interdunes and enrichment of fine material in nebkha surfaces, which was closely related to redistribution of ground surface soil. In these cases, soil erosion occurred in interdunes and windward slopes while deposition occurred in nebkhas and leeward shadows, and resulted in the fine material in interdunes being constantly blown to under shrubs.

The formation of nebkhas is a result of the far source and near source sediments continuously accumulating around vegetation (Khalaf *et al.,* 1995). The *Tamarix* plants with high and large crowns are widely distributed and their soft assimilating branches can help to capture and deposit some suspended sediment under shrubs. At the same time, the wind–sand activity is relatively strong in the interdune and *in situ* sand grains are mainly in saltation movement, and some of them are blocked under shrubs. Thus, soil particles under shrubs had the worst sorting range, while interdunes had the best range, followed by leeward shadows and nebkha margins. This study also found two modal particles in the study area, with the smaller near 10 μm and belonging to the range of particles with suspended movement. It is inferred that some of the suspended load transported over long distances had settled due to the weakened wind by vegetation. The sorting of larger modal particles was better than for smaller modal particles, which may be the result of *in situ* sand redistribution under long-term wind action.

5. Conclusion

There were different characteristics of surface erosion and deposition in *T. ramosissima* nebkhas and interdunes with different vegetation coverage. The surface of nebkhas and interdunes mainly experienced sand accumulation in the plot with vegetation coverage of 30 %. The nebkha body and leeward shadow mainly experienced sand accumulation, while the interdune was subject to wind erosion when vegetation coverage was 10–20 %. Most of the nebkha surface and the interdune experienced strong wind erosion when vegetation coverage was < 5 %. When the total vegetation coverage decreased, the effect of wind erosion increased. The average particle diameter of the surface soil of nebkhas and interdunes showed a gradually increasing trend. For a single nebkha, the maximum values of average particle diameter were mainly from the interdune while the minimum values were mainly under shrubs, corresponding to the soil erosion in the interdune and deposition on the nebkha surface. With the decrease of total vegetation cover, the differences in average particle diameters between different parts of the nebkha surface were significantly weakened. Only under conditions of appropriate vegetation coverage can *T. ramosissima* nebkhas effectively resist wind erosion and intercept sand flow substances to promote their growth and development. This also improves soil nutrients and creates good living conditions for *T. ramosissima* and for the establishment of other plants. From the perspective of maintaining security of oases, total vegetation coverage should be maintained at least at 10 % in desert–oasis ecotones.

Acknowledgements

This research was funded by the National Natural Science Foundation of China (Grant No. 41371042). We thank all staff at the Qira Station for Desert Stepper Ecosystem Research and Obverstation for their excellent field and lab assistance.

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3. Improving erosion risk management in transboundary river basins for better regional environment: A case study of the Upper Blue Nile River

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Abstract

In the drought-prone Upper Blue Nile River (UBNR) basin of Ethiopia (area = 172 000 km^2), soil erosion by water is widely believed to be the major land degrading agent resulting in both a significant on-site and offsite consequences affecting the countries downstream. However there have been limited systematic studies addressing such a typically diverse agro-ecologic basin, mainly because of insufficient data and lack of adoptable methodologies. We analyzed variability of soil erosion, prioritized erosion-risk areas and proposed management options to minimize the impacts through integrated application of field observation, spatial analysis and modeling. Results show that the basin generates an average soil loss rate of 27.49 (range = 0-200) t ha^{-1} yr^{-1}, with overall soil loss value of about 4.73 × 10^8 t yr^{-1}, of this about 5% comes from gullies and 26.7% leaves the country. Variation in agroecology (average factor score = 1.32) followed by slope (1.28) were the two major factors responsible for this high spatial variability. Soils and land use types each had a relative importance by a factor of about 0.85. About 39% of the basin is experiencing from severe to very severe (> 30 t ha^{-1} yr^{-1}) soil erosion problem and this is strongly linked to the population density. If appropriate soil and water conservation practices targeting about 79% of the moderate to very severe erosion-prone areas (> 15 t ha^{-1} yr^{-1}) are implemented, the total sediment yield from the basin could be reduced by about 62%, that can minimize downstream reservoir siltation, flooding and pollution problems. Strengthening the regional environmental data monitoring programs to improve access to good quality and representative data for detailed planning and research purposes still remains important.

Keywords: Soil erosion, Water conservation practices, Environmental data monitoring

4. Adoption of advanced techniques to improve national resilience to climate change in Lebanon

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Abstract

Lebanon is witnessing extreme climatic variability associated with severe hydrological and agricultural drought. Observation over the last forty years shows an increase in average monthly and average annual temperature by 1.5-2.0 C coupled with a decrease in rainfall by 6% and regression of forest cover. Comparing the Normalized Differential Vegetation Index between 1999 and 2012 showed negative change in 11700 ha of the territory and the occurrence of hot spots in 6000 ha of the Lebanese land. Rainfall pattern and fast snow melting are reported as the two main factors of recurring floods and forest fires. The creation of the early warning platform (SuNaR) at CNRS-Center for Remote Sensing created the potential to build national resilience to adapt to climate change and enhance national preparedness to drought. The platform uses advanced remote sensing tools for the monitoring of water quality, observation and monitoring of land surface temperature, standard precipitation index, vegetation health index, burn severity index and algorithms to map the areas prone to flood and forest fires and provide early warning for prevention and risk management. A temperature-index snowmelt model between 2002 and 2013 using *Tropical Rainfall Measuring Mission* was developed to simulate hydrological processes of surface runoff, groundwater recharge, evapotranspiration, and snow accumulation and melt. Research undertaken at the CNRS is targeting crop reaction to increased temperature and water shortage through the improved agricultural practices. Results show the possibility to improve the resilience of irrigated field crops to high temperature effect and deficit irrigation, revealed by lower canopy temperature, better biomass production and higher water productivity.

Keywords: Climate change, Early warning platform, Water productivity, Remote sensing

1. Introduction

Mediterranean regions are among the most vulnerable to the projected climate change in the 21st century. Recent studies suggest that climate change would have direct impacts on the hydrologic regimes of most Mediterranean river basins. Projected changes are expected to affect both the frequency and magnitude of surface flow, ground water recharge, snow accumulation, and evapotranspiration. The current study calls for the implementation of a basin model that integrates ground measurements and remote sensing data in the evaluation of hydrological processes in Lebanon.

Lebanon is witnessing extreme climatic variability associated with severe hydrological and agricultural drought. Observation over the last forty years shows an increase in average monthly and average annual temperature by 1.5-2.0^{o}C. There is obvious oscillation in the rainfall rate and intensity, but a general decrease in rainfall at about 6-8% exists. This is also attached with the changing hydrological regime due to: 1) the changing rainfall patterns, 2) seasons time-shifting and 3) high daily meteorological diversity.

The geomorphology of Lebanon is different from the surrounding regions in the Middle East, because it composes mountain ridges that extend parallel to the Mediterranean Sea. Thus, the mountainous alignment of Lebanon makes it a climatic barrier that receives cold air masses derived from west and then condensate these masses as rain and snow. Therefore, this elevated region is merely invulnerable to drought from meteorological point of view, but it can be, as the current status, under water scarcity due to fluctuating climatic conditions and increased water demand, notably in the view of mismanagement of water resources.

2. Climatic trends and the development of national resilience to climate change

Based on ground measures and data from remotely sensed products (i.e. TRMM), updated rainfall map of Lebanon was produced and elaborated by CNRS (Figure 1). It shows geographic discrepancy in the rainfall rates over different Lebanese regions (20 stations). The obtained map was based on data from 1950 up to 2013, where gaps also existed. It reveals that some regions in Lebanon experienced decrease in rainfall rate, beside an increase in other regions of the country.

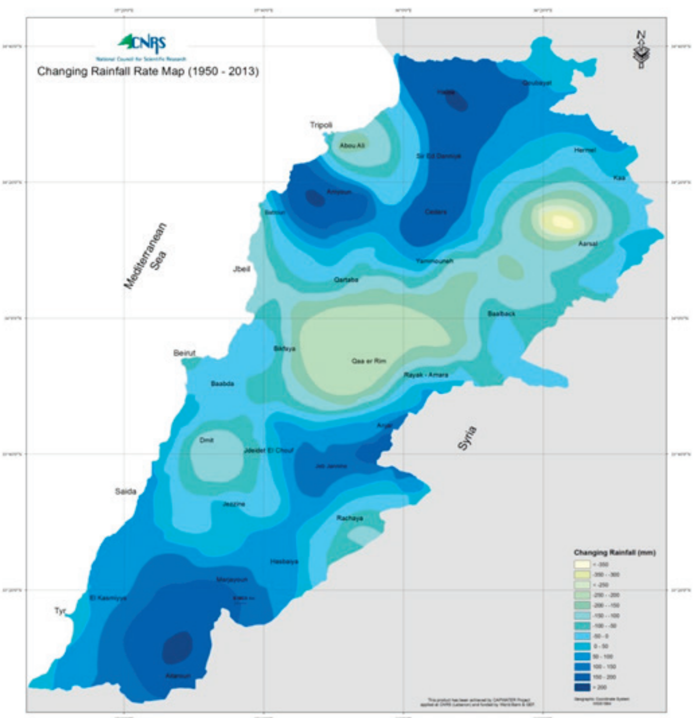

Figure 1. The changing rainfall rates in Lebanon between 1950-2013.

It is a paradox to rank Lebanon's climate among the aridity margins, or describe it as arid or semi-arid region (Shaban and Houhou, 2015). While it has sufficient water resources, and rainfall ranges between 700mm and 1500mm (averaging about 910mm). In addition, there exist several surface and subsurface water sources. Also, Lebanon is the only geographic region in the Middle East where snow cover remains for several months on the mountain chains covering an average area of $2500km^2$. In addition, Lebanon has 12 permanent watercourses (rivers) that discharge water at about 3500 million m^3/year. There are also more than 2000 major springs with an estimated discharge of 1250 million m^3/year, and the renewable groundwater reserve exceeds 1500 million m^3/year (Shaban, 2014).

Along with remotely sensed product analysis, statistical indices are also considered, such as De Martonne indices. An example has been applied on ten representative sites and the western zone of Lebanon. It is also obvious that the irregularity in the climatic conditions in the coastal zone of Lebanon is observed in many stations, more or less, since 1997 which can be presumed as the start-time of the climatic oscillations in Lebanon (Figure 2).

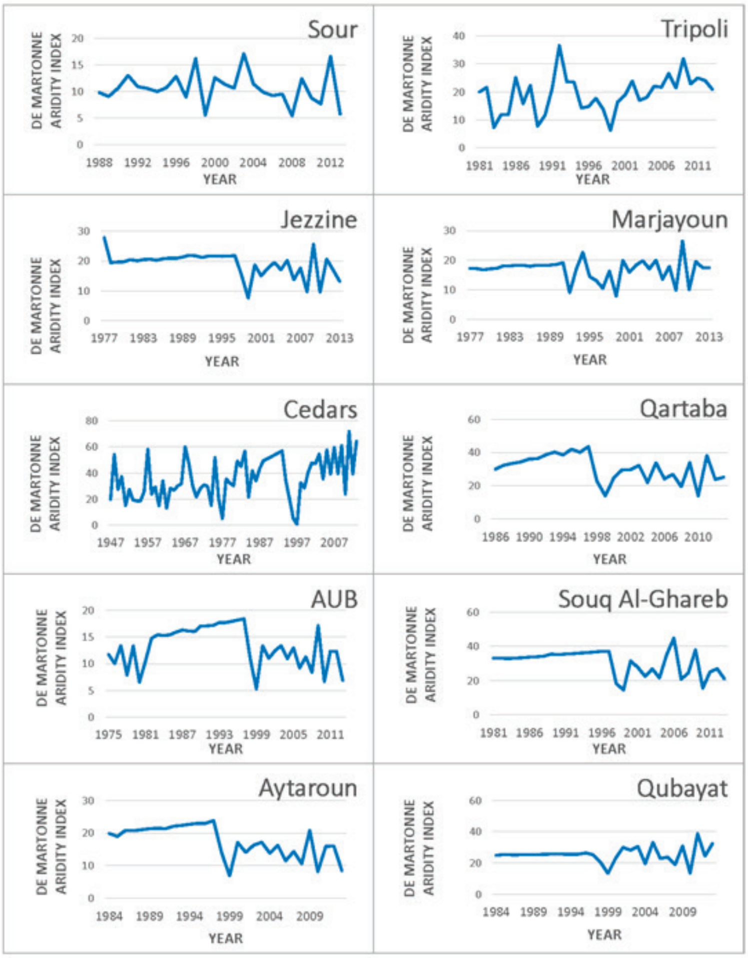

Figure 2. De Martonne aridity index for the investigated years in the coastal zone of Lebanon (Shaban and Houhou, 2015).

Yet, the climatic behaviour in Lebanon is not well demonstrated, and this is accompanied with the misunderstanding of the water cycle as a whole. The reason behind this can be attributed to the oscillating climatic conditions with the lack of complete time-series of meteorological and hydrological data and information. Therefore, several studies exist, but with abrupt discrepancy in results.

Recently, water resources in Lebanon show abrupt decrease in the volume of water in rivers and springs that ranges between 50-60%, fluctuating the discharge/capacity of the major lakes, as well as the rapid reduction of snow cover area due to high sunlight radiation. Therefore, the influenced hydrologic regime has been reflected on groundwater, which shows abrupt decline in volume and water table. Therefore, the misidentification of recurring temporary dry spells as droughts, which implies an extreme abnormal situation, can result in societies becoming maladapted and increasingly vulnerable because of unnecessary asset depletion or inappropriate mitigation measures (Smakhtin and Schipper, 2008).

2.1 Catchment-based modeling approach to evaluate hydrological processes using ground data and remote sensing approaches

This research is motivated by the arguable debate on the availability of ground data needed for the formulation and calibration of hydrological models in the eastern part of the Mediterranean Sea. Remote sensing dataset are introduced and loosely coupled to the model to cross validate the outputs and identify processes that can be spatially mapped using remote sensing approaches. A semi-distributed, two bucket soil moisture model was used to generate the hydrological responses based on a set of physical and time series inputs (Yates *et al.,* 2005). Monthly ground climatologic variables of precipitation and temperature in addition to the TRMM 0.25°× 0.25° data were used. Various national land cover maps, the MODIS yearly land cover data, in addition to a digital elevation model were used to estimate the Runoff Resistance Factor (RRF). Precipitation is partitioned into rainfall, snow, runoff and infiltration depending on temperature, topography and RRF, land cover and crop coefficient, and soil characteristics. Water in the first bucket is partitioned into evapotranspiration (ET), interflow, and deep percolation. The second bucket partitioned water either as base flow or groundwater storage.

The model included a temperature-index snowmelt model, which computes the estimated snow accumulation and snowmelt as function of total precipitation and melting coefficients. The TERRA-AQUA MODIS snow products were combined into a MODIS TAC (Terra-Aqua Combined) using an enhanced statistical method (Hall and Salomonson, 2004). The coarser AMSR-E SWE was combined with the MODIS TAC to generate a downscaled AMSR-E SWE dataset using probability distribution (Mhawej *et al.,* 2014). The model was implemented at major Lebanese River Basins and run at monthly time step between 2002 and 2013 to simulate hydrological processes of surface runoff, groundwater recharge, evapotranspiration, and snow accumulation and melt.

Observed meteorological variables and flow measurements from gauging stations were statistically tested to verify data integrity. Remotely sensed TRMM data (Huffman *et al.,* 2009) were compared to ground observation. The correlation between the observed precipitation and TRMM data at the basin scale was acceptable (raged between 65 and 90% – bias between -20 and -5mm/month) indicating that the TRMM data is appropriate for hydrological modeling when ground data are lacking. An initial set of parameters was developed and applied for each basin. The most sensitive model parameters were then adjusted using an optimization approach. The model performance was assessed using objective functions against observed flow. The general performance rating revealed very good performance over 65% of the basins (PBIAS < ±10; 0.7<NSE <0.85; 0.3 <RSR <0.5; 0.9<R<0.95) and good in the rest of the cases (Nash and Sutcliffe, 1970). Results also revealed that the model performance increased when the snow component was included. The MODIS monthly ET data were validated against the model ET outputs (Mu *et al.,* 2007). Statistical tests indicated good correlation and suggest that spatially mapped ET can be used for estimating ET at the basin scale (average correlation between MODIS and Model ET ranged between 70 and 80% and the PBIAS = ~7.5 and 20%) (Figure 3). The MODIS TAC was validated against ETM+ and revealed an overall overlay of ~85%. The deviation between the remotely sensed and ground measured SWE was ~60mm.

Total annual precipitation ranged between 350 and 1150 mm/year (2000-2013) of which 12-23% was snow contribution. The percent partition between precipitation and evapotranspiration, recharge, and surface runoff were 0.44 (STD = ±0.11), 0.32 (±0.09), and 0.24 (±0.07) respectively (Figure 4). The overall water budget over the entire time period is summarized in Figure 5.

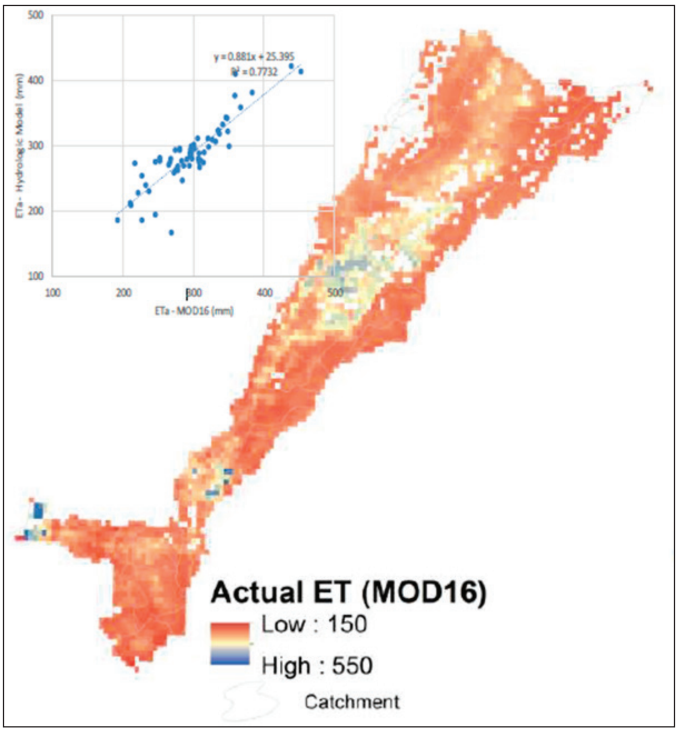

Figure 3. Scatterplot of MOD16 and modeled actual ET– yearly average (2000-2013).

This study demonstrated that the integration of ground measured data and remote sensing approaches may be successfully implemented for the operation of basin scale hydrological processes.

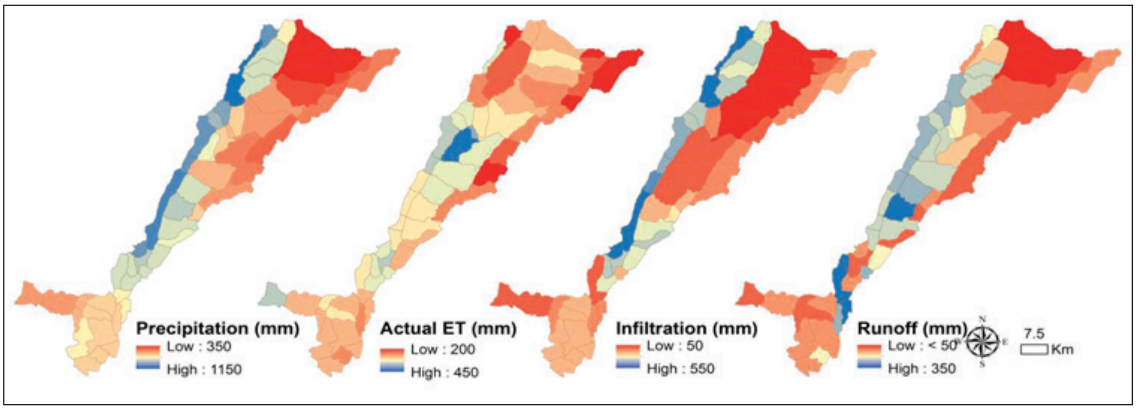

Figure 4. Hydrologic processes at the sub-basin scale of (a) precipitation (combined TRMM and ground based); (b) evapotranspiration; (c) recharge; and (d) surface runoff – yearly average (2000-2013).

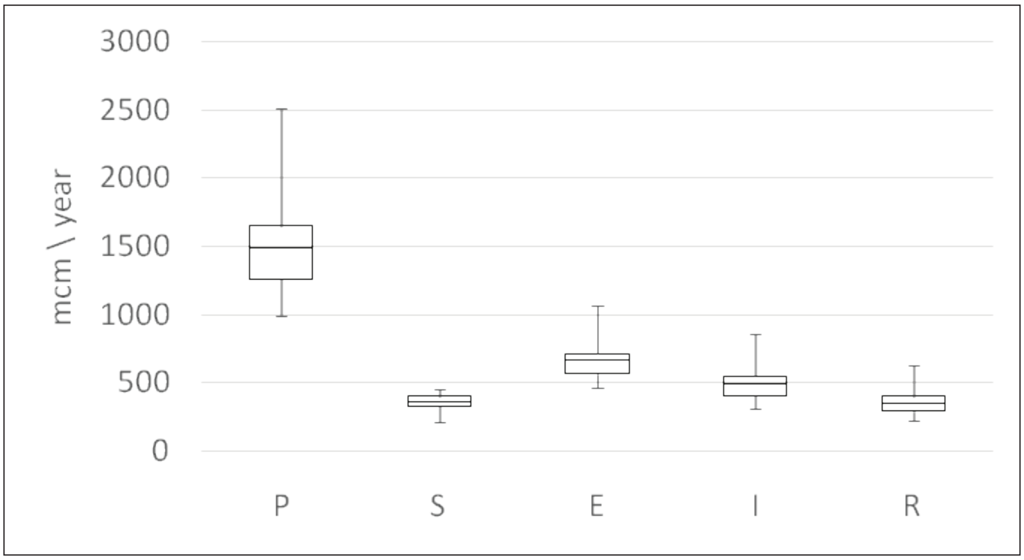

Figure 5. Boxplot of basin hydrologic processes million m^3 (mcm) – yearly average (2000-2013). P is precipitation, S is snow estimates, E modeled ET, I = groundwater recharge, and R = Surface runoff.

This approach not only facilitates the examination of a wider range of hydrological processes, but also provides reliable monthly variations of these processes that would be impossible to investigate using conventional methods at national and regional scales. The proposed methodology is expected to offset the initial high investment cost needed for the implementation of traditional hydrological models.

2.2 Sustainable Natural Resource management platform and early warning system (SuNaR)

With a purpose of testing tailored technology to the Country needs and to provide scientific and technical support in the preparedness and prevention strategies developed by the competent institutions, the CNRS through its Remote Sensing System has established in October 2015 a Sustainable Natural Resources Management Platform (SuNaR) and early warning system.

The SuNaR platform is equipped with skilled experts, hardware and software, internet based satellite receiving station and associated infrastructure for the production and storage of geo-information serving decision making in emergency operations, and to implement proper prevention and preparedness actions, high quality information on water resources, drought, forest fires, floods. The SuNaR platform acquires hydro- meteorological satellite based information from the EUMETSAT network and ground station (LARI & CNRS stations) for forest fires, floods and drought predictions.

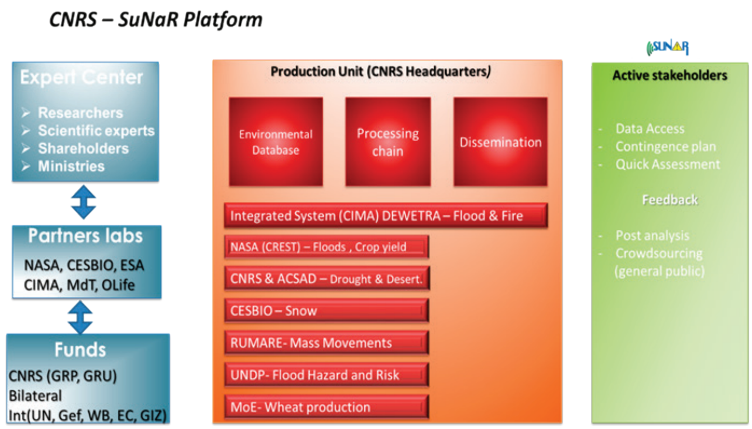

Figure 6. SuNar platform structure.

2.2.1 SuNaR platform: The CNRS's SuNaR early warning system platform is composed of an expertise Center, a production center, and an active stakeholder structure (Figure 6). The expertise located at the Remote Sensing Center in Mansourieh is composed of the scientific body of the CNRS and all other Lebanese scientist in the domain working on developing research tools and algorithms and wish to make their scientific contribution. The Expertise Center is connected with regional and international labs and scientific centers (NASA, CESIBIO, CIMA, etc.) and feeds the production center. The Production Center located at the CNRS headquarters in Bir Hassan is a purely technical body, formed by a team of engineers and technicians. It insures the production and the implementation of the product in an operational way, the production on time of each product with an adapted logging configuration to trace back errors, and to disseminate the products. The production center is comprised of an environmental database and automatic ingestion system, a processing system, and a dissemination system. The Active stakeholders is the portal upon which levels of data access will be given to stakeholders depending on their relation to SuNaR platform i.e. people acting on the ground (DRM unit, Ministries, Civil defense, Police), scientific experts, lab partners, end users, etc. The dissemination structure hosts the crowd sourcing, post analysis, and contingency plans.

***2.2.2 SuNaR graphical web interface*:** SuNaR hardware and software architecture, based on three-tier software technology distributed over separate servers ensures compliance with the requirements of a flexible and reliable Decision Support System. Decision makers are provided with high resolution and up-to-date information of the expected and observed risk through a multi-layer Graphical User Interface (GUI). Through the web server the user has access to remote web services. The main component of the application is a control map, which incorporates facilities and imageries provided by Google® Map. In compliance with the Open Geospatial Consortium, any layer can be remotely or locally added and published as Web Service (WxS)

The SuNaR Interface is designed to easily display forecast and real time monitoring. A user-friendly query system guides the user into the display of information in order to estimate possible future impacts of incoming weather related events.

SuNaR has five control areas, which defines the main functionalities of the system (see A, B, C, D, E in Figure 7). **A**: The Google Maps® engine embedded in SuNaR provides the official worldwide toponym supplied by Google® along with the locations of all Automatic Weather Stations (AWS). **B**: The main upper toolbar provides access to information layers and the functionalities available in SuNaR (Background layers, Dynamic layers, Weather Stations Network, Navigation tools, WMS query, and Measuring tools). **C**: The navigation tree is located on the left side of the SuNaR window. The root nodes of the tree correspond to the dynamic layers in the top panel of the SuNaR window. The layers structure comprises the active layers, along with the "static" offline layers loaded on the Geo-Server (ancillary data, risk assessment, elements at risk). **D**: A set of navigation tools allows users to display information and maps at different scales (zoom) and to navigate on the maps using the pan command. **E**: The time range of the data visualised by SuNaR allows selecting and navigating through the time scale used for the representation of the data. The user can select a time window from a specific date in the past to the present, up to 72 hours from the last run of the system in the future time.

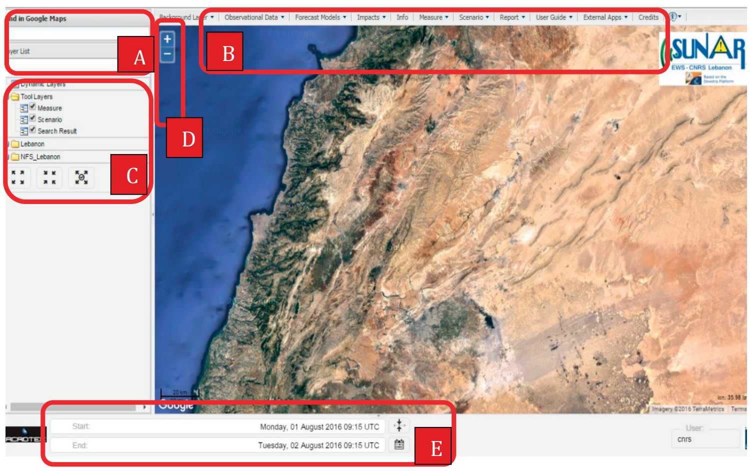

Figure 7. SuNaR graphical web interface.

2.2.3 Earth Observation (EO) data acquisition and integration

Several EO data are acquired from different sources and integrated in the operational chain related to flood, forest fire and droughts forecasting. One of the main sources of EO data is the EUMETSAT Network of Satellite Application Facilities, in particular, the acquired products useful for Land Surface Analysis (LSA-SAF) and the product in Support to Operational Hydrology and Water Management (H-SAF). Most of the Land Surface Analysis products are derived from the geostationary MSG/SEVIRI acquisition. These products are integrated in the SuNaR in order to introduce new information concerning the monitoring phase of natural disasters. Other information is acquired and introduced in the algorithms of the models (RISICO and Continuum) in order to improve the performances of the models. Moreover the Snow Cover Area MODIS daily .product produced by NASA is acquired and used in the flood forecasting chain

2.2.4 Hydrometeorological EO data

The H-SAF products are particularly useful for the hydrometeorological forecasting chain. The H-SAF objective is to provide new satellite-derived products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by mean of the following identified products:

- Precipitation (liquid, solid, rate, accumulated);
- Soil moisture (at large-scale, at local-scale, at surface, in the roots region);
- Snow parameters (detection, cover, melting conditions, water equivalent).
- The products that are acquired and operationally used (visualized on SuNaR and assimilated in the flood and forest fire forecasting chains after the validation experiments) are:
- Soil moisture products: SM OBS 1 - H07, SM OBS 2 - H08, SM DAS 2 - H14
- Precipitation products: PR OBS 3 – H03, PR OBS 5 – H05
- Snow product: SN OBS 1 – H10

All the products are available for the H-SAF area [25-75°N lat, 25°W-45°E long], or globally, in near real time mode and are distributed to end-users via EUMETCast, the EUMETSAT's primary dissemination mechanism for the near real-time delivery of satellite data and products, or from H-SAF FTP server. Table 1 summarizes the main characteristics of each product.

2.2.5 Processing of EO data for Hydro meteorological purposes and use within the SuNaR platform

2.2.5.1 Soil moisture products: The soil moisture satellite products are pre-processed in order to be visualized on the SuNaR platform and to be useful for hydro meteorological forecasting and monitoring. All the original products H07, H08 and H14 are firstly reported on the domain of interest on a regular grid with a geographic step of 0.033°. In particular the Soil Water Index (Wagner et al. 1999) is derived from SM-OBS-1 (H07) product and represent the root zone soil moisture. The root zone is the hydrological-active part of the soil very important for the catchments response to rainfall events. The H14star is derived from SM-DAS-2 (H14) and is normalized to be comparable to SWI extracted from H07. On SuNaR platform will be possible to visualize:

- H14star (derived from SM-DAS-2 H14)
- SWI (derived from SM-OBS-1 H07)
- SM-OBS-2, H08

Table 1. Main characteristics of the satellite products visualized on SuNaR and used in the hydro meteorological forecasting chain to update the Drought, Flood and Dorest fire modules

	Soil moisture			Precipitation		Snow
	H07	**H08**	**H14**	**H03**	**H05**	**H10**
Coverage	Globe	H-SAF area	Globe	Limited H-SAF area	H-SAF area	H-SAF area
Cycle	36 hours	36 hours	Daily	15 min	3 hours	Daily
Resolution	25 km	1 km	25 km	Europe: 8 km	Europe: 8 km	1 to 5 km
Dissemination	EUMETCast	EUMETCast	H-SAF ftp site	EUMETCast	EUMETCast	EUMETCast
Formats	BUFR	lat-lon grid - BUFR	GRIB	fixed grid (Meteosat projection)	GRIB	lat-lon grid

The **H14star** product is created from SM-DAS-2 and provides the saturation degree at different depths (0-7 cm, 0-28 cm, 0-100 cm). It is available every day at 00.00 UTC. The saturation degree is obtained as the weighted mean of the H14 original product (0-7 cm, 7-28 cm, 28-100 cm and 100-289 cm). For each of the three levels the soil moisture data are normalized between 0 and 1 using the minimum and maximum values of each level (the minimum and maximum values were evaluated on a two years period, from January 2012 to December 2013).

The **Soil Water Index (SWI)** product is created using the SM-OBS-1 (H07) product. It represents the saturation degree of the root zone of the soil. The SWI is calculated by applying the filtering methodology developed by Wagner et al., 1999. It depends on a parameter (T), which allows defining the depth of the soil layer in which we want represent the saturation degree: great T values are representative of deeper soils. Everyday at 00.00 UTC the H07 observations of the previous 32 days are considered and the SWI is calculated for three different T values (6, 12 and 32 days). The obtained SWI maps are then rescaled on the climatology of H14star product using a linear rescaling method. This procedure allows having two products (SWI and H14star) that can be directly compared. Three maps will be available on SuNaR platform figure:

- SWI for T=6 days and H14* 0-7 cm
- SWI for T=12 days and H14* 0-29 cm
- SWI for T=32 days and H14* 0-100 cm

The **SM-OBS-2 (H08)** data processing procedure generates a map twice a day: the first at 00.00 UTC results from the combination of all the segments observed by the satellite during the ascending pass, while the second, at 12.00, is relative to the descending pass.

2.2.5.2 Precipitation products: The **PR-OBS-3 (H03)** data processing procedure reads the H03 product values every 15 minutes and generates an instantaneous rainfall map [mm/h] over

H-SAF domain. These maps are then shown on SuNaR platform (Figure 8). The same procedure is applied for the **PR-OBS-5 (H05)** product.

2.2.5.3 Snow products: The **SN-OBS-1 (H10)** product is available daily at 04.00 UTC and provides a Snow Cover Area map, an example of the visualization of the product is shown in figure (CA-3).The **MOD10A1** product of NASA will be downloaded daily, georeferenced and merged and used in the Snow Multidata Mapping and Model (S3M) algorithm to update the Snow Cover Area state.

2.3 Adoption of modern technique to monitor water quality

The regular and continuous monitoring of the environmental status of aquatic ecosystems is essential for their conservation and safe use. Traditional monitoring methods are time consuming and expensive. Modern monitoring systems allow regular and low cost monitoring of the water quality of the freshwater bodies.

Some water quality parameters like chlorophyll, turbidity, phycocyanin and many others can be measured by traditional *in situ* sampling methods coupled with laboratory measurements and analyses. However, these methods are often limited in both time and space, and are expensive and time consuming. Remote sensing can be a key tool for assessing and monitoring water quality in water bodies as it allows frequent surveys over large areas in a cost-effective way. Many studies have affirmed temporal and spatial advantages of remote sensing techniques in monitoring and assessing over traditional monitoring methods (Kabenge *et al.*, 2016; Song *et al.*, 2013; Wu *et al.*, 2013).

Several missions to monitor and capture water quality parameters with high spatial resolution were lunched recently. The parameters include the surface concentration of chlorophyll, harmful algal blooms, suspended materials, colored-dissolved organic matter, and turbidity (or water clarity), giving a clear indication of the health and pollution levels. With the Landsat OLI lunched in 2013 by NASA, water quality can be monitored with a resolution of 30 m and a revisiting time of 16 days. The ESA has also lunched Sentinel-2 mission's (first lunch in 2015), with a spatial resolution of 10 m, 20 m and 60 m and a current visiting time of 10 days (the revisiting time is expected to increase after the new expected lunching, in 2016).

To examine the accuracy of Landsat OLI in estimating chlorophyll-a in Lake Qaraoun, Chlorophyll-a was measured and Landsat OLI images were processed. Chlorophyll-a quantification, used to estimate total phytoplankton biomass, was carried out according to Lorenzen method (Lorenzen, 1967). A duplicate of each sample was filtered using Whatman GF/C filters that were then kept frozen at -20 ºC for 16 h. Chlorophyll-a was extracted from these filters in 90 % acetone by ultrasonication and agitation. The extracts were centrifuged at 3500 rpm for 10 min to reduce the turbidity. About 2 mL were used for chlorophyll-a quantification by spectrophotometry, then a correction was performed by adding 60 µL of 0.1 M HCl to these 2 mL to measure the amount of chlorophyll-a degradation product, pheophytin-a.

Four cloud free images of path 174 and raw 37 are used in this study. These images were downloaded freely from the USGS website http://earthexplorer.usgs.gov/. They are Level 1T processed, meaning that they have undergone systematic terrain calibration and geometric calibration. However, they need radiometric calibration and atmospheric correction to achieve the purpose of chlorophyll-a concentration retrieval. These two procedures are conducted by the ENVI software in this work. Radiometric calibration was performed on all image data used in this work as recommended by the USGS website. An atmospherical correction was then done using FLAASH (Fast Line-of-sight Atmospheric Analysis of Hypercubes) provided by ENVI (Exelis, Boulder, CO) as shown in Figure 8.

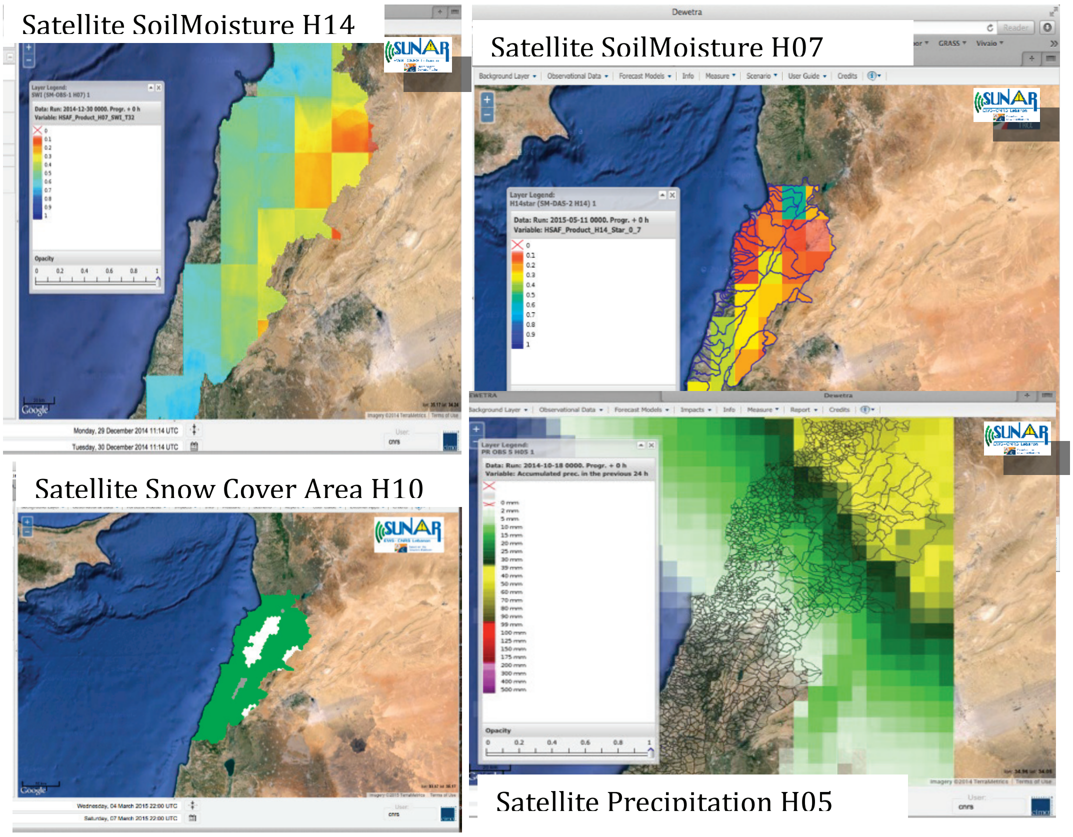

Figure 8. Example of the display of the soil Moisture H14 & H07, Precipitation H05, & Snow Cover Area H10.

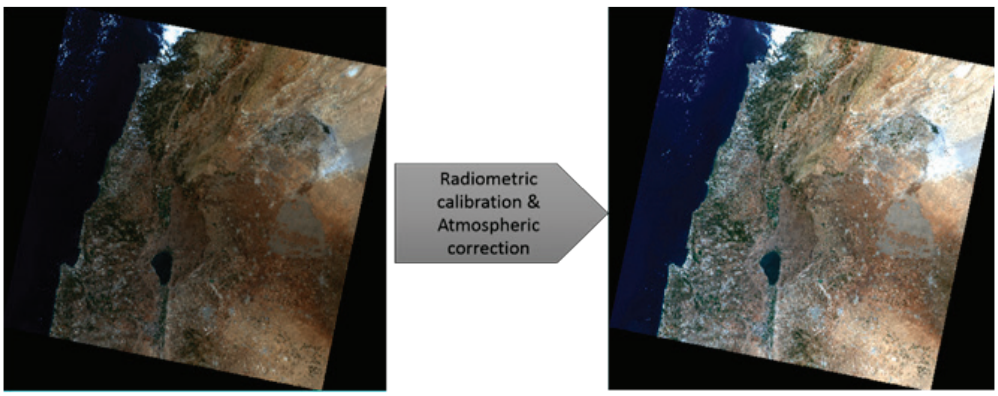

Figure 8. Image processing: radiometric calibration and atmospheric correction.

Linear regression relationships between *in situ* chlorophyll-a concentration and Landsat OLI bands 1-5 was performed in order to determine which Landsat single bands can be used to estimate chlorophyll-a concentration in Karaoun Reservoir. On single band level, the *in situ* chlorophyll-a measurement correlated best with band 5, with R=0.75 and R^2=0.57. Previous investigations (Brezonik *et al.*, 2005; Duan *et al.*, 2007) suggested that band combinations including ratios, multiplication and/or average might provide useful relationships to estimate chlorophyll-a concentration in inland waters. Many tested band combinations showed good correlation with *in situ* chlorophyll-a measurements. However, the best band combination with R=0.85 and R^2=0.72 was obtained for B2:B4 band ratio multiplied with B5 (Figure 9).

The algorithm resulting from the linear regression relationships between *in situ* chlorophyll-a concentration and Landsat OLI was examined on 10 July 2015. As shown in Figure 10, the algorithm estimated correctly the high and heterogeneous distribution of chlorophyll-a during 10 July 2015.

This monitoring approach using Landsat OLI can be transposed and tested on other eutrophic lakes and reservoir throughout the world with different characteristics to verify its efficiency as cost effective method for the monitoring of phytoplankton biomass and other water quality parameters that can give indications of pollution levels.

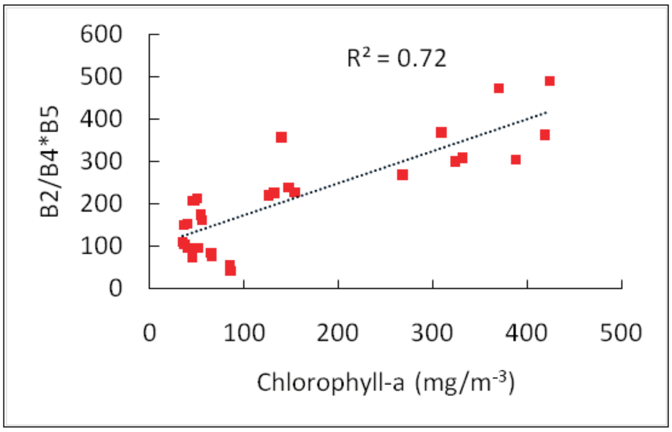

Figure 9. Correlation between in situ chlorophyll-a and best band combination of Landsat OLI, B2/B4*B5, n=29.

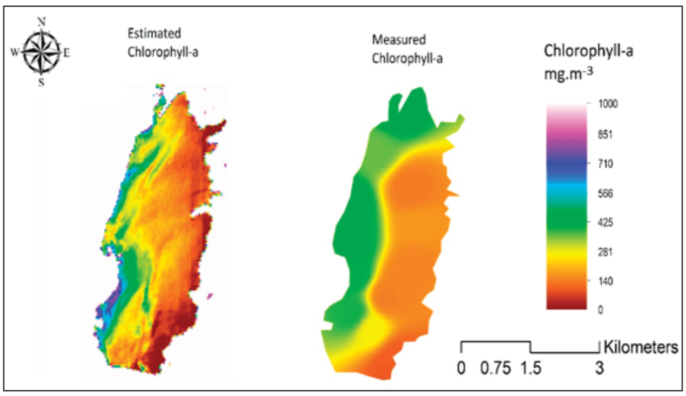

Figure 10. Comparison between measured and estimated chlorophyll-a using Landsat OLI at Lake Qaraoun on 10 July 2015.

2.4 Enhancing field crops performance under restricted water supply through improved management practices

A trial on potato (*Solanum tuberosum* L.) response to three doses of potassium (K) under deficit irrigation was conducted under dry sub-humid conditions in Bekaa plain, Lebanon, between April 8th and July 31st, 2015. Grown on clay, neutral pH, Eutric Fluvisol, table potato crop (cv. 'Spunta') was fertilized at three levels of K: 120 (K_1), 240 (K_2) and 360 kg K_2O ha^{-1} (K_3), tested against a zero-K treatment (K_0). All treatments received equal amounts of nitrogen (150 kg N ha^{-1}) and phosphorus (150 kg P_2O_5 ha^{-1}). The crop, subjected to mild deficit irrigation (85% of evapotranspiration) starting from the shoot development stage, was irrigated with a drip system. Soil moisture was monitored throughout the season by moisture sensors inserted at 25cm and 50 cm soil depth to schedule the irrigation. The crop performance was assessed by measuring canopy temperature and chlorophyll content as a function of the different K applications. The K_3 treatment exhibited higher chlorophyll contents during flowering, tuber initiation and bulking stages (Figure 11).

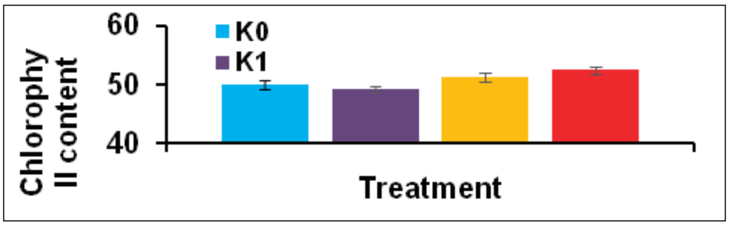

Figure 11. Chlorophyll content (relative arbitrary units) in potato leaves under different K application doses, measured on 24-Jun, at full bloom and tuber initiation. Bars indicate mean of 32 measurements (4 plants, 8 leaves per plant) ±SE.

At midday, the K_3 canopy temperature was the lowest (29.6 °C), compared to K_0 (31.0 °C), indicating facilitated stomata aperture, and consequent carbon exchange rate (Figure 12). These results demonstrate the important role of K in establishing and maintaining carbon translocation from source leaves to sink organs, thus enhancing potato productivity even under moderate drought conditions. The final tuber yield increased significantly from 2.3 in K_0 to 3.3 kg m^{-2} in K_3. The average tuber weight and commercial tuber weight were significantly greater in the K_3 treatment while the tuber dry matter content was unaffected by the application of potassium (Table 2).

Table 2. Fresh tuber yield, number of tubers, average tuber size, average size of commercial tubers (ø >3.5 cm), and tuber dry matter content at full maturity on 30-Jul. Different letters indicate significant differences *($p<0.05$)* within a column

Treatment	Tuber yield	Number of tubers	Average tuber weight	Average commercial tuber weight	Tuber dry matter content
	(kg m^{-2})	Tubers m^{-2}	(g)	(g)	(%)
K_0	2.331 ^{b}	30.9	75.4 ^{b}	119.0 ^{ab}	19.28
K_1	2.741 ^{ab}	34.2	80.1 ^{b}	110.4 ^{b}	19.39
K_2	2.664 ^{ab}	33.0	80.7 ^{b}	122.0 ^{ab}	19.49
K_3	3.305 ^{a}	26.2	126.3^{a}	162.5 ^{a}	19.57

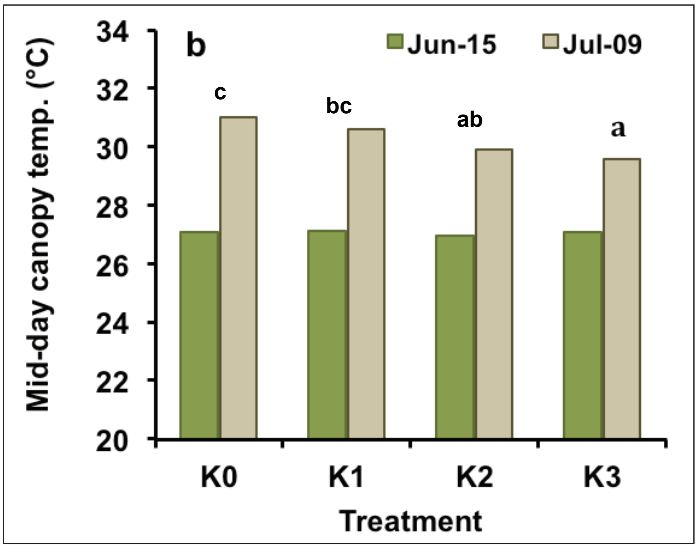

Figure 12. Effect of the potassium level (K1: 120, K2: 240 and K3: 360 kg of K2O ha-1) on potato midday canopy temperature on 15-Jun and 9-Jul. Different letters indicate significant differences ($p<0.05$) on 9-Jul.

Further increase in potato tuber yields should be sought through the distribution of K applications during the season, particularly during the crucial stage of tuber bulking, when K requirements rise. Potassium role in regulating plant water relations in potato should be further examined in order to cope with extreme weather conditions that often occur in semiarid and dry sub-humid regions.

3. Conclusion

In view of the existing unfavorable status in Lebanon, a number of adaptation measures have been adopted to reduce and mitigate the impact of climate change and drought on water resources and agriculture sector. These are applied on two major levels:

- Individual level: This is implemented by consumers to regulate water supply for their needs, notably that water supply from the governmental sector in Lebanon does not exceed 30-40% of demand. The adaptation measures on the individual level include: storage tanks, mountain lakes, proper and more efficient irrigation systems and scheduling, rooftop water harvesting and many other methods to conserve water.
- Institutional level: This is applied by the governmental sector, and it has larger-scale application. It includes adoption of new water policies and legislations, especially in streaming climate change and drought in water strategies of Lebanon. It is also elaborated by executing large-scale water projects, such as dams and lakes, conveying channel and collective irrigation networks.

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5. Diversity and distribution of bacterial species compositions in sand dunes in an Asian dust source area, the Gobi Desert

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Abstract

Microorganisms associated with particles in East Asian desert regions are transported up to atmospheric area and dispersed to downwind environment by Asian dust (Kosa) events. There is a possibility that the transport of microorganisms beneficially and negatively impact ecosystems, human life, and atmospheric processes. However, bacterial communities in dust source regions such as the Gobi Desert have rarely been investigated. In this study, air samples and soil samples were collected from the Gobi desert areas. The microbial communities in soils and airs were analyzed and compared to each other for elucidating the transport process from ground surface to atmosphere. The methods used in this research were DNA extraction, PCR amplification, and purification, then sequencing using MiSeq sequencing approach targeting 16S rRNA genes. MiSeq sequencing approach revealed that bacterial communities in the sand samples were predominantly composed of the phyla Proteobacteria, Actinobacteria, Acidobacteria, and Bacteroides. The members of genus *Sphingomonas*, which are soil bacteria and could be pathogenic to human and plants, occupied most parts of the bacterial communities. Air samples included the families of Micrococcaceae, Bacillaceae, Sphingomonodaceae, Oxalobacteraceae, Bradyrhizobiaceae, Chitinophagaceae, and Cytophagaceae, which were similar to the bacterial compositions in sand samples. These bacterial communities are predicted to disperse to downwind environment during Kosa events. Additionally, we analyzed heavy metals in soil of Gobi desert. We assessed the relationship between bacteria and heavy metal.

Keywords: Microbial communities, Asian dust, Gobi desert, DNA sequencing

6. Practical techniques for desertification control and livelihood improvement in the Sahel, West Africa

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Abstract

Desertification is one of the globally concerned problems with complex phenomena related to land degradation and poverty. Despite great efforts in these decades, the problem still remained unsolved. Under increasing population, desertification is primarily caused by daily subsistence livelihood activities, especially in semi-arid Africa. This is a difficult aspect, since local people have to combat desertification without addressing its underlying causes. Technique should, therefore, be designed to satisfy desertification control and livelihood improvement concurrently. In this presentation, we introduce some of the cases of practical techniques, which were developed together with local people, toward the afforestation site located in agro-pastoral ecotone under 'Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI)'. 'Contour-lines of Andropogon' technique: It combines Zai (planting pit with manure) and Kukokse (line planting), which is an indigenous technique originated in Burkina Faso. It is effective in reducing water-related soil erosion, trapping nutrients and harvesting rain water. It also contributes to household economy, as the harvest of Andropogon from three rows, each 100 meter long and with a total width of 5 meters, is sometimes equivalent to millet grains consumed in one to two months. Modified afforestation technique: Afforestation is one of the commonly practiced activities for desertification control. In our design, tree seedling and crops, such as millet and cowpea, are planted together in Zai. The planting pit collects rainwater, while manure encourages plant growth. The people weed the crops, and, as a result, the growth of the tree improves. Shallow tillage with animal-driven tools: Shallow tillage of soil using an animal-driven harrow, an indigenous farming tool in India, encourages infiltration of rain water to soil and, thus, improves the growth of grasses and trees. Degraded grassland, dominant in the Sahel, may be converted into productive field with this practice.

Keywords: Desertification control, Livelihood, Semi-arid Africa, Agropastoral ecotone, Afforestation

7. Monitoring aeolian erodibility using synoptic data for preparedness of dust hazard

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Abstract

A dust storm is a hazard, which leads to deaths and missing of human beings and animals, and destructions of infrastructures, etc. A dust haze is also a hazard, which causes harmful health effects. One effective way to prevent such damages is evacuation utilizing an early warning system (EWS). However, the accuracy of numerical dust models, which are employed in many EWSs, is currently insufficient. An occurrence of sand-dust storm depends on the relationship between aeolian erosivity and erodibility. Erosivity is the ability of the wind to cause a sand-dust storm, and it is typically expressed by friction velocity, or simply by wind speed alone. Erodibility is characterized as the susceptibility of a surface to a sand-dust storm, which is influenced by soil and land surface characteristics, particularly the soil particle size distribution, soil water content, vegetation coverage, soil crust, snow cover, etc. Threshold wind speed (TWS) for sand-dust storm is often employed as an index of erodibility, but we have no wide area monitoring system for TWS like surface wind speed monitoring system operating over the WMO synoptic observation network. Many researchers have tried to estimate TWS from erodibility factors. However, monitoring a multitude of erodibility factors is very difficult, and our understandings about the relation between erodibility factors and TWS are insufficient. Therefore, the accuracy of current EWS is still low. We propose a statistically estimated TWS as an index of erodibility, which is calculated from wind speed and present weather observed at meteorological observatories. For an observation that dust occurrence frequency (DOF) increased at many stations in East Asia on April from the 1990s to the 2000s, we discuss its reason in this paper through the results of strong wind frequency (SWF) and TWS, which are indices of erosivity and erodibility, respectively.

Keywords: Dust storm, Dust models, Threshold wind speed, Aeolian erodibility

Theme 6. Biodiversity conservation

1. Weed management activities and their relation to biodiversity conservation and combating desertification

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Abstract

Desertification and biodiversity situations change from year to year and place to place in most of the drylands, depending on the natural factors and human activities. Agriculture is one of the main human activities in drylands but weed control is not always a priority for some landowners. Weeds use many of the limited dryland resources needed for crop plants growth, depriving the crops of those resources. Weed management can limit this deleterious effect of weeds. The weed management methods have some negative and some positive effects on both desertification and biodiversity depending on their type, and time of application. Overgrazing, deep tillage (over cultivation) and herbicides are not suitable methods of weed control in dry land framing. A combination of mechanical and culture methods can successfully reduce weed pressure. Soil moisture being the most limiting factor, weed control method that conserves soil moisture will help dryland agriculture. Application of mulches and conservative tillage can reduce soil evaporation losses while also suppressing weed growth and preventing soil erosion. Generally, crop varieties and many types of weeds support drylands biodiversity. However, invasive weed species are one of the main threats to biodiversity, especially under climate changes. All the forces controlling desertification and biodiversity loss such as agroclimatic hazards and natural resource management as well as organized human activities should be understood to design proper management. Desertification can be remedied through sustainable agricultural practices and the suitable integrated control activities starting from preventive methods during seed bed preparation and minimum tillage or conservative tillage with protection of marginal lands as well as organic mulch and hand weeding during the growing seasons.

Keywords: Drylands, Weeds control, Drought, Soil erosion, Biodiversity, Desertification

2. Spatial-temporal variation characteristics of NPP in the Heihe River Basin, Notherwestern China in a recent 10 year period calculated by CASA Model

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Abstract

In this paper, the spatial-temporal variation characteristics of NPP and related factors in the Heihe River basin were analyzed using the meteorological data of the Heihe River basin, SPOT/ NDVI data, and other modified mathematical statistical methods. The results show that during the 1999-2010 period the total NPP in the Heihe River basin exhibited a fluctuating increasing trend, reaching 0.3×10^{12} gC/a. The multiyear variation value of NPP was 0.19~601.09 gC/m^2 in the whole basin, 3.5gC/m^2 in the upper reaches, 2.06 gC/m^2 in the middle reaches, and 0.31 g/ m^2 in the lower reaches. The NPP of vegetation during January and February tended to slightly decrease, and on average varied between -0.01 and -0.02 gC/m^2, while in June, July, August, and September it greatly increased. The NPP of 10 vegetation types exhibited an increasing trend in 2010 compared to 1999; on average, it increased by 21.02gC/m^2. Among various vegetation types, the increase in the NPP value of swamp vegetation was the largest, reaching 46.24gC/m^2 followed by planted vegetation, steppe types, and meadow types; their values were 39.22gC/m^2, 32.49gC/m^2 and 27.63gC/m^2, respectively. The accumulated NPP in grassland ecosystem was the largest, which is of important significance to the eco-environment of the basin. As viewed for the whole Heihe River basin, the yearly mean cumulative value of NPP of vegetation was negatively related to annual mean temperature and annual total solar radiation but positively related to annual total precipitation, suggesting that water is a limiting factor to the NPP in the Heihe River basin.

Keywords: NPP, NDVI, Climate changes, Eco-environment, Heihe River basin

3. The effect of grazing exclosure on plant community diversity and structure in arid Mediterranean steppe of Algeria

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Abstract

Desertification is a worldwide concern; in Algeria, land degradation threatens more than 20 millions ha of steppe rangelands. Protection from grazing is a technique widely used for the development of the steppes. The aim of this study is to investigate the effect of grazing on plant community diversity and structure. We compared alpha and beta diversities using the Hill Index between grazed and ungrazed areas, and used the additive partitioning of beta diversity to test whether the difference in plant species composition is due to species spatial turnover or nestedness. In addition, we assessed soil surface conditions; vegetation, litter, bare ground, biological soil crusts and *Stipa tenacissima* cover. For alpha diversity, grazing reduced significantly the diversity of the annual species; however, perennials were not affected significantly. The results revealed a significant compositional difference between grazed and ungrazed areas. Essentially, the additive partitioning of beta diversity indicated that ~74% of the overall beta diversity was due to species turnover and ~26% was due to nestedness. Grazing activity reduced values of the vegetation cover, and the cover of the most dominant species (*Stipa tenacissima)*, was not affected by grazing. Nevertheless, the protection from grazing increased significantly the species diversity, and vegetation cover. This study highlights the importance of protection and conservation for maintaining the plant community structure and diversity in threatened ecosystems.

Keywords: Arid Mediterranean steppe, Degradation, Grazing, Diversity and structure, Species turnover, Conservation

Theme 7. Sustainable management of productivity of rangeland and livestock in dry areas

1. Tolerance of desert sheep and goats to environmental stress, in association with their production and reproduction performance

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Abstract

The negative relationship between the tolerance to environmental stress and the production performance of animals is a serious problem for the livestock breeders in hot dry arid areas. Desert Barki sheep and goats raised in the Coastal Zone of Western Desert, Egypt (457 sheep and 276 goats) were grazed for a distance of 7 km under direct solar radiation on poor pasture in July and August. Individual response to environmental stress (thermal, respiratory and metabolic traits) was measured before and after exposure and animal heat tolerance index was developed. The studied production traits were body weight at weaning, yearling and at exposure, and at fecundity. Light desert lambs at weaning seem to be more sensitive to environmental stress under arid conditions, while heavy lambs at yearling seem to have difficulty thereafter in facing environmental stress of walking long distance under heat stress on poor pasture. Desert goats did not show detectable relationship between their body weight and physiological response to environmental stress. For breeding purpose, it seems that there is no antagonism between selection for tolerance to environmental stress in desert Barki sheep and goats, and selection for their production and reproduction performances under hot dry conditions. However, it is recommended to avoid exposing heavy desert sheep at yearling and light lambs at weaning to environmental stress. The small sized desert Barki goats coped better with the environmental stress under hot dry conditions than desert sheep, without detectable effect on their production and reproduction performance.

Keywords: Barki sheep & goats, Environmental stress tolerance, Heat tolerance index

2. Studies on intercropping systems of some annual salt tolerant forage crops among saltbush shrubs (*Atriplex nummularia* L.) under Sinai saline conditions

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Abstract

South Sinai agro-ecosystems are characterized by hyper arid climate and salt affected soils where saline underground water is the main source of irrigation. The study was conducted to investigate growth traits of winter fodder crops (barley & fodder beet) and summer crops (guar & millet plants) cultivated among saltbush shrubs (*Atriplex nummularia* L.) as affected by intercropping patterns. Biological role of saltbush in soil reclamation was also studied. Two experiments were conducted under saline conditions of South Sinai Research Station, South Sinai Governorate. Twelve treatments, i.e. the combination between two plant spacing systems among saltbush with six intercropping patterns of saltbush, barley and fodder beet as pure stands in winter season. In summer season, guar and millet plants replaced barley and fodder beet for intercropping with the saltbush. The treatments were arranged in a split plot design with four replications. Plants were irrigated using drip irrigation saline water. Mechanical and chemical properties of the soil and chemical analysis of underground irrigation water were determined. Fresh and dry weights, plant height and total yields for winter and summer crops as affected by intercropping in saltbush were recorded. The results indicated that intercropping fodder beet with saltbush significantly increased fresh and dry yields as compared with fodder beet as a pure stand. In summer season, intercropping pearl millet with saltbush showed the highest significant values for fresh and dry yields. Narrow spacing (2.0 m) between *Atriplex* shrubs surpassed the wide spacing (4.0 m) in increasing total winter and summer forage production. It is concluded that inter-planting summer fodder crops (guar and pearl millet) or winter crops (barley and fodder beet) among saltbush, using saline water resources, may provide great forage biomass and nutritious feed materials for small ruminants under saline conditions of Sinai, Egypt to provide high quality feeds all year round, particularly during dry seasons.

Keywords: Winter and summer fodder crops, Salt bush (*Atriplex nummularia* L.), Intercropping

3. Effect of alfalfa hay feeding on energy utilization of Simmental beef cattle kept in Gansu province, China

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Abstract

Gansu province is a major beef cattle production area of China. Drastic and rapid transformation of cattle feeding system is being achieved in the region. The establishment of the feeding regimen allowing moving from conventional grazing to tie-feeding under confined condition is needed. The objective of this work is to determine the effect of the replacement of concentrate (C) with alfalfa hay (AH) on body weight (BW) gain and energy utilization of growing Simmental cattle in Gansu province. Feeding and respiratory trials were conducted using growing Simmental bulls aiming at 1 kg daily gain (DG) in summer and autumn. The animals were allocated to three treatments: 1) control fed experimental diet comprising of corn stover (CS) and C; 2) replacing 10% of C with AH and 3) replacing 20% of C with AH in one-way layout design. Daily feed intake (DMI) and BW were measured during 21 days of feeding trial. The amounts of O_2 consumption, and CO_2 and CH_4 emissions were measured for 2 days of respiration trial following 3 days of adaptation to open-circuit respiration chambers. Heat production (HP) and energy metabolic rate of the animals were estimated in both seasons. Results showed that the DG value was greater for treatment 2 or 3 groups than that of control group in autumn, and was no significant difference between treatment 2 and control group in summer. Energy metabolic rate appeared to decrease along with the increase of DMI in autumn, and treatment 3 in summer led to DG decline without significant difference in DMI among the treatments. HP values of all the autumn treatments were greater than those in summer. It is concluded that the dietary substitution rate of AH may not affect DMI, however greater amount of AH allowance may not improve feed efficiency of growing beef cattle in Gansu province.

Keywords: Simmental cattle, Energy metabolism, Conventional grazing, Tie feeding

4. Potential of spineless cactus and lathyrus for fodder in semi-arid central India

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Abstract

The semiarid region of central India is complex, diverse, rainfed, vulnerable, socio-economically heterogeneous, agrarian and backward relative to other regions. In addition, extreme weather conditions, like droughts, short-term rain and flooding in fields add to the uncertainties and seasonal migrations. Crop production and livestock rearing contribute 90% to the farm income, crop residue provides 67% of the animal fodder and failure of rains causes distress. Inclusion of drought resilient species like *Opuntia* (cactus) and *Lathyrus* (grass pea) into the cropping/ farming systems of this region may reduce the vulnerability and add to the fodder security to livestock. Keeping this in view ICARDA-IGFRI collaborative project was initiated to utilize the *Opuntia* and *Lathyrus* species as an alternate source of feed and fodder in different land use management systems and enabling the stakeholders to increase the agricultural production and profitability in the dry areas. In total, 15 accessions of *Opuntia* were received from ICARDA and are being evaluated at IGFRI Central Research Farm for their establishment, survival, growth, biomass yield and quality. Among the different accessions, 'Yellow San Cono' and 'White Rocca Palumba' performed better with 100% survival and average pad length and width of 32 cm and 15 cm, respectively. The selected accessions are being grown under different land use systems (degraded lands, silvipasture, rainfed food-fodder system as alleys) at on station and on farm to supplement the fodder requirement of dry areas. In case of grass pea, the use of varieties 'Ratan' and 'Nirmal' with low ODAP (0.07% and 0.20 %, respectively) with complete package (seed treatment, use of *Rhizobium* culture, seed priming as agronomic practices and the utilization of grasspea in animal ration) is being scaled up (45 ha area with 240 farmers) in Bundelkhand region of Central India. The results of feeding trials in sheep indicated that grass pea grains in the concentrate mixture had no adverse effect on roughage intake, nitrogen balance, rumen fermentation and growth performance of lambs. Grass pea grain can completely substitute groundnut cake as protein source in concentrate mixture of growing Jalauni lambs with reduced cost (15%). The past three years R&D experience of cactus and grass pea in central part of semi-arid India indicates that these species have adequate potential in reducing fodder and feed crisis in dry and drought prone areas and sustaining livestock production of small and marginal farmers.

Keywords: Drought tolerant forages, Grass pea, *Opuntia* sp., Sheep feeding

Introduction

Semi-arid central India, mostly comprising Bundelkhand, is the most backward region of India and already suffering from natural resource degradation, absolute poverty, very low crop productivity (1-1.5 Mg/ha), low rain water use efficiency (35-45 %), high erosion, poor soil fertility, scarce ground water resource, erratic rainfall, frequent droughts, heavy biotic pressure, frequent crop failures resulting in scarcity of food, fodder and fuel and high migration (Palsaniya *et al.,* 2008, 2010a, 2012a and 2012b). The rainfall of area had already decreased (for example, by 319.5 mm over the period of 76 years from 1068.4 mm with the rate of 4.2 mm/year at Jhansi) and frequency of droughts increased (out of last 15 years, 9 years experienced moderate to disastrous drought) in recent past (Palsaniya *et al*., 2016). Acute shortage of fodder, *Annapratha* (letting animals loose and unattended during the crops season) and distress sale of animals is frequently reported from the region (Palsaniya *et al.,* 2010b). Under such condition, it becomes inevitable to identify and introduce alternative fodder crops especially for marginal and unutilized lands and land use systems of Bundelkhand region for sustaining livestock productivity.

Spineless cactus (*Opuntia ficus-indica* (L) Mill) is a succulent and drought resilient xerophytic plant of multiple benefits to both man and animals especially under stress condition (Felker *et al.*, 1997). Low water requirement, high regeneration capacity, wider adaptation to soil types and harsh climates make cactus a suitable candidate to incorporate into productive forage based systems under such conditions (Sunil Kumar *et al.*, 2016). Moreover, it has higher carrying capacity than any other drought tolerant fodder in extreme arid and semi-arid areas and remains green and succulent during drought, thus capable of supplying the much needed energy, water and vitamins to livestock during drought periods.

Grass pea (*Lathyrus* spp.) is a very popular crop in many Asian and African countries where it is grown either for livestock feed or human consumption. The most important trait of grass pea consists of its drought tolerance and adaptability to diverse climatic conditions. In spite of the importance of grass pea for human and livestock, the crop has limited uses due to the presence of neurotoxic compound β-ODAP in seeds and plant parts, which causes Lathyrism in human beings and animals.

Under the uncertain situations of rains both in normal and marginal lands, non-conventional forage crops provide a viable option by providing high biomass to livestock's of poor farmers. Therefore, keeping above facts in view, ICARDA-IGFRI collaborative project was initiated to find out the potential of *Opuntia* and *Lathyrus* species as an alternate source of feed and fodder in dry areas of semi arid central India. The project envisages building a strong foundation through utilization of conventional and non-conventional fodder resources for crop diversification and development in semi-arid regions of India for better livestock productivity with supported and improved livelihood activities in prevailing mixed farming situations.

Methodology

As a part of this programme IGFRI received 15 *Opuntia* accessions from ICARDA in April, 2013. Theses accessions were 'Yellow Rocca Palumba', 'Trunzara Red Bronte', 'Yellow San cono', 'Algerian', 'Yellow Santa Margherita Belice', 'Zastron', 'Red Rocca Palumba', 'White Rocca Palumba', 'Red San Cono', 'White San Cono', 'Seedless Rocca Palumba', 'Morado', 'Roly poly', 'White S cono' and 'Blue Motto'. Similarly, Lathyrus was also obtained from ICARDA. These were multiplied and used for feeding trials at IGFRI research farm. Fresh *Opuntia* cladode samples were collected from fifteen accessions, chaffed and dried at 60^0C till constant weight. Dried cladodes were ground and analyzed for crude protein (AOAC, 2000) and cell wall constituents (Van Soest *et al*., 1991). *In vitro* dry matter digestibility (IVDMD) was determined using the standard method (Tilley and Terry, 1963) by incubating 0.5 g sample in 50 ml digestion solution (40 ml of CO_2 saturated phosphate carbonate buffer and 10 ml strained sheep rumen liquor. Cactus and lathyrus feeding trials were also conducted to find out their suitability as animal feed.

Results

Cactus

After planting in nursery for multiplication in three blocks, survival percentage was recorded in all the accessions. Yellow San cono and White Rocca Palumba survived 100% while others 30-80% (Table 1). The data revealed that Yellow Rocca Palumba, Trunzara Red Bronte and Yellow San Cono attained an average length of pads 32-33 cm and width 15cm. The moisture content was maximum with Yellow San Cono (97.1%) followed by Zastron (96.41%) and Trunzara Red Bronte (96.33%). By and large, the moisture percentage in cladodes ranged from 93.0-97.0%. It is also clear from the data, average green biomass yield was highest in Yellow S cono (48 kg/plant/annum) followed by Algerian (46.6 kg/plant/annum), and Zastron (46.5 kg/plant/annum), while the lowest yield was recorded under Roly Poly (15.3 kg/plant/annum) and Blue motto (16.4 kg/plant/annum). Crude protein (%) in cladodes ranged from 9-13 percent and was very low in NDF and ADF content which ranged from 31-40 and 17-23 percent respectively. This indicates the suitability of material to be used in arid and semi-arid region to cover the demand of water and nutrition required by livestock, up to some extent. The best performing cactus accessions will be tested in different land use systems like degraded land, silvipasture blocks, rainfed food-fodder based system and will also be evaluated for sustaining the targeted livestock population which includes small and marginal farmers of semi-arid region of India.

Cactus feeding trial

The average *in vitro* DM digestibility of all 15 accessions of opuntia was 66.29 percent ranging from 54.84 to 76.31 percent. The results of feeding trial conducted on opuntia fed in conjunction with various dry forages (Egyptian clover straw, gram straw and lathyrus straw) and green napier grass have shown that animal relished the opuntia. The DM intake and its digestibility were appreciable on opuntia based diets (Table 2). However, on sole feeding of opuntia, incidence of inconsistence faeces and lose of body weight in sheep were invariable noticed. Hence sole feeding of opuntia to any class of livestock is not advisable.

Lathyrus feeding trial

The purpose of this study was to determine the nutrient utilization and growth performance of sheep fed grass pea hay based diet and to compare its feeding value to Berseem hay (*Trifolium alexandrinum*), a conventional legume fed to livestock in India.

Table 1. Survival, growth and yield of *Opuntia* cladodes planted in nursery for multiplication

SNo.	Accession name	Survival %	Average length (cm)	Average width (cm)	CP (%)	Average yield (kg/plant/year)
1	Yellow Rocca Palumba	40	28.5	15.25	10.59	22.4
2	Trunzara Red Bronte	80	33	15	9.58	20.8
3	Yellow San cono	100	32	15	11.34	48.0
4	Algerian	60	28.5	12.25	10.65	46.6
5	Yellow Santa Margherita Belice	60	25.5	15.5	13.08	43.6
6	Zastron	40	33.5	12	9.77	46.5
7	Red Rocca Palumba	33	27.5	14.25	11.46	20.0
8	White Rocca Palumba	100	26.75	13	10.82	43.7
9	Red San Cono	30	25	13.5	10.13	29.8
10	White San Cono	50	27	12	10.47	25.2
11	Seedless Rocca Palumba	100	25.5	10.25	9.95	18.0
12	Morado	66.7	27.75	14.75	11.00	20.0
13	Roly poly	66.7	34.5	14.25	9.06	15.3
14	White S cono	33.3	28.5	13.75	11.65	23.2
15	Blue Motto	33.3	24	10.25	11.30	16.4

Table 2. Effect of replacement of 1/3rd dietary DM through *Opuntia*, on DM intake and digestibility in sheep (n=8 in each group)

Experimental group	DM intake (% of body weight)	DM intake (g/kg $W^{0.75}$ of body weight)	DM digestibility (%)
Opuntia* + Green Napier	3.39	79.32	61.49
Opuntia* + Berssem hay	4.15	100.11	62.00
Opuntia* + Lathyrus straw	4.35	101.71	60.09
Opuntia* + gram straw	3.45	82.24	55.95

*1/3rd dietary DM was replaced through opuntia

Eighteen growing 'Jalauni' lambs of live weight (15.46 ±0.57 kg) were divided in to three groups of six animals in each. Animals of G1 (control) was fed berseem hay *ad libitum* as basal roughage whereas in the diet of G2 and G3, berseem hay was replaced with grass pea hay @50% and 100%, respectively. All the groups received 200 g crushed maize grain daily for 90 days. At the middle of the experimental feeding, a digestion cum metabolism trial was conducted for 7 days.

DM intake (kg per 100 kg live weight and g per kg $W^{0.75}$) was comparable among the groups. Digestibility of nutrients viz., DM, OM, CP, NDF, ADF was not significantly different among the groups (Table 3). Digestible crude protein (DCP) intake (g/d) ranged from 64.68±4.22 in G2 to 68.00±3.01 in G3. Total digestible nutrients (TDN) intake (g/d) was also comparable among the groups. Nutrient content (%) in terms of DCP and TDN were 8.64±0.56 and 62.89±1.73, 8.42±0.73 and 62.89±0.64, 9.03±0.24and 64.63±0.63, respectively in different diets. Daily live weight gain (g/d) was 84.10±3.59 in G1, 83.53±4.30 in G2 and 86.05±3.77 in G3, respectively. No adverse effect on feeding grass pea hay on body condition was observed in experimental lambs. It was concluded that nutrient intake and utilization and growth performance were comparable in Jalauni lambs fed either berseem hay or grass pea hay based diet and grass pea hay could safely be incorporated in small ruminants' diet without any adverse effect on body condition.

Table 3. Nutrient intake and utilization in *Jalauni* lambs fed grass pea hay based diet

Parameters	G_1	G_2	G_3	SEM	P value
Body weight (kg)	20.13	20.25	19.45	-	-
DMI(g/d)	779	775	752	28.61	0.787
DMI% BW	3.87	3.84	3.86	0.18	0.993
CPI (g/d)	114.21	111.76	109.91	3.95	0.749
TDNI (g/d)	488	487	486	17.09	0.993
DCPI(g/d)	67.1	64.68	68	3.79	0.819
Digestibility coefficients (%)					
DM	66.29	65.27	64.28	1.3	0.568
OM	67.75	66.33	65.96	1.24	0.582
CP	58.88	59.32	60.78	3.84	0.935
NDF	53.95	54.32	50.76	1.87	0.377
ADF	54.83	54.1	56.2	1.68	0.68
EE	64.6	63.44	62.11	1.58	0.561
NFE	72.72	72.02	70.45	0.83	0.06
N intake (g/d)	17.9	17.9	17.99	0.79	0.995
Fecal N (g/d)	7.07	7.17	6.77	1.06	0.963
Urinary N (g/d)	5.92	6.19	6.26	0.43	0.835
N balance (g/d)	4.9	4.53	4.95	0.54	0.834
N retention as % NI	27.4	25.77	27.38	3.25	0.921
Nutrient density (%)					
DCP	8.64	8.42	9.03	0.55	0.731
TDN	62.89	62.89	64.63	1.12	0.48

Future strategies

The best performing accessions will be selected and multiplied on larger scale and will be popularized on farmer's fields under different land use systems like degraded land, silvipasture blocks, rainfed food-fodder based system for providing the fodder to livestock during lean and dry period. The system developed so will also be evaluated for sustaining the targeted livestock population of small and marginal farmers of semi-arid region of Bundelkhand (India). Expansion of *Opuntia* and *Lathyrus* as non-conventional fodder crops in rainfed and dry areas will be done to .increase availability of fodder during post rainy season and other lean periods

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5. Impact of the good rainy-year of 2015/2016 over the productivity of crops and livestock in CZWD and the livelihood of Bedouin Community

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Abstract

The Coastal Zone of Western Desert, Egypt (CZWD) is historically a pastoral area. Raising small ruminants is the main socioeconomic activity there. The area has faced major changes over the last 50 years: demographic growth, urbanization, touristic development and agro-ecological diversification. More recently, the area has faced a long drought period from 1995 to 2011, with low and erratic rainfall (< 150 mm). Paucity of rainfall has affected farming systems and household livelihood. The Bedouin communities have diversified their farming systems based on livestock, barley and fruit trees to face such long drought. In the year 2015/2016, the area witnessed a good rainfall of >400 mm, which reflected positively in the area. This study analyzes the impacts of this rainy-year on the crop-livestock farming, and the livelihood of the Bedouin community. The analysis is based on household surveys of 60 families, between March and May 2016, in the rainfed zone of Matrouh, and comparing them with the data collected on the same livestock breeders in 2014/15. The productivity of barley grains averaged 350kg/Fed in 2016 vs. no grains in 2014/15. Olive trees produced 1300 kg/Fed this year, double that of the last year. Fig production was 3000 kg/Fed, 170% more than 2014/2015. Grazing period was less than one month in 2014/15, compared to 5 months in 2016 with good quality pasture, and significantly less use of the expensive concentrate feeds. Reproductive performance of sheep (lamb born/ewe/year) was 0.86 in 2016 vs. 0.81 in 2014/15. Estimates for goats were 1.18 and 1.3 kid, respectively.

The breeders stated that they could well recover their losses over the past drought years, however, they did not increase the size of their flocks, waiting to know the climatic conditions of the next year.

Keywords: *Beduin* community, Central Zone of Western Desert, Goats, Sheep, Drought

6. Market chain of the imported camels from Horn of Africa to Egypt, as a cheap source of meat

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Abstract

The aim of the study was to understand the market chain of the imported camels from Horn of Africa to Egypt. Different partners of the market chain (23 agents, 36 traders, 22fatteners and 16 butchers) were interviewed during 2011/12. The study covered four main camel markets: 1) Shalateen, south of Egypt at Sudan borders, 2) Daraw, Aswan government, 3) Berqash, Giza government, and 4) Belbais, Sharqia governorate. These markets receive camel herds from Horn of Africa countries (Sudan, Somalia, Djibouti, Eretria and Ethiopia). There are two pathways to transfer these camels, the first and main one is camels trekked on hoof from Sudan in a long journey to Shalateen and Daraw (for 40 days). In the second one, camels are shipped from Somalia, Djibouti, Eretria and Ethiopia through Red Sea to Suez port; then they are transported by trucks to Berqash and Belbais markets. The survey revealed that the number of camel agents (representative of the camel owner in country of origin) in Shalateen, Daraw and Berqash markets are 14, 10 and 14, respectively. Agents classify the received consignment according to the animals' number and weight (>200 and > 500 kg). Most of traders are working in more than one market and cooperate with each other. The average weekly transactions were 35, 69, 24 and 17 camels / trader in the Shalateen, Daraw, Berqash and Belbais markets, respectively. Camel fatteners practice different types of agriculture activities, besides camel raising (66%, 50%, 100, and 33%, respectively). Average transaction was 13, 11, 3 and 8 camel/ fattener, respectively. The common constrains facing camel fatteners were increasing feedstuff prices and absence of veterinary care. Average number of camel slaughtered weekly was 3, 4, 7 and 7 per butcher, in the four markets respectively. Importing live camels to Egypt is historically an important regional trade, but still very traditionally organized. Data from slaughter houses showed that meat from imported camels was 28417.8 ton in 2011/12 and is growing. It contributes around 12 % of the total meat produced in Egypt. Camel is considered a cheap source of meat in many parts of Egypt, especially in Giza and Sharqia governorates. It is important to pay more attention to improving its market chain to promote inter-regional trade with Horn of Africa.

Keywords: Market chain, Camel, Egypt, Horn of Africa**,** Meat production

7. Case study for dryland management and rehabilitation in Jordanian Badia

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Abstract

The Governing Council (GC) of the UN noted that the available information and analysis confirmed that there was a large influx of refugees and their livestock into Jordan as a result of Iraq's invasion of Kuwait. Also a large increase in the numbers of refugees and livestock caused significant environmental damage to Jordan's rangeland and wildlife habitats in the dryland area. The final estimate of the effect was recognized as damage to 7.1 million hectares of rangeland in the Jordanian Badia and loss of wildlife and destruction of rangelands wildlife habitat led to loss of non-endangered wildlife populations. In April 2013 a Community Action Plan (CAP) was developed. It is a cooperative action plan seeking to apply the appropriate biophysical and technical measures for restoring the degraded dryland in the Jordan Badia involving the local community in the implementation and in establishing and running a sustainable grazing management system. Since it would be impossible to include the whole of Badia, which accounts for 80% of the country, twelve watersheds were selected that have the highest potential for restoration, and represent about 12% of Jordanian national area. The CAP consists of three main components: a. Biophysical component, entitled " Integrated watershed management" that aims at enhancing the water security of the Badia rangelands and provides an opportunity for the fodder crops to grow, and drylands to recover the biodiversity; b. Socio-economic component entitled "Integrated livestock and socio-economic management" that provides care for the livestock, packages of incentives that motivate and support the herdsmen to cooperate in the rangeland restoration efforts and builds capacity among their community for sustainable development of dry land resources; c. Integrated component that utilizes the principles of the above components to establish a system of sustainable fodder crop production, which is managed and utilized by the community through cooperatives.

Keywords: Badia, Environmental damage, Integrated watershed management

8. The concept of integration of aquaculture and agriculture in Egypt

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Abstract

The food security is one of the important issues for the policy makers in Egypt. Land and water scarcity are among the leading constraints to the Egyptian agricultural production. Expanding aquaculture projects in Egypt overloaded the required fresh water needed for agriculture. Therefore, new aquaculture areas should be utilized. Today, more than 130 intensive tilapia rural farms and 25 commercial aquaculture farms have been constructed in various desert zones of seven different provinces. In 2014 the Egyptian integrated desert aquaculture has produced 2,444 tonnes fish using around 270,000 m^3 of fish water tanks, with an average production 10 kg of fish/m^3. Pioneer desert aquaculture farms have reached a fish biomass production ranging from 25 to 50 kg/m^3. The main fish produced with 90 % of the total desert aquaculture production was Nile tilapia (*Oreochromis niloticus)* and red tilapia (*Oreochromis mossambicus* x *Oreochromis niloticus*) and the remaining 10% was mainly the North African catfish *(Clarias gariepinus)*, flathead grey mullet (*Mugil cephalus*), European seabass *(Dicentrarchus labrax)*, Gilthead seabream *(Sparus aurata)*, and Eel (*Anguilla Anguilla*). The water source comes from Nile, geothermal underground water, agricultural drainage and/or brine water from the desalination stations. The water temperature is ranging from 22 to 26°C and salinity from <0.5 to >26 g/l. Most of the commercial aquaculture farms have adopted flow-through systems (FTS) to mainly irrigate agricultural land in desert zone, with the advantages of producing three different crops (fish/plant/sheep), in addition the biogas. While most of the farms are strictly dependent on FTS, three of them have upgraded their systems to include recycling system in both fresh and brackish water. Although the brackish water used for aquaculture purposes varies in salt concentrations, (> 26 g/L), it is utilized for integrated agriculture, e.g. the irrigation of different halophytes plants, mainly Salicornia (*Salicornia europea*), Suaeda *(Suaeda aegyptiaca)* and Atriplix *(Atriplex hortrnsis)* combined with intensive European seabass and gilthead seabream aquaculture, with a yearly production of 50 tonnes per year for both species. This review presents the desert aquaculture current situation, best practices, lessons learned and experiences as well as future sustainable development projects, mainly the planned agricultural mega-projects, for the reclamation of 630,000 ha of desert land for this purpose.

Keywords: Aquifer, Brackish aquaculture, Geothermal underground water, Egypt, Integrated aqua-agriculture, Tilapia, Water scarcity.

9. Potential of tannin-ferrous plants to reduce methane emissions and improve small ruminant production in dry areas

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Abstract

Raising small ruminants is the main economic activity of agricultural communities in dry areas. These animals often depend on low quality crop residues and expensive feed supplements. The northwestern desert of Egypt is considered as a source of tannin-ferrous plants (TFP) round the year. These plants have a lot of nutritive issues that need to be resolved before depending on them as a good quality fodder. *In vitro* experiments were conducted to evaluate the effect of several mixtures of TFP with ammonia treated straw (ATS) on dry matter degradation, Ammonia-N and methane (CH_4) production. Six treatments were examined: Cassava with untreated straw (Trt 1); Cassava plus ATS (Trt 2); prosopis (*Prosopis juliflora*) plus ATS (Trt 3); acacia (*Acacia saligina*) plus ATS (Trt 4); Cassava +Acacia+ ATS(Trt 5); and Cassava+ prosopis + ATS (Trt 6). In addition, twenty-four growing Barki male lambs, aged about 3 months, were used to study the effect of the tested rations on growth performance. The results showed that the condensed tannin (CT) content ranged from 20 g/kg DM (cassava) to 23 g/kg DM (prosopis). Methane production per unit of fermented DM was inversely related to protein solubility. Trt 6 presented a lower ($P<0.01$) ruminal NH_3-N concentration associated with the decreasing ($P<0.01$) in rumen protein degradability. Methane production was highest for Trt1 at all incubation times. After 24 h of *in vitro* incubation, CH_4 production was 28, 17, 18, 17, 15, and 14 ml, respectively. Daily body gains were significantly affected by tested rations. The highest values were recorded with Trt 6. Consequently, consumption of combination of TFP containing varied classes of secondary components with resource of NPN lead to reducing CH_4 emissions from ruminants and improving lamb growth.

Keywords: Tannin-ferrous plants, Methane emissions and Barki lamb growth

Introduction

Raising small ruminants is the main economic activity in arid and semi-arid regions in Egypt. These animals often depend on low quality crop residues and expensive feed supplements. Tannin-ferrous plants (TFP) such as cassava and acacia could play an important role in solving this problem. They are widely distributed throughout the northwestern desert of Egypt round the year. However, these plants have a lot of nutritive issues that need to be resolved before their use as a good quality fodder. The present study was conducted to evaluate the potential of several mixtures of TFP to reduce methane emissions and improving small ruminant's production in dry areas.

Materials and methods

***In vitro* system:** An *in vitro* incubation system was used to evaluate the following treatments: (Trt1) *Prosopis juliflora* (P) + ammoniated wheat straw (AWS) at a ratio of 50:50 ; (Trt2) *Cassava* (C)+AWS at a ratio of 50:50; (Trt3) *Acacia saligna* (A)+ AWS at a ratio of 50:50; (Trt4) A+ C:+AWS at a ratio of 25: 25: 50; (Trt5) A+ P+ AWS at a ratio of 25: 25: 50; (Trt6) P+C+AWS at a ratio of 25: 25: 50. A 12 g sample of the mixtures was subjected to *in vitro* dry matter digestibility as described by A.O.A.C (1995).

Sample collection, preparation and chemical analysis:

Samples from each ingredient (leaves and twigs) were chopped into small pieces and dried in an oven at 55 °C for 48 h prior milling. Feed samples were analyzed for dry matter (DM) and total ash using the method of A.O.A.C (1995). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed by the Van Soest method (Van Soest, 1965). Condensed tannins were determined by the butanol-HCl-iron method (Porter *et al.,* 1985). Ammonia N **(**NH_3 -N**)** and Volatile fatty acids **(**VFA**)** concentrations were estimated using gas production technique (Patra *et al*., 2006). Phenolic compounds were determined by method of Makkar (2003). Blood samples were collected from the jugular vein once before feeding (3 animals in each) at the end of growing period. Blood samples were centrifuged at 4000 rpm for 20 min.

Lamb growth performance:

The experiment was conducted in the Borg El Arab Research Station, Animal Production Research Institute, Agricultural Research Center, Egypt. Twenty four growing male lambs of 'Barki' breed, aged about 3 months and weighing on average 12.18±0.17 kg , were divided randomly into six groups, and used to study the effect of the tested rations on growth performance, blood metabolic response, and feed efficiency. The animals were weighed at the beginning then bi-weekly. The feeding experiment lasted 16 weeks. The level of the ingredients in the concentrate portion was adjusted to maintain iso-protein and iso-caloric nature in the experimental rations .accordingly to the nutrient requirement (NRC, 1985) for the growing sheep

Digestibility and nitrogen balance trials:

Digestibility trial was conducted using three animals chosen randomly from each group. The digestibility trial lasted 22 days, the first 15 days were considered as a preliminary period, followed by a 7 day period as collection period. The animals were weighed at the beginning and at the end of the trial. Animals were housed in individual metabolic cages. During the metabolism trials, animals were fed their normal allowances according to the experimental scheme. Faeces and urine were quantitatively collected from each animal.

Statistical analysis: Data were statistically analyzed using One-way Layout with means comparisons procedure SAS (2003).

Results and discussion

The chemical composition, condensed tannin and methane production of experimental rations are presented in Table 1.The results showed that the crude protein (CP) and crude fiber (CF) were nearly similar in all rations. The lowest hemi-cellulose and condensed tannin (CT) contents were recorded with Trt4. Methane production per unit of substrate fermented was the lowest for Trt4. Thus, methane production showed negative correlation with CT and fiber (hemi –cellulose) components.

Table 1. Chemical composition, condensed tannin and methane production of experimental rations

Item	Experimental rations					
	Trt1	Trt2	Trt3	Trt4	Trt5	Trt6
	P:AWS	C:AWS	A:AWS	A:C:AWS	A:P:AWS	P:C:AWS 1
OM	83.90	82.93	87.23	85.93	89.00	89.81
CP	15.70	14.70	15.40	15.36	16.86	14.12
CF	37.23	38.10	38.80	38.20	38.23	38.43
EE	3.13	3.54	4.22	3.58	3.90	3.04
NFE	26.84	26.64	28.81	28.79	27.07	29.22
Ash	14.10	17.02	12.77	14.07	11.00	10.19
Fiber fraction:						
CWC	43.00	44.26	41.23	43.12	40.42	42.32
ADF	20.30	30.00	28.00	19.00	25.22	24.00
Hemi-cel2	15.70	14.26	13.23	24.12	25.20	28.32
CT [3]	10	12	10	24	16	18
CH [4]	14	15	13	17	18	17

[1]P= *Prosopis juliflora*, C= Cassava, A= *Acacia saligina*, AWS= Ammoniated wheat straw; [2]Hemi-cellulose = CWC-ADF; [3]condesed tannin (g); [4] methane production (ml/200mg DM)

In vitro digestibility data (Table 2) indicated that pH ranged from 6.50 to 6.85 for tested rations. Rumen ammonia nitrogen and total volatile fatty acids were significantly higher in Trt4, associated with the lower content of tannin. Narjisse *et al.* (1995) reported that rumen ammonia was depressed ($P < 0.05$) by tannin infusion in sheep.The negative effects of plant phenolic compounds on their fermentation and digestion were also reported by others (Guglielmelli *et al.,* 2011; Jayanegara *et al.,* 2011; Sebata *et al.,*2011). The negative effect of tannins on fermentation could be related to the formation of tannin-carbohydrate and tannin-protein complexes that are less degradable or to toxicity to rumen microbes (Bhatta *et al.,* 2009). A high gas production (GP) indicated greater fermentation to support rapid rumen microbial growth (Gemeda and Hassen, 2015).

Table 2. Reaction (pH), Ammonia nitrogen and total Volatile fatty acids concentration of experimental rations

Fermentation parameters	P:AWS Trt1	C:AWS Trt2	A:AWS Trt3	A: C:AWS Trt4	A: P :AWS Trt5	P:C:AWS Trt6
pH	6.80^{a}	6.66^{a}	6.85^{a}	6.50^{a}	6.57^{a}	6.70^{a}
NH_3- N (mg/100 ml)	5.30 ^{ab}	5.80^{a}	4.70^{b}	6.30^{a}	5.80^{a}	6.00^{a}
TVFA's (mg/100 m)	6.00^{b}	7.00^{ab}	5.85 ^{b}	7.90^{a}	7.55^{a}	7.70^{a}

Means within the same row and with same letters are not significantly different (P<0.05)

Crude protein digestibility was significantly (p<0.05) affected by tested rations (Table 3). The highest crude protein and fiber digestibility was obtained in rams fed with Trt4 ration. Data of blood serum parameters are presented in Table 4. The results indicated that most tested blood parameters (except globulin) were significantly affected by tested rations. Generally, all tested blood parameters were within the normal range as reported by Kaneko (1989) for healthy goats and in line with findings of Shaker *et al.* (2014) who used salt tolerant shrubs mixture in small ruminant rations.

Table 3. Nutrient digestibility of experimental rations

Nutrients	P:TWS Trt1	C:TWS Trt2	A:TWS Trt3	A: C:TWS Trt4	A: P :TWS Trt5	P:C:TWS Trt6
Dry Matter Digestibility (%)	55.70^{a}	57.30^{a}	56.30^{a}	61.70^{b}	58.40^{a}	59.30^{a}
Crude Protein Digestibility (%)	58.50^{c}	62.30^{a}	61.90^{a}	68.20^{b}	60.50^{a}	61.40^{a}
Crude Fiber Digestibility (%)	56.50^{c}	59.30^{a}	55.90^{a}	62.20^{b}	59.50^{a}	60.40^{a}

Means within the same row and with same letters are not significantly different (P<0.05)

Table 4. Effect of feeding experimental rations on some blood serum parameters

Item	P:AWS Trt1	C:AWS Trt2	A:AWS TRt3	A: C:AWS Trt4	A: P :AWS Trt5	P:C:AWS Trt6
Total protein, g/dl	$7.10{\pm}0.25^{b}$	$8.11{\pm}0.50^{a}$	$7.06{\pm}0.46^{b}$	$7.45{\pm}0.25^{ab}$	$6.82{\pm}0.51^{b}$	$6.55{\pm}0.51^{b}$
Albumin, g/dl	$3.63{\pm}0.29^{b}$	$4.61{\pm}0.38^{a}$	$3.87{\pm}0.23^{b}$	$3.90{\pm}0.29^{b}$	$3.70{\pm}0.23^{b}$	$3.94{\pm}0.23^{b}$
Globulin, g/dl	$3.46{\pm}0.10^{a}$	$3.50{\pm}0.14^{a}$	$3.19{\pm}0.24^{a}$	$3.86{\pm}0.10^{a}$	$3.12{\pm}0.29^{a}$	$3.45{\pm}0.29^{a}$
Alb/Glob ratio	$1.05{\pm}0.10^{b}$	$1.31{\pm}0.07^{ab}$	$1.22{\pm}0.04^{ab}$	$1.45{\pm}0.10^{a}$	$1.20{\pm}0.07^{ab}$	$1.55{\pm}0.07^{a}$
Urea-N, mg/dl	$23.19{\pm}0.52^{a}$	$22.62{\pm}0.39^{ab}$	$22.13{\pm}0.65^{ab}$	$24.10{\pm}0.52^{a}$	$21.50{\pm}0.43^{b}$	$23.20{\pm}0.43^{a}$
Creatinine, mg/dl	$1.81{\pm}0.12^{a}$	$1.23{\pm}0.11^{b}$	$1.24{\pm}0.18^{b}$	$1.92{\pm}0.12^{a}$	$1.21{\pm}0.10^{b}$	$1.72{\pm}0.10^{a}$
AST, u/l	$30.10{\pm}0.48^{a}$	$31.05{\pm}0.58^{a}$	$30.44{\pm}0.59^{a}$	$31.15{\pm}0.48^{a}$	$30.18{\pm}0.52^{a}$	$30.48{\pm}0.52^{a}$
ALT, u/l	$16.11{\pm}0.45^{b}$	$17.98{\pm}0.29^{a}$	$17.96{\pm}0.32^{a}$	$17.20{\pm}0.45^{b}$	$17.94{\pm}0.40^{a}$	$16.90{\pm}0.40^{ab}$

Means in the same row with different superscripts differ significantly at P<0.05.

Daily body gains were significantly affected by tested rations. The highest values were recorded with Trt4. This could be attributed to increase in dry matter intake compared with other groups (Table 5). There is an inverse relationship between high CT level in forages and their palatability, voluntary intake, digestibility and N retention in ruminants (Min et al 2006, Soltan et al 2012).

Table 5. Growth performance and feed efficiency of Barki lambs fed with different experimental rations

Item	P:TWS Trt1	C:TWS Trt2	A:TWS Trt3	A: C:TWS Trt4	A: P :TWS Trt5	P:C:TWS Trt6
No. of lambs	5	5	5	5	5	5
Feeding period, weeks	18	18	18	18	18	18
Initial weight, (kg)	12.32±0.29	12.02±0.06	12.28±0.11	12.08±0.46	12.30±0.29	12.02±0.06
Final weight, (kg)	28.25±0.46[c]	31.42±0.53[b]	31.66±0.48[b]	33.00±0.48[a]	31.00±0.46[b]	31.99±0.53[b]
Total gain, (kg)	15.93±0.32[c]	19.40±0.53[b]	19.38±0.42[b]	20.92±0.13[a]	18.70±0.32[b]	19.97±0.53[b]
Daily body gain, (g)	126.43±0.003[c]	154±0.004[b]	154±0.003[b]	166±0.001[a]	148±0.003[b]	156±0.004[b]
Daily feed intake:						
Roughage (g/h/d), (R)	450	490	490	600	520	490
CFM (g/h/d), (C)	320	340	345	350	320	345
Total DMI (g/h/d)	770	830	835	950	840	835
DMI as %BW	2.7	2.6	2.6	2.9	2.7	2.6
R/C	60:40	60:40	60:40	60:40	60:40	60:40
CP intake (g/h/d)	120	129	125	133	126	128
Feed conversion						
Kg CP/Kg gain	0.143	0.150	0.155	0.160	0.154	0.153

Means in the same row with different superscripts differ significantly at P<0.05.

Conclusion

Consumption of combination of TFP, containing varied classes of secondary components, fed with source of non protein N led to reducing CH_4 emissions from ruminants and improving lamb growth performance.

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Theme 8. Arid lands communities, their indigenous knowledge and heritage, and socio-economic studies

1. Rural development in dryland areas of the Qinghai-Tibet Plateau of China: problems and prospects

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Abstract

The Qinghai-Tibet Plateau is a large area in western China that has some of the world's driest deserts and highest mountains. It is the water tower of Asia with the headwaters of major rivers, including four transboundary ones. The people and their livestock are well adapted to the extremely harsh conditions. Survival depends on application of local ecological knowledge (LEK) built up over generations. Rural development faces many challenges because of: i) Sparse populations without permanent habitations, ii) Strong cultural traditions and religious philosophy, iii) Lack of infrastructure (roads, bridges, railways, mobile phone towers), iv) Low level of formal education among local peoples, v) Widespread poverty in some areas, leading to ecological refugees, and vi) Impending climate change (melting glaciers, floods, landslides). The government response is to:

- Improve the public infrastructure e.g. the newly completed high speed railway to Lhasa that connects Beijing and other east coast cities to Tibet via Qinghai, upgraded highways, airports
- Encourage sedentarization of semi-nomads by creation of villages with schools, medical clinics, welfare office for pension payments to eligible citizens etc.
- Assist in relocating ecological refugees, step up the campaign to alleviate poverty
- Implement measures to restore degraded pasturelands, combat desertification and protect biodiversity
- Implement strategies to mitigate the impact of climate change, including risk analysis, campaigns to raise awareness among the herders and farmers, provide assistance to those most under threat.
- Promote socio-economic and ethno-anthropological studies to better inform government intervention strategies, including ways to better use LEK in government initiatives.

This paper focused on experience gained from working with Tibetan ethnic groups in the "Three Rivers" region in the headwaters of the Yellow, Yangtze and Mekong rivers. Data are presented from field work based PRA and other sociological tools that sought to assess the attitudes and expectations of local people to impending global change, including global warming.

Keywords: Local ecological knowledge (LEK), Rural development, Tibetan ethnic groups

2. Added value from industries introduced in villages, reclaimed lands and oases

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Abstract

A considerable portion of the agricultural resources is being treated as valueless waste. This leads to the loss of sustainable resources as a comparative advantage and the associated loss of opportunity of sustainable development. This can be attributed to the narrowness of the angle by which we are accustomed to view these renewable resources, as well as the absence of the appropriate means to turn the waste to wealth. The first aspect is associated with the level of the R & D activities. The role of the researchers is proceeding from the understanding and valorization of the traditional technical heritage of use of these resources, to develop a contemporary method for the use of these resources, to rediscover them as a material base for the satisfaction of human needs on the local, national and international levels. The second aspect is associated with industry. Industry here is understood in broad terms as those activities conducted under defined conditions to transform the state, shape or properties of the agricultural resources to satisfy a certain requirement along a predetermined path of transformation to a final product. Based on this definition, industry includes a wide spectrum of activities including: sorting (to various sizes or quality levels), packaging, drying, freezing, pressing, squeezing, filtering, threshing, baling, etc. The above mentioned definition opens several degrees of freedom: in selection of geographical location of industry (e.g. in village, town or city), in site selection on the microscale (e.g. field, field head, house, workshop, industrial premises) of various areas and infrastructural requirements, manpower involved (e.g. men, women, children), source of power (human labor, sun, wind or water energy, or energy from hydrocarbons), level of technology (manual, mechanized, fully automated processes), and mobility (e.g. stationary or mobile as for example fish processing on board of fishing ships). Industry could also be classified into preparatory processing of a resource and the processes of manufacture of a final product. In this paper the new vision of whole resource use will be illustrated giving different examples. A new perception of resource components will be given to associate them structurally with the performance criteria of different products / services. An integrated approach will be suggested for the industrialization of the rural areas to realize the objective of endogenous sustainable development, as well as a high added value along the value chain, from the field to the market, including selection of industrial projects, their spatial distribution and appropriate technology.

Keywords: Industries, Rural development, Waste management

Introduction

Perhaps until the sixties of the last century the subsistence economy was dominant in most of the villages and the oases in the Arab world. Relying on their culturally-rooted technical heritage, accumulated and self-developed by successive generations, villagers and Bedouins were able to satisfy their basic needs using the locally available resources, most of which were products of agricultural activity. The drastic and abrupt change of the style of life due to the westernization wave propagating in rural and desert areas, as well as the compulsory modernization process, pushed by successive governments and investors, has violated the cultural continuity in the Arab region and destroyed the historically-woven symbiotic relations between the villagers/Bedouins and their local contexts and resources (El-Razy). Many of these resources, especially the residues of the agricultural resources, became redundant turning to be a burden on the environment and a source of environmental pollution. The most dangerous result of this process is the loss -- and perhaps forever -- of the unique to each local community traditional knowledge, including the technical heritage that may have been a spring board for the improvement of the means of livelihood of members of these communities. The adoption of the new style of life has increased the financial burden on villagers/ Bedouins, incommensurate to the increase of the prices of their agricultural products leading to the threatening of the economic feasibility of the agricultural activity at large.

As far as the drylands are concerned, the above mentioned conditions have been exacerbated by the climate change leading to the decrease of the rate of rain fall by 30%, deleteriously affecting the intensity of plant cover falling short of satisfying the needs of livestock, which has exceeded the carrying capacity of the natural flora. All these conditions are behind the increase of migration of the youth from villages and desert communities to big cities and abroad in search for better life conditions. This situation poses a serious challenge to development agencies and society at large.

A new vision is needed to view the agricultural resource in its integrity including the main and secondary (and even tertiary) products. Here, application of science and technology is needed to rediscover the available local resources with the objective of satisfaction of contemporary needs on the local, national and international levels. Viewed from the perspective of the local community, this endeavor may be perceived as a process of revitalization of thinking and imagination of the village/oasis inhabitants leading to the unleashing of their endogenous capabilities and thus helping them to compose a new contemporary edition of their culturally-developed style of life. Within this framework lies a great opportunity for innovation in trying to make full use of the uniqueness each village/oasis possesses: in historical experience, ecological conditions and resource endowment to find out their comparative and competitive advantages and use them in development. Thus the great diversity the Arab region has in cultural backgrounds, historical experiences, ecological conditions and resource endowment will serve as an inexhaustible source of innovation in achieving sustainable development.

The localized development

The neoliberal capitalist system endeavors to neutralize the factors of production world-wide (e.g. raw materials, labor, capital, etc.) and to merge them in huge systems of production (e.g. transnational companies). This leads to the violation of ties of belonging associating people with their local contexts and resources, destabilizing them and turning them to be passive consumers of whatever is offered to them in the international market. Thus whole local cultures are threatened to disappear destroying with them the potentiality of emergence of new alternative models of development. Therefore, efforts should be directed to the localized development. This needs to adopt a new approach of planning from the grass root level upward. The objective here is to discover, on the local micro level, the comparative and competitive advantages of local communities that may lead to the establishment of innovative production systems with new economic features to satisfy local needs, as well as national and international needs making use of the market niches opened by the world market.

Endogenously initiated patterns of development

The endogenously initiated patterns of development – as opposed to the exogenously imposed pattern – mean that the local community acquires the feeling of ownership of the change from the very start, beginning from the idea. This means the involvement of community members and enabling them to take responsibility to act. This also opens an inexhaustible source of innovation and guarantees sustainability of development.

Tailoring of science and technology to serve the needs of the local community

There are no readily available recipes to tailor science and technology to suit the needs of local communities. Each case/local community has its own specificity. This endeavor begins with deep understanding of the socio-cultural and economic conditions of the local community, the traditional knowledge and the technical heritage it has and its ability to absorb and assimilate modern knowledge and techniques. Then comes the stage of selection of the appropriate elements of science and technology and their tuning with the cultural background of the local community. The criterion of success here is: how far the introduced elements of science and technology were properly assimilated by the members of the local community leading to their empowerment and increasing their ability to absorb and assimilate more advanced knowledge and techniques? The results of this creative process may be new syntheses between the traditional knowledge/technical heritage and modern science and technology.

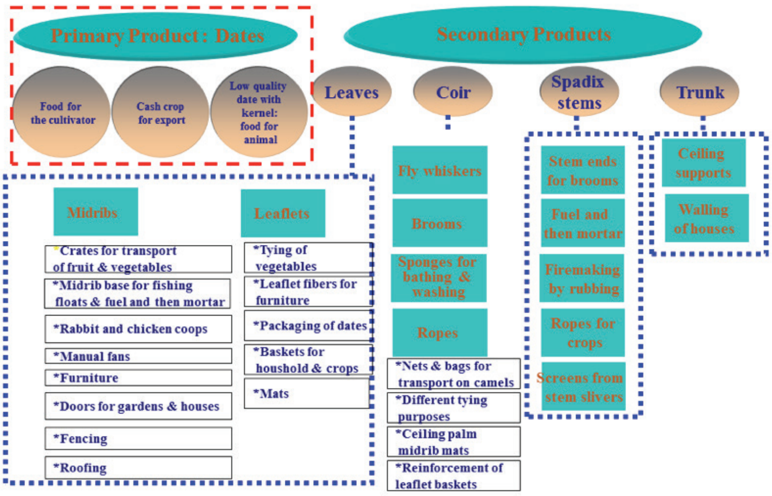

Figure 1. Traditional uses of palm midrib in village.

Multi-sectorial model of thinking from the developmental point of view

We have to transcend the unidirectional view of the agricultural production as confined to the sector of agriculture and associate the three economic activities agriculture, industry and trade on the local level as possible with the objective of increasing the developmental returns along the whole value chain, from the agricultural production to the selling of the final product. This idea will urge us to search for the comparative and competitive advantages each village/oasis has and

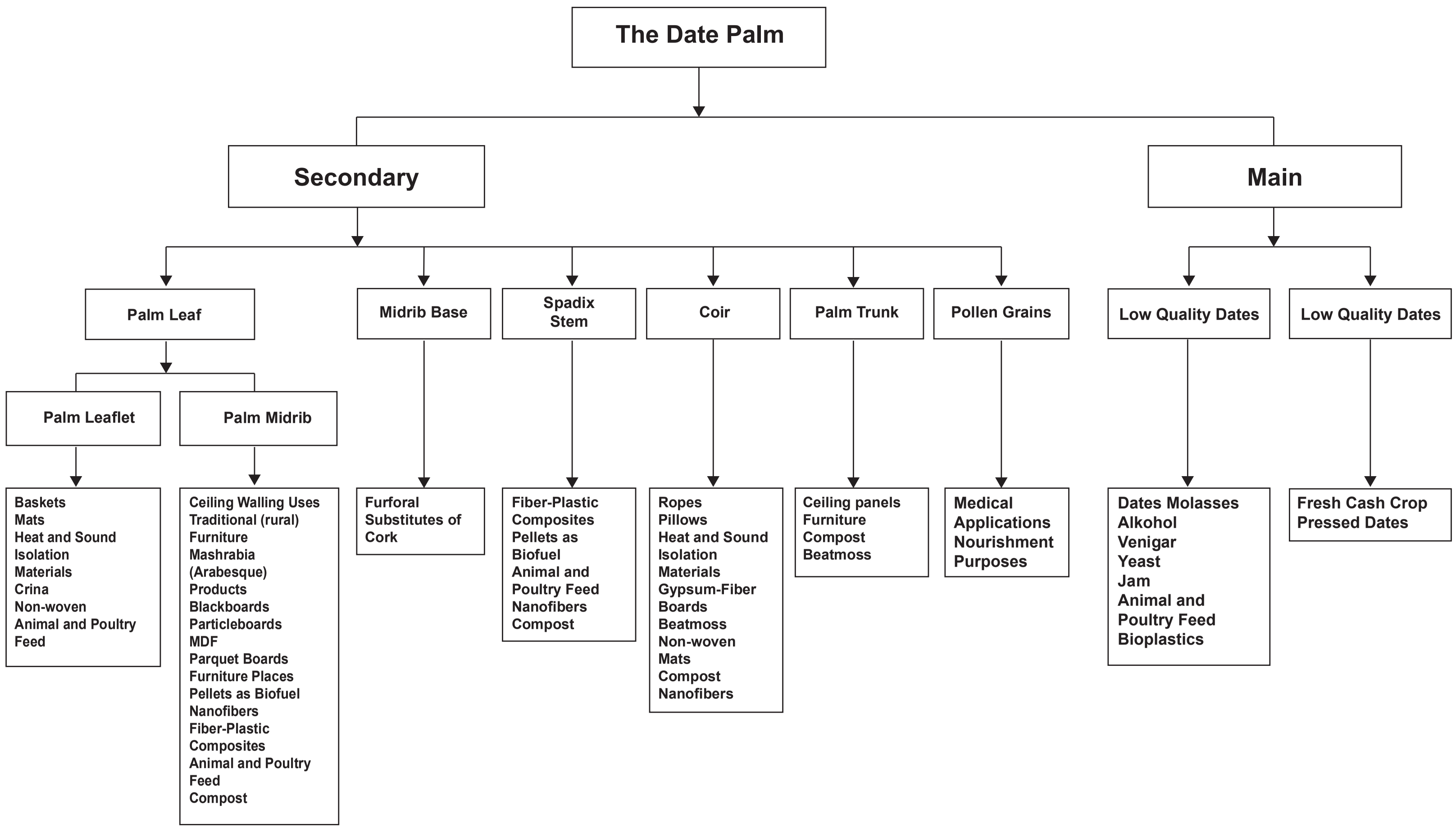

Figure 2. A modern edition of the concept of the whole resource use for the date palm.

study its specificity (e.g. historical experience, cultural background, ecosystem features, etc.) to find out what is unique to it and how this uniqueness can be expressed in a product/service that can be marketed locally, nationally or internationally. This line of thinking will end up by coining trademarks, associated with a wide spectrum of products/services, characterizing each village/oasis.

The use of whole resource

The cash crop ideology is strange to the Egyptian/Arab traditional village. Along with the history, the cultural traditions have woven symbiotic relations between the villagers/Bedouins and the elements of flora and fauna around them. Figure 1 illustrates an example of these relations with the date palm, showing that all the products of the resource, primary and secondary, were totally used to satisfy the needs of the farmer. That is why the vocabulary of the village/oasis did not know the term "waste". Figure 2 illustrates a modern concept of the whole resource use as applied to the date palm. Generically speaking, this concept can be applied to villages, oases and reclaimed lands leading to the dissemination of waste-free industrial activities.

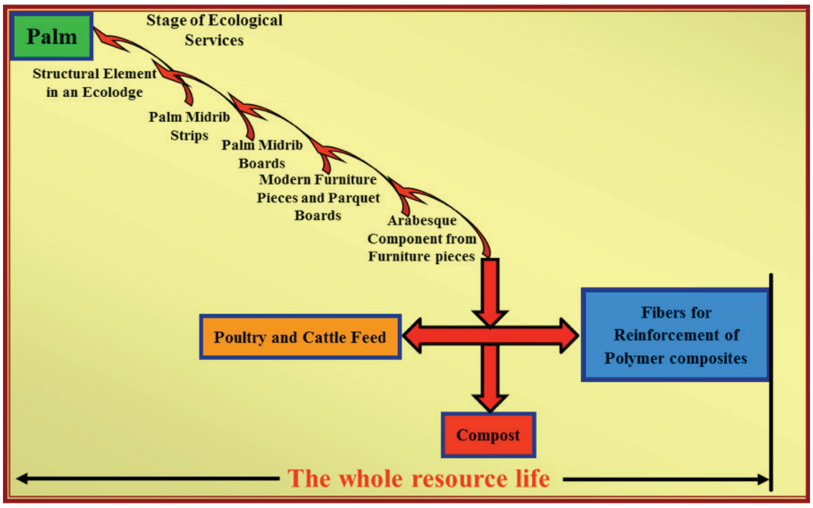

Figure 3. The principle of use of the whole development potential applied to the palm midrib

The use of the whole development potential means maximizing the whole resource use efficiency, which is in tune with sustainability. In addition, this will decrease or eliminate the need for landfills and add to sustainability. Figure 3 illustrates the principle of use of the whole development potential applied to the palm midrib

Opportunities of innovation hidden behind the plant resources

The first interface of innovation lies between our perception of the structural properties (on the macro and micro levels), physical and mechanical properties, chemical composition, etc. and the performance criteria of service or a product, needed in the local (beginning from the village), national and international levels. The innovative product of this interface is new ideas of services or products, associated with the use of agricultural resources.

The second interface of innovation lies between the idea of the new service or product and the socio-cultural context, where it is being produced. The innovative product of this interface is a new technology, appropriate for the concerned socio-cultural context. The appropriate technology is the one that could be easily assimilated by the local community, strengthening its structure and enabling the local community to modify it and innovate new technologies

Meaning of industry

Let us adopt a generic understanding of industry as an activity, conducted under predetermined conditions, to transform the state, shape or properties of an agricultural resource to satisfy certain criteria or requirements along their path of transformation to final products. Thus, this wide definition of industry opens the potentiality – when needed - to separate the different stages of preparation of the agricultural resources with the purpose of use of comparative advantages at a village or an oasis level.

Approach of industrialization

Priority for remote villages and oases

Here it is assumed that more remote the location of the village/oasis, higher are the chances it was not distorted by the process of westernization and compulsory modernization. This means that the identity and specificity of the local community is still preserved. This may be reflected in authentic traditional knowledge and technical heritage, as well as vital relations with local resources. Thus remote villages and oases offer chances for developing new endogenously formulated models of modernization enjoying cultural continuity and relating the past heritage with future examples of sustainable development.

Industry should go to people

Contrary to what has happened during the industrial revolution in the eighteenth century in the West, industry will have to go to people in the villages and oases. First of all the industrial activities/establishments should be in harmony, ecologically and socially, with the village and oasis contexts; it is expected that the strong socio-cultural networks of the village/oasis (e.g. nuclear and extended families, neighborhood relations, tribal relations, etc.) may lead to innovative forms of industrial relations as compared with those prevailing in modern cities. This suggests the need to search for alternatives of location of industrial activities in the fields and fruit gardens, public spaces in villages/oases, as well as houses (e.g. courtyards). Within this context, home industrial production may provide a strong comparative advantage in the economic sense (decrease of the cost of overheads and infrastructural needs, saving of time of transportation to work and back to home, etc.). In addition, the location of industry at home will facilitate the permeation of the culture of industry to the members of the local community via the strong family and tribal relations, as well as neighborhood networks in the village/oasis.

Building of personal skills

The main thrust of industrialization of the village/oasis should be the building of personal skills in manual and semi-manual (partially mechanized) crafts. This will facilitate the dissemination

Table **1.** List of the industrial projects executed from 1992 to 2016

No.	Project Name	Geographical Location	Source of funding	Duration
	Establishment of the first of its kind factory for the manufacture of blockboards from date palm leaves' midribs.	El-Kharga city, the New Valley governorate	GTZ	The factory opened in 27/10/1993
	Manufacture of furniture for 150 community schools in Asiut, Sohag and Kena governorates from date palm midrib blockboards in collaboration with UNICEF	Asiut, Sohag and Kena governorates	UNICEF	1995
	Establishment of a training centre for training of villagers in El-Dakhla oases on the manufacture of Mashrabiah (Arabesque) items from date palm leaves' midrib.	El-Dakhla oases	GTZ	The Centre opened in 1995
	Investigation of the possibility of use of cotton stalks in particleboard production		Regional councils for Research and Extension	1998-1999
	Dissemination of Mashrabiah (Arabesque) industries in the villages of El-Fayoum governorate relying on the date palm midribs as an industrial material	Al-Aalaam village, El-Fayoum governorate	CARE International	Dec., 2002
	Manufacture of fig jam from priceless figs	Shammas village,Sidi Barrani, Marsa Matrouh governorate	UNDP in Egypt	2006-2007
	Manufacture of untraditional cattle fodder from agricultural residues	Kafr El- Arab, Faraskour, Damietta governorate	Dana Gas company	2008-2009
	Manufacture of untraditional cattle fodder from agricultural residues	Ezbet El- Haga Ratiba, Meniet El-Nasr, Dakhalia governorate	Dana Gas company	2009-2011
	Dissemination of industries relying on the use of date palm secondary products (parquet and block boards from palm midribs: exploratory phase)	El-Kayat village, Menia governorate	Masr El-Kheir	Nov. 2010 – Oct. 2012
	Project of dissemination of micro industrial project relying on palm leaflets and midribs	Beer El-Abd villages, North Sinai governorate	The society of Experts in Sci. and Tech.	2011-2012
	Manufacture of organic compost from prunning of date and dome palms and mango trees	Faris village, Kom-Ombo province, Aswan governorate	Dana Gas company	21/3/2010 – 31/3/2013
	Manufacture of parquet and furniture pieces from palm midribs: exploratory phase	El-Kayat village, Menia governorate	GEF	Feb. 2013- April 2014
	Dissemination of industries relying on the use of date palm secondary products (parquet, furniture and Crina from palm midribs): Pilot phase	El-Kayat village, Menia governorate	Swedish SIDA The Japanese Embassy	July 2015- Dec. 2016

of industry via training apart from the level of literacy (e.g. the level of literacy is very low, especially among women in villages of Upper Egypt). Besides, the building of personal skills satisfies the criterion of sustainability in providing labor opportunities. It has been proven from field studies that it is possible to easily shift from one industrial activity to another in the same realm of craft. In Damietta governorate, for example, the same families have shifted from hand weaving to mechanized weaving of bed sheets and covers. In Kafr El-Dawar, the same families manufacturing irrigating wheels (Sakia) from local timber resources have shifted to the manufacture of window frames and doors from imported European pine. The traditional axe and plough smiths of Kafr El-Dawar have also shifted to the manufacture of modern ploughing tools and agricultural machines. This necessitates: A) Giving due care to strengthen the value of love of work: not only for earning a living, but also as a mean of self-expression. Care should be also given to inculcate the value of doing work with passion and drive to do it very well. B) Giving due care to the carriers of traditional knowledge and technical heritage (men and women) as national treasures and mentors to train young generations. Invaluable, mostly oral, experiences in different fields of industrial expertise are subject to be lost, perhaps forever, with the negligence, and eventually the demise, of those distinguished artisans.

Opportunities offered by industrialization

Traditional products

There are many traditional products that are unique to so many villages and oases in the Arab region. These products are being manufactured from natural materials, specific to each location, i.e. they are green products. Besides, they have strong cultural expressiveness, i.e. they carry cultural motifs of expression. These products composed in the past elements of the traditional life style of many villages/oases. Due to the drastic change of the life style, the local demand of these products is quickly decreasing leading to the loss of jobs, neglect of the unutilized resources, and most dangerously, the disappearance of the associated traditional knowledge and technical heritage. Here lies a big opportunity to open new markets for these products: internationally to satisfy the needs of green consumers worldwide, and nationally to support eco-tourism within the blossoming movement of establishment of eco-lodges. Within this framework, it is necessary to modify the designs of traditional products, design new products and train the artisans to manufacture them setting new quality standards to suit the new consumers. The palm leaves baskets may serve as an example.

There are a lot of neglected resources, which may not present a threat to the environment, but they could present a material base for so many industrial activities that may provide sustainable labor opportunities to the members of local communities: in the villages/oases, as well as towns and cities. Hereafter are examples of some of these resources.

Sheep wool: It is estimated by the author that a sheep renders within its life span ~ 15 kg of wool. This resource could be a springboard for the dissemination of the spinning and weaving industry to produce a wide variety of wool products and thus providing additional income to support rangeland economic activity. Similarly the camel and goat hair could be a material base for industrial activities to be disseminated in rangeland areas. It is estimated by the author that a camel and goat render 41 and 9 kg of hair within their life span, respectively.

Cattle bones: The specific weight % of bones of the cattle being slaughtered could be estimated as follows: sheep 25%, camel 20-22%, buffalo 20% and cattle 18% (estimated by the author). These resources may represent a material base of wide spectrum of industrial activities that could be disseminated in villages and oases to produce different products such as bracelets, necklaces, paper cutters, small souvenirs, animal glue etc.

Date kernels: The date kernels represent ~12% of the total weight of dates, this resource can be used in the manufacture of different products such as rosaries, palm kernel oil and animal and poultry feed.

Use of agricultural residues: Huge quantities of agricultural residues are seasonally available. Their presence in the fields, or near-by locations, is associated with the hazards of infestation by insects, their open-field burning leading to the pollution of the environment, as well as the loss of fertile land they occupy. Examples of the annually available quantities (tons per hectare) of these residues (El-Mously, 2002) are rice straw 4.84, maize stalks 4.84, sorghum stalks 4.62 and cotton stalks 3.584. These resources can be a sustainable material base for the establishment of industrial projects, such as compost, animal and poultry feed and composite panels (e.g. Particle-boards and MDF).

Examples of projects

Executed projects

Table 1 illustrates the industrial projects executed in the period from 1992 to 2016.

Suggested industrial projects

Table 2 presents a summary of industrial projects, suggested by the author in 2009 to the Ministry of International Cooperation, within its endeavors to support the victims of mines in the North West Coast Region.

Table **2.** A summary of industrial projects, suggested by the author in 2009 to the Ministry of International Cooperation within its endeavors to support the victims of mines in the North West Coast Region.

No.	Project title	Location	Investment cost, L.E.	Number of labor opportunities
	Fig jam	Sidi Barrani villages	810000	30
	Barqee wool blankets	Marsa-Matruh villages	310000	20
	Pickled olive	Siwa Oasis	495000	30
	High quality virgin olive oil	The whole North-West Coast Region	1000000	30
	Mashrabiah from fig and olive tree pruning	Sidi Abdel Rahman	75000	10
	Sheep and goat skin preparation for tanning	The whole North-West Coast Region	1111500	40
	Sheep and goat tannary		5900000	20
Total			9701500	180

A suggested strategy to support industrial development in villages, oases and reclaimed lands

Following are the elements of suggested strategy to support industrial development in villages, oases and reclaimed lands:

- Launching of projects: on the regional and international levels for sharing of information and coordination in the area of development of SMEs, based on the agricultural resources as a base material for industrial activities.
- Launching – on the regional level – of research projects on the industrial use of renewable resources, as a springboard for establishment of joint industrial project.
- Support of establishment – on the national level – of NGOs in rangelands to support the rational management of rangelands, dissemination of industrial projects to improve the added value of agricultural resources, as well as the marketing of products.
- Establishment – on the level of each governorate – of a fund for support of local industrial projects to be financed by levies put on every hectare of cultivated land to support these industries withstand the pressures of globalization.
- Launching of national programmes for recording and preservation of traditional knowledge and technical heritage, associated with the use and manufacture of agricultural resources.
- Building of preferential systems on the level of governorates to support products, locally manufactured from agricultural resources.
- Establishment of permanent exhibitions to be put on the path of tourist movement with the purpose of helping the local artisans and investors market their products.
- Support of applied research on the manufacture of innovative products from agricultural resources.
- Support of pilot industrial projects of manufacture of new products from agricultural resources.
- Development of the curricula of the existing technical school and colleges (and the establishment of new ones) with the purpose of tuning the content of technical education and its profiling to suit the needs of development of each governorate. This tuning and profiling processes should be built on the deep understanding of the comparative and competitive advantages each governorate has in the manufacture of distinguished products.
- Establishment of technology incubators on the governorate level to search for the local entrepreneurs and support them in acquiring organizational skills, as well as new technologies to produce innovative products from agricultural resources.
- Support for participation in international fairs with the purpose of helping local producers market their products making use of the opportunities offered to them via niches for their products in the international market.

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3. Adobe architecture, between tradition and innovation

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Abstract

The most important thing that links people together is Earth; Indian wisdom says: "Soil and Soul belong together". One can easily feel and see the members of the family along with their neighbors and friends, happily preparing and working together to build their clay homes by using the earth as a building material. Unfortunately, the industrial revolution in the construction sector with its high technology achievements could not provide sufficient help to the settlement branch in our developing countries as promised. On the contrary for the last few years, we could create sustainable, economic, healthy and human settlements by applying and improving the traditional Adobe Architecture. According to the Kyoto Agreement in 1997, countries have agreed to reduce the use of the following productions until the year 2050: Reinforcing rods down to 80%; Aluminum down to 90%; and Cement down to 85%. The question arises as to how do we keep this agreement if we don't use the natural available building materials, i.e. clay and applying appropriate technology? This paper will review: (1) History of Clay Architecture; (2) Improvement methods of Adobe construction; (3) Examples of appropriate improved Adobe Architecture Projects in Egypt (Desert and urban area); Africa (Burkina Faso, Senegal, Somalia) and Asia (Saudi Arabia); and (4) Practical training of local crafts and students.

Keywords: Clay architecture, Examples of Adobe construction, Kyoto Agreement 1997, Training of local crafts

4. Assessment of impacts, adaptation and vulnerability to climate change in North Sinai region, Egypt

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Abstract

The livelihood vulnerability index (LVI) and the Intergovernmental Panel on Climate Change (IPCC) vulnerability index (IPCC-VI) approaches were used to assess the vulnerability of rural and urban regions of Sahl El Tina and Baloza areas, North Sinai Region, Egypt to climate change. Apparently, the region is highly vulnerable to salinity and drought that may be attributed to climate changes. The aim of the present study is to explore the socioeconomic drivers of climate change and their impacts on a farming community and to give an insight into possible mechanisms of future adaptation strategies. Equal numbers of rural and urban farmers, about 100-150 of each, were interviewed to collect information on human and natural capital, besides social, financial, and physical attributes impacted by climate changes. The study showed that drought is the most significant manifestation of climate change, especially in rural areas. Rural Sahl El Tina and Baloza communities are significantly more vulnerable to climate change than the urban community. Their isolation, illiteracy, lack of awareness, and fragile ecosystem are causes of vulnerability. The two areas in the regions showed high capabilities to overcome exposure threats to climate change. Adequate adaptive capacity of farmers is the main cause for their ability to overcome climate change impacts. These results might be explained in view of farmer local knowledge that helps them to survive even through the harshest times. The preliminary results showed that there was an overall reduction in crop yields under climate change even when adaptation was taken into account. Changes in crop variety, crop calendar, and irrigation, and the amount and nitrogen fertilization were the main options produced through the analysis steps. It is concluded that the involvement of the rural population and extension services in capacity building programs is an essential adaptation measure, with rapid information flow among and between these two groups.

Keywords: Livelihood vulnerability index, Climate change, Farmer's local knowledge

5. Rural women's empowerment in a dryland community: The case of the New Valley governorate, Egypt

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Abstract

The objectives of this study are to: i) Measure the rural women's empowerment level, and ii) Determine factors affecting it. Data were collected through personal interviews of 300 rural women (240 from Al-Mounirah village belonging to El-Kharga district and 60 from Al-Thaniyah village belonging to Darb El-Arbaien, Paris District), during the period from May to June 2016, using a questionnaire. Frequencies, percentages, range, average, standard deviation, weighted average (relative weight), T test, Pearson's simple correlation, Step-Wise Regression Analysis, and verification of hypotheses were used for data processing and presentation. Findings revealed that dimensions of rural women's empowerment could be ranked as social (relative weight = 60.8%), cognitive and psychological (RW = 60.7% for each), economic (RW = 58.7%), and finally the political dimension of empowerment (RW = 56%). Of the studied eleven independent variables, eight variables accounted for 71.9% of variance in rural women's economic empowerment, seven accounted for 61.7% of variance in political empowerment, eight accounted for 69.6% of variance in social dimension, one accounted for 4% and 1.6 of variance in cognitive and psychological dimensions, respectively. Results also indicated that the eight independent variables (family type, average of sons' education, average age of sons, family size, women's age, women's employment status, and husband's age) accounted for 63.4% of variance in rural women's overall empowerment. The study concluded that rural women's empowerment could be strengthened through support factors influencing it.

Keywords: Rural women, Empowerment, Drylands, New Valley (Egypt).

1. Introduction

In the Middle East and North Africa (MENA) countries agriculture is central to national economies and women have a central role in the generation of products. Gender relationships are fundamental to understanding the way farm work is organized inside the household and beyond, the way resources such as land, finance, labor, equipment are managed, and the way decisions are made. The potential of sustainable development and poverty reduction through social and economic growth will not be achieved unless there is a concerted effort by committed government and development agencies to work towards gender equality and women's empowerment (Abdelali-Martini, 2011).

There are five approaches to the planning of gender in the Third World as follows (Zuniga, 1993; Bhushan, 1998): 1.The wellbeing approach develops programs to provide goods to low incomes women, since they are in charge of their families, thus helping women to help their families. This kind of program only recognizes and reinforces the reproductive role of women. 2. The equity approach promotes the reduction of discrimination against women, through policies and programs and recognizes the productive role of women in society. 3.The anti-poverty approach assumes that women's poverty is caused by their lack of land, capital, training and employment. Thus, it promotes programs that empower women to generate income to overcome poverty. 4.The efficiency approach aims to guarantee that development is more proficient and compelling through women's economic contribution, with participation often equated with equity. Women are seen entirely in terms of their ability to compensate for declining social services by broadening their working day. 5. The empowerment approach perceives that the concept of gender is a sociocultural construct and brings out the social relation between men and women, in which women have been systematically subordinated.

Among the above five approaches, it is the empowerment approach that perceives the triple role of women in the family, economic production and the community, and suggests challenging the social structure and oppressive situation women have to suffer. Women have to expand their power not in terms of domination over others, but in terms of gains over their self-esteem and internal force. This implies women have the right to decide about their own life and to influence social change, through their capacity to gain control over crucial natural and cultural resources (Zuniga, 1993).

As indicated by Division for Sustainable Development of the UN (2015) empowering women and promoting gender equality is urgent to accelerating sustainable development. Finishing all forms of discrimination against women and girls is not only a fundamental human right, but it also has a multiplier impact over all other development areas. So, achieving gender equality and empower all women and girls is one of the UN's Sustainable Development Goals (SDGs). Gender equality and empowered women are catalysts for increasing development endeavors. Investments in gender equality yield the most astounding of all development investments. Increasing the role of women in the economy is part of the solution to the financial and economic crises and critical for economic resilience and growth (OECD, 2012a).

Kabeer (2001) defines empowerment as "the expansion in people's ability to make strategic life choices in a context where this ability was previously denied to them". Women's empowerment includes enhancing decision-making, control over income, awareness about personal rights and freedom, improving position in the family, and in general the confidence of rural women in their capacities (Parveen, 2007; Yasmin & Ikemoto, 2015). Empowerment is complex and multidimensional and it takes time to change profoundly-embedded power relations. However, this also means that there are numerous entry points and that, although empowerment doesn't happen incidentally, supporting empowerment in one domain – economic, social or political – will have positive effects in the others (OECD, 2012b).

There are five main domains for empowerment as follows (Stromquist, 1995; Malhotra, et. al., 2002; OECD, 2012b): 1. Economic empowerment: It is the capacity of women to practice control over their livelihoods through their capacity to make choices on what productive activities to engage and invest in, to choose how and when to engage in markets and to influence the terms on which they do so. 2.Political empowerment: It is about impacting policy, making demands and calling the state to account. In its absence an enabling environment for pro-poor growth is impossible. Political empowerment is a perplexing process that happens in the always moving and obscured limits of state-society relations. 3. Social empowerment: It is about finding a way to change society so that one's own particular spot inside it is respected and recognized on the terms on which the individual or group wants to live, not on terms dictated by others. A feeling of autonomy and self-value is an important and direct contributory factor for enabling somebody to participate in politics and take optimum advantage of services, such as health and education. 4. Cognitive empowerment: It refers to women's understanding of their conditions of subordination and the reasons of such conditions at both micro and macro levels of society. It includes gaining new knowledge to make an alternate comprehension of gender relations as well as destroying old beliefs that structure powerful gender ideologies, knowledge about their sexuality and legitimate rights. 5. Psychological empowerment: It incorporates the development of feelings that women can act at individual and societal levels to enhance their condition as well as the formation of the belief that they can succeed in their change endeavors.

Rural women make major and multiple contributions to accomplishing food security and production of the food for household consumption and for sale as well as continuing their critical role in terms of reproduction; their activities are not defined as "economically active employment" in national accounts but are essential to the well-being of their households. Their capability to do so is limited by multiple and diverse constraints by persistent structural gender disparities that prevent them from enjoying their economic and other rights (Hill, 2011). Empowerment of rural women is dependent on several factors, including ownership and control over land; access to diverse types of employment and income-generating activities; access to public goods (such as water, village commons and forests), infrastructure, education and training, health care, financial services and markets; and opportunities for participation in political life and in the design and execution of policies and programs (United Nations, 2015).

Agriculture is a major sector in the Egyptian economy (55% of the population depends on it) and it represents about 13% of GDP and 20% of total exports and foreign currency earnings. Egypt has one of the lowest man / land ratios in the world with about 8.9 million feddans (1 feddan=0.4 ha) to 3.7 million farmers. The total cultivated area is estimated to be 3% only of the total land area; farms are generally small, 81% of them cover less than three feddans. Agriculture accounted for high percent of female employment and it is still the most important sector for female employment in sub-Saharan Africa and Asia (United Nations, 2015). Human Development Index (HDI) in 2015 was 0.690, ranking Egypt at the 108th place among 188 middle-income countries (UNDP, 2015).

Moreover, Egypt still performs poorly on gender equality and the empowerment of women, especially when it comes to women's education, wage employment and political participation. Gender-based HDI is 0.868, ranking Egypt among the 5th group countries (Countries are divided into five groups by absolute deviation from gender parity in HDI values), its value reached 0.633 for females compared to 0.729 for males (UNDP, 2015). Egypt ranked 77 out of 80 countries on the Gender Empowerment Measure with a GEM value of 0.274 where the percentage of women in decision-making was 9% in technical and professional positions and the ratio of estimated female to male earned income was 0.26. According to the World Economic Forum (2015), Egypt is ranked 136 among 145 countries with Global Gender Gap (GGG) index value of 0.599.

Since the Fourth World Conference on Women held in Beijing in 1995, the Egyptian government has been dynamic in bridging the gender gaps in fields like health and education and in redressing gender unfair legislations. There is a solid political commitment at the highest level to advance the status of women and a National Council for Women (NCW) was established in 2001 with a wide mandate, huge staff and government budget, and a network of branches in all governorates.

The New Valley governorate (with five administrative districts) is located in the south-west part of western desert of Egypt. It represents about 44% of the total area of Egypt, and 67 % of the total area of Egyptian western desert. The question addressed in this paper is: What is the status of rural women's empowerment in the New Valley governorate? In other words, how rural women assess their status of empowerment? The objectives of this study were to: i) measure the rural women's economic, political, social, cognitive, and psychological empowerment level and ii) determine factors affecting the empowerment.

2. Methodology

Two districts (El-Kharga and Paris) were randomly selected from the new valley's five districts. Two villages (Al-Mounirah and Al-Thaniyah) were then randomly selected, one from each district, for this study. To identify the sample size, the study used the table of Krejcie and Morgan (1970) for determining sample size from a given population. The population of this study was 706 at Al-Mounirah and 80 at Al-Thaniyah village. The sample size was 248 family from Al-Mounirah and 66 from Al-Thaniyah village. Data were collected from 300 rural women (240 from Al-Mounirah and 60 from Al-Thaniyah village), during the period from May to June 2016, through personal interviews using a questionnaire.

The questionnaire was designed and pre-tested for achieving the study objectives. It included sets of questions to measure the independent variables, as follows: 1) Respondent's age: 2) Husband's age; 3) Respondent's level of education: number of respondents' official education years, 4) Husband's education; 5) Family type: 1 = simple, 2 = complex, 3 = extended; 6) Family size; 7) Average age of children; 8) Average of level of education of children; 9) Respondent's employment status: 1 = not employed, 2 = government employee, and 3 = self-employed; 10) Farm land ownership: 1 = none, 2 = one feddan or less, and 3 = more than one feddan; and 11) Livestock ownership: measured by number of farm animals in sheep equivalents (where one large animal was counted as five sheep and two goats as one sheep).

With regard to the dependent variable, 'rural women's empowerment', was quantified using the dimensions in accordance with OECD (2012b) and Stromquist (1995). The dimensions used are: 'economic empowerment', 'political empowerment', 'social empowerment', 'cognitive empowerment', and 'psychological empowerment'. Each dimension further contains four statements which have been identified and pre-tested to measure the dimension. Rural women were asked to indicate their opinion on the empowerment statements; their response were based on a five-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3= no opinion, 4 = agree, and 5 = strongly agree). The responses for each dimension ranged from 4 to 20; these responses were divided in three categories: low (score 4 – 9), medium (score 10 – 15) and highly empowered (score 16 – 20). Addition of the score of five dimensions resulted in the total score of empowerment. Respondents were classified into three categories: low (20 – 46 scores), medium

(47 – 73 scores), and highly empowered (74 – 100 scores). The reliability of the scale (0.849) was estimated by Cronbach's alpha. The relative weight (RW) or weighted average of rural women's empowerment was calculated according the following formula after giving weights of 1, 2, and 3 for the categories of low, medium and highly empowered, respectively: RW = ((Sum (category's individuals * category's weight) / (total sample size * greater weight))*100.

In order to achieve the second objective, sixty-six hypotheses (H1.1. to H6.11) were formulated as follows: Rural women's economic empowerment is significantly affected by the eleven studied variables (Rural women's age (H1.1), Husband's age (H1.2), Rural women's education level (H1.3), Husband's education level (H1.4), Family type (H1.5), Family size (H1.6), Average age of children (H1.7), Average education level of children (H1.8), Rural women's employment status (H1.9), Farm land ownership (H1.10), and Livestock ownership (H1.11)). Women's political empowerment is significantly affected by the eleven studied variables (hypotheses H2.1 to H2.11). Rural women's social empowerment is significantly affected by the eleven studied variables (hypotheses H3.1 to H3.11). Rural women's cognitive empowerment is significantly affected by the eleven studied variables (hypotheses H4.1 to H4.11). Rural women's psychological empowerment is significantly affected by the eleven studied variables (hypotheses from H5.1 to H5.11). Finally rural women's overall empowerment is significantly affected by the eleven studied variables (hypotheses from H6.1 to H6.11). Frequencies, percentages, range, average, standard deviation, weighted average (relative weight), t test, Pearson's simple correlation, Step-Wise Regression Analysis, and hypotheses verification were used for data processing and presentation.

3. Results and discussions

3.1 Characteristic of the study's sample

Results (Table 1) show that the age of respondents ranged between 21 to 60 years. The majority (57.3%) are over 46 years old. The majority (66.3%) have low educational level. The majority (59%) are belonging to the type of simple family with a family size less than six members (62.3%). More than two-fifths (41%) of their children are young (≥21 years old) and educated with average of ≥12 years of official education. With regard to their employment, the findings showed that the majority of respondents (69%) were not employed, 79.6% of them were non-owners of farmlands. Nearly half of the respondents had low level of livestock ownership.

3.2 Level of rural women's empowerment

In order to investigate the mean differences of women's empowerment in the two studied villages, the means were compared by t test. With a degree of freedom (df) of 298, the difference between the two means was 1.67, SED was 2.53, t value was 0.658 (not significant at P=0.05), suggesting that there are no differences in rural women's empowerment in the two studied villages. Therefore, the results of both samples were combined for further analysis.

Results in Table 2 indicate that mean score of dimensions of women's empowerment ranged from 10.33 to 11.72, the highest relative weight (RW) being of social empowerment (60.78%) followed by cognitive empowerment and psychological empowerment (60.57% for each). The economic and political empowerments were in the last with RW reaching about 58.67% and

56.33%, respectively. It is thus clear that rural women's perception of their social empowerment was the highest identifiable dimension of their empowerment, while the political dimension was the lowest. These results reflected on the total number of rural women's empowerment. The highest proportion of respondents (44.6%) was 'medium empowered'. The number of the 'less empowered' was next (35.7%). The number of highly empowered women was the least (19.7%), as indicated in Table 2.

Table 1. Distribution of rural women by their studied characteristics (n = 300)

No.	Variables	Range		Mean (mode*)	S.D.	Categories					
						Low		Medium		High	
		Min.	Max.			F	%	F	%	F	%
X1	Rural women's age	21	60	44.82	11.86	65	21.7	63	21.0	172	57.3
X2	Husband's age	25	62	48.97	11.74	65	21.7	91	30.3	144	48.4
X3	Rural women's education level	0	16	5.62	6.58	199	66.3	41	13.7	60	20.0
X4	Husband's education level	0	16	7.58	6.47	147	49.0	69	23.0	84	28.0
X5	Family type	1	3	1*	-	177	59.0	109	36.3	14	4.7
X6	Family size	3	11	5*	-	187	62.3	79	26.3	34	11.3
X7	Average age of children	1	30	17.30	9.58	103	34.3	74	24.7	123	41.0
X8	Education level of children	1	16	8.41	5.57	103	34.3	69	23.0	128	42.7
X9	Women's employment status	1	3	1*	-	207	69.0	62	20.7	31	10.3
X10	Farm land ownership	1	3	1*	-	239	79.6	50	16.7	11	3.7
X11	Livestock ownership	5	84	34.7	15.32	139	46.3	105	35.0	56	18.7

Table 2. Distribution of rural women by their level of empowerment

No.	Dimensions of Empowerment	Range		Mean	S. D.	Categories						RW (%)
						Low (4 – 9)		Medium (10 – 15)		High (15 – 20)		
		Min.	Max.			F	%	F	%	F	%	
y1	Economic empowerment	4	19	11.67	4.97	134	44.6	104	34.7	62	20.7	58.67
y2	Political empowerment	4	18	10.33	4.89	152	50.6	89	29.7	59	19.7	56.33
y3	Social empowerment	4	19	11.72	4.06	120	40.0	113	37.7	67	22.3	60.78
y4	Cognitive empowerment	4	19	11.49	4.11	128	42.6	98	32.7	74	24.7	60.67
y5	Psychological empowerment	4	19	11.49	4.09	125	41.6	104	34.7	71	23.7	60.67
Y	Overall empowerment	20	94	56.70	17.54	107	35.7	134	44.6	59	19.7	61.33

3.3 Factors affecting rural women's empowerment

Pearson's correlation coefficient was used to determine the direction, strength, and significance of the bivariate relationships of the variables in the study. Table 3 shows that nine variables were significantly correlated with the economic empowerment (y1) at 0.01 level of probability. These variables are: women's age (X1), husband's age (X2), women's education level (X3), family type (X5), family size (X6), average age of children (X7), level of children's education (X8), women's employment status (X9) and farm land ownership (X10). Ten variables highly correlated with political empowerment (y2), nine of them at 0.01 level of significance (namely: women's age, husband's age, women's education level, husband's educational level, family type, family size, average age of children, level of children's education (X8), and farm land ownership (X10). The women's employment status was significant only at 0.05 level of probability. Findings also revealed that there are nine variables significantly related with social empowerment (y3): women's age, husband's age, women's education level, family type, family size, average age of children, level of children's education, women's employment status and farm land ownership.

With regard to rural women's cognitive (y4) empowerment, there were significant correlation coefficients with five variables namely: family type, family size, level of children's education, women's employment status and farm land ownership. Three variables namely: family type, family size, and farm land ownership were significantly related with psychological empowerment (y5).

Table 3. Pearson's correlation coefficients between level of rural women's empowerment and the studied variables

No.	Variables	Dimensions of empowerment					Total
		Economic	Political	Social	Cognitive	Psychological	
	Women's age	0.262**	0.288**	0.159**	0.071	0.019	0.212**
	Husband's age	0.294**	0.312**	0.211**	0.089	0.048	0.251**
	Somen's education level	-0.265**	-0.276**	-0.199**	-0.111	-0.082	-0.243**
	Husband's education level	-0.084	-0.306**	-0.089	-0.090	-0.073	-0.088
	Family type	0.549**	0.521**	0.465**	0.207**	0.132*	0.461**
	Family size	0.546**	0.537**	0.463**	0.188**	0.132*	0.486**
	Average of age of children	0.329**	0.345**	0.244**	0.088	0.056	0.280**
	Education level of children	0.339**	0.348**	0.261**	0.133*	0.056	0.298**
	Women's employment status	0.165**	0.142*	0.153**	0.130*	0.084	0.172**
	Farm land ownership	0.322**	0.272**	0.330**	0.196**	0.140*	0.332**
	Livestock ownership	-0.051	-0.041	-0.028	0.070	0.051	-0.004

Table 3 indicates that the level of women's over all empowerment (Y) was significantly related with ten variables at 0.01 level of probability (X1 to X10). The livestock ownership had no relation with any dimension of empowerment. Also, husband's level of education was not related with the economic, social, cognitive, and psychological empowerment of women.

In order to investigate the contribution of the studied independent variables in interpretation of variance in the studied dependent variables (dimension of women's empowerment), step-wise regression analysis was used. Results are presented below.

3.3.1 Factors impacting rural women's economic empowerment

Table 4 shows the strength of the relationship between the model and the dependent variable, rural women's economic empowerment (y1). R indicates correlation between the observed and predicted value of the dependent variable. Larger value of R indicates stronger relationship and also indicates that model fits the data well. R^2 is the proportion of variation in the dependent variable explained by regression model. Higher value of R^2 (0.726) indicates that model had good predictive ability. The regression analysis showed that eight independent variables (i.e. family type, family size, average age of children, average educational level of children, women's age, women's education level, husband's age, and women's employment status) had positive (R = 0.852) and statistically significant relationship (P 0.000 < 0.01) with women's economic empowerment (dependent variable y1). The independent variables accounted for 71.9 percent (adjusted R^2 = 0.719) of variance in dependent variable. Table 4 further revealed that the most significant factor impacting women's economic empowerment is family type (X5) with largest percent of explained variance (29.9%) and other significant factors with high predictive ability are average education level of children, average age of children and rural women's age, in the decreasing order of importance, while the lowest significant factors impacting rural women's economic empowerment were husband's age and women's employment status. The observed t values of all factors in the model were significant at 0.01 level of probability. In summary, there was sufficient statistical evidence to support hypotheses H1.1, H1.2, H1.3, H1.5, H1.6, H1.7, H1.8 and H1.9.

Table 4. Accumulative effect of studied variables on rural women's economic empowerment

Model	Variables	R	R2	Adjusted R2	% of explained variance	F	t
1st	Family type (X5)	0.549	0.301	0.299	29.90	128.54**	11.34**
2nd	Family size (X6)	0.570	0.324	0.320	2.08	71.29**	3.18**
3rd	Average age of children (X7)	0.676	0.457	0.451	13.17	83.03**	-8.50**
4th	Education level of children (X8)	0.798	0.637	0.632	18.05	129.34**	12.09**
5th	Women's age (X1)	0.826	0.682	0.676	4.45	126.01**	-6.45**
6th	Women's education (X3)	0.843	0.711	0.705	2.87	120.15**	5.44**
7th	Husband's age (X2)	0.848	0.719	0.712	0.69	106.62**	-2.84**
8th	Women's employment status (X9)	0.852	0.726	0.719	0.65	96.43**	2.79**

3.3.2 Factors impacting rural women's political empowerment

With regard to factors affecting rural women's political empowerment (y2), Table 5 shows that it was significantly (P 0.000 < 0.01) related to seven independent variables (i.e. family size, average age of children, average educational level of children, family type, women's age, women's education level, and husband's education level). The independent variables accounted for 61.7% (adjusted R^2 = 0.617) of variance in the dependent variable (y2). The most significant factor impacting political empowerment was family size, followed by the level of education of children, age of children, family type, women's age, women's education level and husband's educational level, in the decreasing order of importance.

Table 5. Accumulative effect of studied variables on rural women's political empowerment

Model	Variables	R	R^2	Adjusted R^2	% of explained variance	F	T
1st	Family size (X6)	0.537	0.288	0.286	28.60	120.79**	10.99**
2nd	Average age of children (X7)	0.62	0.385	0.381	9.48	92.959**	-6.83**
3rd	Level of children's education (X8)	0.702	0.492	0.487	10.64	95.70**	7.91**
4th	Family type (X5)	0.735	0.541	0.534	4.71	86.76**	5.56**
5th	Rural women's age (X1)	0.753	0.568	0.560	2.61	77.21**	-4.29**
6th	Women's education level (X3)	0.77	0.593	0.585	2.48	71.28**	4.31**
7th	Husband's education level (X4)	0.775	0.626	0.617	3.22	69.91**	-2.19*

3.3.3 Factors impacting rural women's social empowerment

Table 6 shows the result of regression analysis of the relationship of nine independent variables (i.e. family type, women's age, educational level of children, family size, women's education level, women's employment status, age of children, farm land ownership, and husband's age) with women's social empowerment (y3). There was a positive and statistically significant (P 0.000 < 0.01) relationship (R = 0.840) with this dependent variable (y3). The independent variables accounted for 69.6% of variance (adjusted R^2 = 0.696) in women's social empowerment. Findings also revealed that factors impacting women's social empowerment could be ranked as: educational level of children, family type, family size, women's education level, women's age, women's employment status, age of children, farm land ownership, and finally husband's age, in decreasing order of importance. The observed t values were significant at 0.01. The findings imply that there was sufficient statistical evidence to support hypotheses H3.1, H3.2, H3.3, H3.5, H3.6, H3.7, H3.8, H3.9 and H3.10.

Table **6.** Accumulative effect of studied variables on rural women's social empowerment

Model	Variables	R	R^2	Adjusted R^2	% of explained variance	F	T
1st	Family type (X5)	0.465	0.216	0.213	21.35	82.14**	9.063**
2nd	Rural women's age (X1)	0.51	0.260	0.255	4.20	52.30**	-4.220**
3rd	Education level of children (X8)	0.697	0.486	0.481	22.55	93.34**	11.402**
4th	Family size (X6)	0.762	0.581	0.576	9.48	102.41**	8.191**
5th	Women's education (X3)	0.808	0.653	0.647	7.18	110.85**	7.817**
6th	Women's employment status (X9)	0.827	0.684	0.678	3.00	105.71**	5.328**
7th	Age of children (X7)	0.833	0.694	0.686	0.88	94.46**	-3.034**
8th	Farm land ownership (X10)	0.837	0.701	0.693	0.66	85.33**	2.696**
9th	Husband's age (X2)	0.840	0.705	0.696	0.33	77.15**	-2.046*

3.3.4 Factors impacting rural women's cognitive empowerment

Family type (X5) had positive (R = 0.207) and statistically significant relationship (P 0.000 < 0.01) with this dependent variable (y4) (Table 7). But it accounted for only 4% (adjusted R^2 = 0.040) of variance in dependent variable. The observed t value was significant at 0.01 level of probability. There was thus sufficient statistical evidence to support the hypothesis H4.5.

Table **7.** Effect of studied variables on rural women's cognitive empowerment

Model	Variables	R	R Square	Adjusted R Square	% of explained variance	F	T
1^{st}	Family type (X5)	0.207	.043	.040	4.00	13.41^{**}	3.66^{**}

3.3.5 Factors impacting rural women's psychological empowerment

Table 8 reports the relationship between the model and the rural women's psychological empowerment (y5). Farmland ownership had positive (R = 0.207) and statistically significant (P 0.000 < 0.05) relationship with this dependent variable (y5). The observed t value of the factor (X10) in the model was significant at 0.05 level of probability. Thus, there was sufficient statistical evidence to support the hypothesis H5.10.

Table 8. Effect of studied variables on rural women's psychological empowerment

Model	Variable	R	R Square	Adjusted R Square	% of explained variance	F	T
1^{st}	Farm land ownership (X10)	0.140	0.020	0.016	1.6	5.99^{*}	2.45^{*}

3.3.6 Factors impacting rural women's overall empowerment

Table 9 shows the result of regression analysis for the overall empowerment (Y). Eight independent variables (family type, women's age, educational level of children, family size, age of children, women's education level, women's employment status and husband's age) had positive (R = 0.802) and statistically significant (P 0.000 < 0.01) relationship with rural women's overall empowerment. The independent variables accounted for 63.4% (adjusted R^2 = 0.634) of variance in this variable (Y). The most significant factor was family type, followed by the educational level of children. The observed t values of X5, X1, X8, X6, X7, X3 and X10 were significant at 0.01 level of probability, whereas observed t value of husband's age was significant at 0.05. Thus, there was sufficient statistical evidence to support the hypotheses H5.1, H5.2, H5.3, H5.5, H5.6, H5.7 H5.8 and H5.10.

Table 9. Accumulative effect of studied variables on rural women's overall empowerment

Model	Variables	R	R Square	Adjusted R Square	% of explained variance	F	T
1^{st}	Family type (X5)	0.488	0.238	0.236	23.56	93.15^{**}	9.651^{**}
2^{nd}	Women's age (X1)	0.513	0.264	0.259	2.30	53.15^{**}	-3.203^{**}
3^{rd}	Education level of children (X8)	0.671	0.450	0.444	18.54	80.59^{**}	10.002^{**}
4^{th}	Family size (X6)	0.726	0.528	0.521	7.72	82.37^{**}	6.979^{**}
5^{th}	Age of children (X7)	0.778	0.606	0.599	7.80	90.39^{**}	-7.642^{**}
6^{th}	Women's education level (X3)	0.789	0.622	0.614	1.50	80.35^{**}	3.531^{**}
7^{th}	Women's employment status (X10)	0.798	0.637	0.628	1.41	73.21^{**}	3.481^{**}
8^{th}	Husband's age (X2)	0.802	0.643	0.634	0.52	65.61^{**}	-2.264^{*}

4. Conclusion

The study showed the dimensions of rural women's empowerment could be ranked according to their relative weights as 'social empowerment', followed by 'cognitive', 'psychological', 'economic', and 'political' empowerment. Of the eleven independent variables, nine were significantly (eight positively, and one negatively) correlated with women's economic empowerment, ten were significantly (eight positively, and two negatively) correlated with political empowerment, nine were significantly (eight positively, and one negatively) correlated with social empowerment, five and three significantly and positively correlated, respectively, with cognitive and psychological dimensions of women's empowerment. Nine independent variables significantly (eight positively, and one negatively) correlated with women's overall empowerment.

The ownership of livestock was not significantly correlated with any dimension of women's empowerment. The education level of rural women was significantly and negatively correlated with 'economic', 'political', 'social' dimensions of empowerment and overall women's empowerment. The education level of husband also significantly and negatively correlated with women's political empowerment. The remaining independent variables had positive correlation coefficients.

This study also sought to analyze the impact of demographic variables in empowering the rural women. Multiple regression analysis revealed that eight factors (family type, family size, average age of children, level of education of children, women's age, women's education level, husband's age, and women's employment status) significantly influenced rural women's economic empowerment. Finally, eight factors (family type, women's age, educational level of children, family size, age of children, women's education level, women's employment status and husband's age) significantly influenced rural women's overall empowerment.

Traditionally, rural women's role was to provide support to their husband and family, which was indicative of the suppression of women in rural household. The results of this study show that rural women's empowerment was impacted by their socio-economic conditions. Governments and development partners can play an important role in helping strengthen rural women's empowerment through support factors influencing empowerment stated in this study. This study also provides future directions to the academics and practitioners who want to work on this area to enrich the literature related to women empowerment. Moreover, future studies may explore developing multi-dimensional indicators to measure rural women empowerment including dimensions that were not included in this study, such as personal, legal, interpersonal dimensions, to gain better understanding and arrive at good generalization.

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6. Maximizing the use of wild medicinal plants for the development of populations in the South East of Egypt

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Abstract

This study was conducted in the area from Shalateen to Halayeb in South East of Egypt. The study aimed at maintaining and organizing the use of medicinal wild plants to maximize the economic return to the Bedouins in this area, and also to increase their share in the total market value of medicinal plants that they collect and add value to. Forty-six stands representing 13 localities were selected to study the distribution, habitat, density, productivity, chemical composition, and active materials of the medicinal plants in the study area. The marketing study was conducted through the survey of the local market to determine the types of products to be developed (oil extraction, herbal teas, wholesale), the types of customers and their requirements, create a brand for the products, and develop the packaging and design holder for the products. Forty-four medicinal and aromatic plant species were recorded in the study area. These plants are distributed in eight habitats. The highest density was recorded of *Zygophyllum simplex*, followed by *Rumex vesicarius* and *Chenopodium murale. Rhizophora mucronata* had the highest productivity followed by *Avicenna marina* and *Lycium shawii*. The ash content ranged between 3.34% (*Balanities aegyptiaca*) and 32.86% (*Salvadora persica*). Tannins, saponins and alkaloid contents were also evaluated. The marketing study revealed that more than 50% of the herbs exported were sold in bulk. None of the herbs most requested for export was from Shalateen. The local marketing and the customers of five medicinal species selected from these species were surveyed. The package type and form of these plants were designed and named as Shala-Tea products. These plants are: senna (*Senna italica*), lavender cotton (*Achillea fragrantissima*), desert dates (*Balanities aegyptiaca*), bitter apple (*Citrullus colocynthis*), Kaf Mariam (*Anastatica hierochuntica*), and hibiscus (*Hibiscus sabdariffa*).

Keywords: Bedouins, Wild medicinal plants, Value addition, Marketing

Introduction

Large human population in developing countries is dependent on plant resources for healthcare because although allopathic medicines can cure a wide range of diseases, their high price and occasional side-effects are causing many people to return to herbal medicines, which tend to have fewer side effects (Baqar, 2001). Herbal medicines are being used by about 80% of the world population, primarily in the developing countries, for primary health care (Dubey *et al.,* 2004). In developing countries, low-income people such as farmers, people of small isolated villages and native communities having no access to modern medicines depend on traditional medicines and use many native plants for the treatment of common diseases. In last few decades, traditional knowledge on primary healthcare has been widely acknowledged across the world. It is estimated that 60% of the world population and 80% of the population of developing countries rely on traditional medicine, mostly plant drugs, for their primary health care needs (Shrestha and Dhillion, 2003). Therefore, there is an urgent need to document the medicinal and aromatic plants associated with traditional knowledge, because this knowledge is orally passed on from one generation to the next and is vulnerable to be lost (Baqar, 2001).

Shalateen-Halayib area is a region located in the far south eastern Egypt on the African side of the Red Sea, with an area of 35,600 square kilometers. It is located between latitudes 22 and 23.30 N and longitude between 34.5 and 37 E. There are three major towns: Halayib, Abu Ramad and Shalateen. The area is characterized by the enormous of plant diversity in mountains and valleys of the region. There being conducive environments for different plant species, there are some 350 species found here, many of which are of medical importance.

This study aimed at ensuring maintenance of medicinal wild plants and organize their use to maximize the economic return in the Shalateen - Halayib area. The objective was also to develop the value chain in order to support establishing a complete industry from the farm to international markets.

Materials and methods

During this work, spanning over 50 days, the vegetation of the Red Sea Coast sector from Shalateen to Halayb, passing through Abu Ramad, was surveyed. Forty-six stands were selected according to the degree of change in the floristic composition and abundance of medicinal species. The vegetation type included seven stands in Wadi Abraq, eight in Wadi Kansosroob, seven in Wadi Marafi, four in Wadi Hodein, two in Wdi El- Deef, and one in Wadi Abu Sahfa, four in Adaldeed, five in Sharm El- Medifa, two in Ras Hederiba, and one in each of Wadi Lahmey, Wadi Ezab, Wadi D’eyeb and Wadi Sarmatai (Plate 1).

In each selected stand, a list of species was recorded and 3 randomly quadrates (10 x 10 m) were made. According to Muller-Dombois and Ellenberg (1974), species density was calculated per unit area. Taxonomic nomenclature followed Tackholm (1974) updated by Boulos (1995).

The fresh weight and dry weight of the dominant medicinal species were determined in each stand. One-fourth of the new areal parts of ten individual plants was collected randomly during the winter season. The fresh weight was determined. The plant materials were cleaned dried in a sun drier at 30 - 55°C for 48 hour to determine the productivity of the dominant medicinal species. The percentage of water content was estimated according to Rowell (1994).

Phytochemical analysis of the aerial parts of 27 plant species belonging to different families was performed for the following constituents: glycosides, alkaloids, flavonoids and/or phenolics, saponins, tannins, unsaturated sterols and/or triterpenes. The total flavonoids were determined spectrophotometerically by the method described by Karawya and Aboutable (1982). The total alkaloids were estimated using two methods the acid-base titration and the gravimeteric methods as described by Balbaa (1986) and Woo et al. (1977). The total tannins were estimated according to Makkar and Goodchild (1996). Phenolics content was determined according to Pulido et al. (2000).

PSh= Perennial shrub, T= tree, PHb= Perennial herb, PGr= Prennial grass, Su= succulent, An= annual.
1= alkaloids, 2= flavonoids, 3= saponins, 4= tannins, 5= terpenoids, 6= steroids

Plate 1. Locations in surveyed area.

The marketing study was conducting through the survey of the local market. This included determining the situation of the local market (the suppliers and their sizes), identifying the potential retailers of our final products (pharmacies, herbalists, bazaars, etc.), and determining the types of products to be developed (extracted oils, herbal teas, wholesale). The marketing plan included product development (according to the types of customers and their requirements) and packaging and labeling (to create a brand for our products, develop the packaging and design a holder for the products). Under the market research, some field research was also conducted by visiting pharmacies, kiosks and the hypermarket in Shalateen. This research was conducted in the form of a questionnaire distributed to companies from various industries (pharmaceutical, herbal teas, herbs and seeds, cosmetics, homeopathy centers and organic product distributers). The concerned companies were contacted by telephone and e-mails; the questionnaire included the names of the r plants identified in the region.

Results

Vegetation

Seven habitats were distinguished in the studied area between Shalateen and Halayeb. These were wadi bed, salt marshes, coastal desert, coastal sand dunes, mangrove, Delta wadi and rocky slopes of mountain. Sixteen species were recorded in wadi bed, ten in rocky slopes of mountain, eight in salt marshes, three each in both coastal sand dune and coastal desert, while two species were recorded each in both of delta of wadies and mangrove habitats (Table 1).

Forty-four species were promising as medical species belonging to 34 genera, representing 26 families in the study area. The highest number of species belonged to Fabaceae (7), followed by

Chenopodiaceae (5), Zygophyllaceae (4), Asteraceae (2), Cucurbitaceae (2), Euphorbiaceae (2) and Urticaceae, while the other families were represented by less than two species. Four species belonged to *Zygophyllum* genus, two species each belonged to genus *Senna*, *Euphorbia* and *Forsskaolea*. The other genera were represented by only one species (Table 1).

Table 1. List of medicinal species recorded in the study area, and their families, life forms, and active materials constituents

Species	Family	Life Form	Habitats
Abutilon pannosum (G. Forst.) Schltdl.	Malvaceae	PSh	Wadi bed
Acacia tortilis (Forssk.) Hayne subsp. *tortilis*	Fabaceae	PHSh	Wadi bed
Achillea fragrantissima (Forssk.) Sch. Bip.	Asteraceae	PSh	Wadi bed
Aeluropus littoralis (Gouarn) Parl.	Poaceae	PG	Coastal sand dunes
Aerva javanica (Burm.f.) Juss. ex. Schult.	Amaranthaceae	PSh	Wadi bed
Arthrocnemum macrostachyum (Moric) Koch.	Chenopodiaceae	PSh,Su	Salt marshes
Atriplex farinose Forssk.	Chenopodiaceae	PSh	Coastal sand dunes
Avicennia marina (Forssk.) Vierh.	Avicenniaceae	T	Mangrove
Balanities aegyptiaca (L.) Delile.	Balanitaceae	T	Rocky slopes of mountain
Chenopodium murale L.	Chenopodiaceae	An	Rocky slopes of mountain
Citrullus colocynthis (L.) Schrader.	Cucurbitaceae	PHb	Wadi bed
Cotula cinerea Delile.	Asteraceae	An	Wadi bed
Crotalaria aegyptiaca Benth.	Fabaceae	PSh	Wadi bed
Cucumis prophetarum L. subsp.*prophetaru*	Cucurbitaceae	PHb	Rocky slopes of mountain
Cyperus laevigatus L. var. *laevigatus*	Cyperaceae	PGr	Salt marshes
Euphorbia consobrina N.E.Br.	Euphorbiaceae	PSh	Rocky slopes of mountain
Euphorbia cuneata Vahl.	Euphorbiaceae	PSh	Rocky slopes of mountain
Forsskaolea tenacissima L.	Urticaceae	An	Wadi bed
Forsskaolea viridis Ehrenb. ex Webb.	Urticaceae	An	Rocky slopes of mountain
Halopeplis perfoliata (Forssk.) Bunge ex. Ung. Sternb	Chenopodiaceae	PSh,Su	Salt marshes
Indigofera articulate Gouan.	Fabaceae	PSh	Delta wadi
Juncus rigidus Desf.	Juncaceae	PHb	Salt marshes
Leptadenia pyrotechnica (Forssk.) Decne.	Asclepiadaceae	PSh	Wadi bed
Limonium axillare (Forssk.) Kuntze	Plumbaginaceae	PSh	Salt marshes
Lycium shawii Roem. & Schult.	Solanaceae	PSh	Wadi bed

Species	Family	Life Form	Habitats
Maerua crassifolia Forssk.	Capparaceae	T	Slopes
Morettia philaeana (Delile.) DC.	Cruciferae	PSh	Rocky slopes of mountain
Panicum turgidum Forssk.	Gramineae	PGr	Delta wadi
Plantago afra L.	Plantaginaceae	An	Rocky slopes of mountain
Reseda pruinosa Delile.	Resedaceae	PHb	Wadi bed
Rhizophora mucronata Lam.	Rhizophoraceae	T	Mangrove
Rumex vesicarius L.	Polygonaceae	An	Rocky slopes of mountain
Salvadora persica L. var. *persica*	Salvadoraceae	PSh	Rocky slopes of mountain
Senna alexandrina Mill.	Fabaceae	PSh	Wadi bed
Senna italica Mill.	Fabaceae	PSh	Wadi bed
Suaeda monoica Forssk ex J. F. Gmel.	Chenopodiaceae	PSh	Salt marshes
Tamarix nilotica (Ehrenb.) Bunge.	Tamaricaceae	PSh	Salt marshes
Taverniera aegyptiaca Boiss.	Fabaceae	PSh	Salt marshes
Tephrosia purpurea (L.) Pers. ssp. *apollinea* (Delile)	Papilionoideae	PSh	Wadi bed
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	T	Wadi bed
Z ygophyllum album L.	Zygophyllaceae	PSh,Su	Coastal sand dunes
Zygophyllum *coccineum* L.	Zygophyllaceae	PSh,Su	Coastal desert
Zygophyllum decumbens Delile	Zygophyllaceae	PSh,Su	Coastal desert
Zygophyllum simplex L.	Zygophyllaceae	An	Wadi bed

PSh= Perennial shrub, T= tree, PHb= Perennial herb, PGr= Prennial grass, Su= succulent, An= annual. 1= alkaloids, 2= flavonoids, 3= saponins, 4= tannins, 5= terpenoids, 6= steroids

According to the survey, the vegetation type of the area was as follows.

Mangrove vegetation

It was dominated by *Avicennia marina* community and *Rhizophora mucronata* mixed with *A. marina* as a codominant or as an abundant associate, or as pure stands. The density of *A. marina* ranged between 1- 7 individual/100m² with an average of 3.4 individual/100m², while the density of *R. mucronata* ranged between 2-3 individual/100m² with an average of 2.5 individual/100m².

Salt marsh vegetation

Most of plant species in this habitat were halophytes. The vegetation included the following communities:

1. ***Limonium axillare* community:** the common species present are *Halopeplis perfoliata,* and less common associates include *Arthrocnemum glaucum, Panicum turgidum, Taverniera aegyptiaca* and *Zygophyllum coccineum* and *Zygophyllum simplex* as annual plant.

2. ***Aeluropus lagopoides* Community:** The most common associates are *Cyperus lagopoides* L., *Sporobolus spicatus* and *Zygophyllum album* while common ones are *Arthrocnemum glaucum, Halopeplis perfoliata, Limonium axillare* and *Tamarix nilotica* and one annual: *Zygophyllum simplex*.

3. ***Sporobolus spicatus* community:** The perennial associates include *Cyperus laevigatus, Limonium axillare, Zygophyllum album* and *Panicum turgidum;* as annual plant *Zygophyllum simplex.*

4. ***Zygophyllum album* community:** The associates include *Aeluropus lagopoides*, *Arthrocnemum glaucum,Atriplex farinosa., Halopeplis perfoliata, Limonium axillare, Sporobolus spicatus, Suaeda monoica, Zygophyllum decumbens, Calotropis procera, Panicum turgidum, Polycarpaea repens,* and *Salsola baryosma*.

5. ***Suaeda monoica* community:** The suffrutescent layer includes *Aeluropus lagopoides*, *Arthrocnemum glaucum, Halopeplis perfoliata, Panicum turgidum,* and *Zygophyllum coccineum*. Prostrate perennials and annuals, *e.g. Aizoon canariense, Caylusea hexagyna,* and *Zygophyllum simplex* form the ground layer.

***Tamarix nilotica* community:** The most common halophytes are *Juncus rigidus* and *Zygophyllum album*; others are *Aeluropus lagopoides*, *Arthrocnemum glaucum, Halopeplis perfoliata, Phragmities australis, Zygophyllum decumbens* and *Limonium axillare*. The xerophytes include *Acacia raddiana, A. tortilis, Calotropis procera, Panicum turgidum, Phoenix dactylifera,* and *Hyphaene thebaica*

Figure 1 shows that the density of halophytes species in these habitat. It ranged from 1.5 individual/100m² in *A .farinosa* to 352 individual/100m² in *A. lagopoides.* The density of 1 individual/100m² was recorded of each of *Calotropis procera*, *H. thebaica and P. dactylifera*.

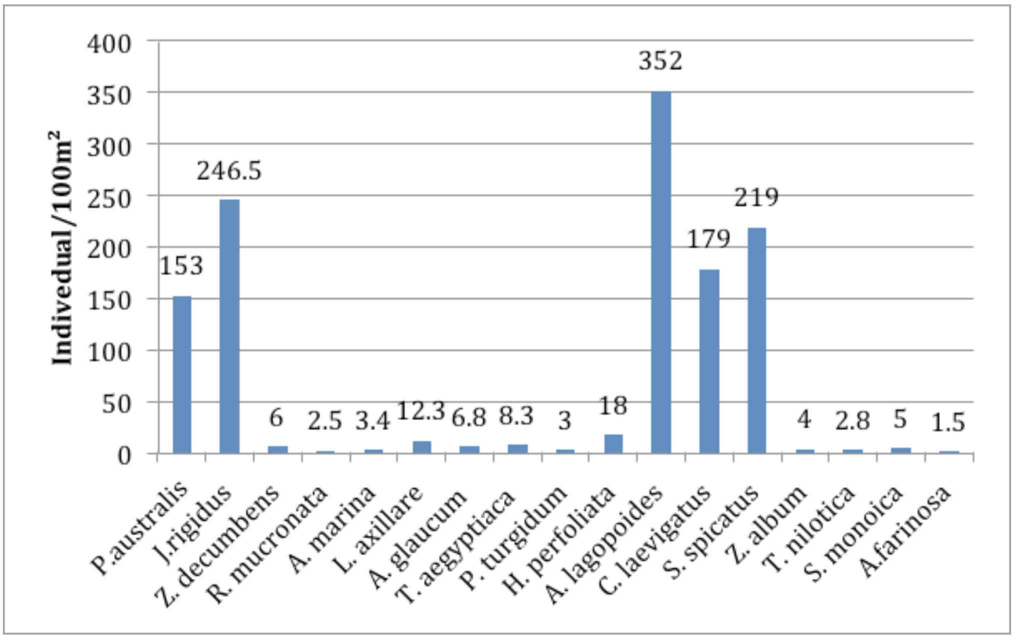

Figure 1. Average density of medicinal halophytes in South east of Egypt.

Coastal desert wadi's vegetation

The littoral downstream belt of the delta of the coastal desert wadies supports halophytic vegetation comprising two communities; one is dominated by Aeluropus lagopoides and the other by Zygophyllum album. The associates, mainly halophytes, include Arthrocnemum glaucum, Halopeplis perfoliata, Limonium axillare, Suaeda pruinosa and Zygophyllum album. The xerophytes (perennials and annuals) include Panicum turgidum, Indigofera articulata and Zygophyllum simplex. The halophytes are Limonium pruinosum, Sporobolus spicatus and Suaeda monoica. Associate species are mainly salt non-tolerant desert perennials and annuals, e.g. Acacia tortilis subsp. tortilis, Crotaloria aegyptiaca, Calotropis procera, Cyperus lavigatus, Panicum turgidum and Zygophyllum simplex. The average density of perennial medicinal species dominated and common in the littoral downstream belt of the delta of the Wadis ranged between 1individual/100m² in C. procera and 7.3 individual/100m² in C. aegyptiaca (Figure 2). The density of annual plant Z. simplex ranged between 1 and 27 individuals/100m² with average 9.1 individual/100m².

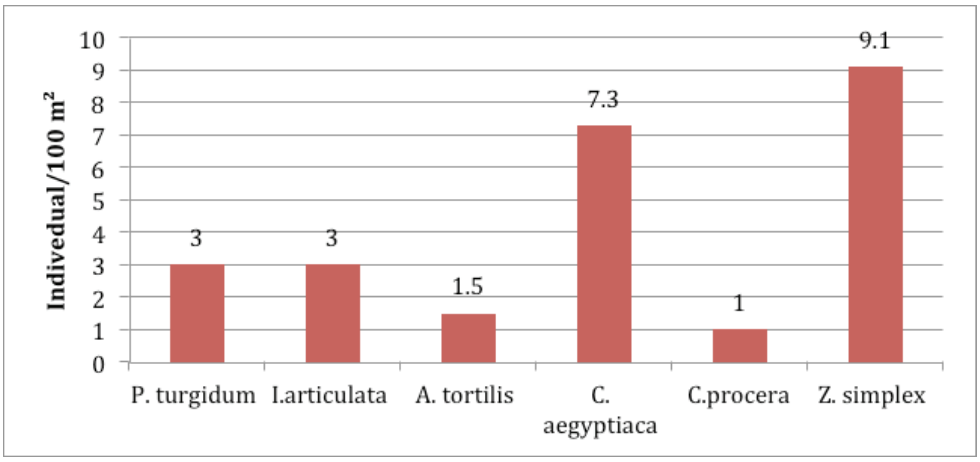

Figure 2. Average density of medicinal species in the littoral downstream belt of the delta of the Wadis.

In the midstream part of these wadies the main channel is dominated by Achillea fragrantissima and Panicum turgidum. Plant cover is 10–15% and it increases to 60–65% during the winter season with dense growth of therophytes. Acacia raddiana is the abundant associate perennial. Other associates include Acacia tortilis subsp. tortilis, Abutilon pannosum, Aerva javanica, Balanites aegyptiaca, Calotropis procera, Morettia philaeana, Delonix elata, Salvadora persica, Senna italiaca , Citrullus colocynthis, Morettia philaeana, Reseda pruinosa, Lycium shawii, Cucumis prophetarum, Stipagrostis ciliaris, Leptadenia pyrotechnica, Senna alexandria, Forsskaolea tenacissima, Forsskaolea viridis, Senna italica, Tephrosia purpurea ssp. apollinea, Zilla spinosa, Solanum incanum, Ziziphus spina-christi, Dipterygium glaucum, Cleome chrysantha, Maerua crassifolia and the annuals Pulicaria undulata, Reseda pruinosa, Astragalus vogellii, Anticharis glandulosa, Rumex viscarius, Rumex simpliciflorus, Arnebia hispidissima, Launaea capitata, Aizoon canariense, Blepharis ciliaris, Tichodesma africanum, Plicosepalus acaciae, Cotula cinerea, Caylusea hexagyna, Pulicaria undulata, Plantago afra L.

Figure 3 shows that in the midstream part of these wadies the density of perennial medicinal species ranged between 1individual/100m² of *Z. spina-christi and* 55.8 individual/100m² of *M. philaeana.* The average density of the annual plants (Figure 4*)* ranged between 8.7 individual/100m² of *T.purpurea* ssp. *apollinea* and 270 individual/100m² of *C. cinerea*

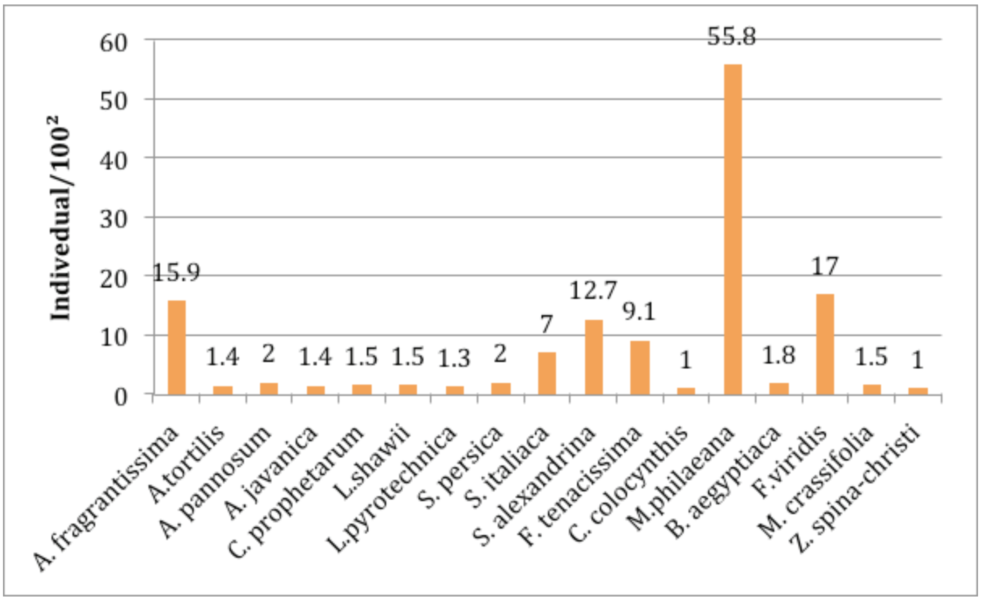

Figure 3. Average density of perennial medicinal species in the midstream parts of wadies in the studied area**.**

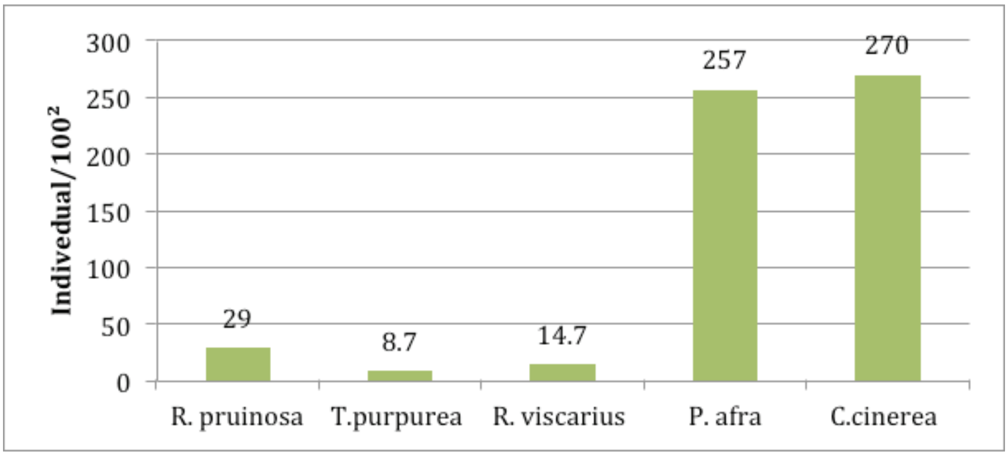

Figure 4. Average density of annual medicinal species in the midstream part of wadies in the area studied.

Vegetation of the mountains facing the Red Sea proper

Three latitudinal zones of vegetation may be recognized: a lower zone of *Euphorbia cuneata*, a middle zone of *E. nubica* and a higher zone of moist habitat vegetation. In the higher zone are stands *of Acacia etbaica, Dodonaea viscosa, Ficus salicifolia, Pistacia khinjuk* and *Rhus* *abyssinica*. Within these higher zones ferns, mosses and liverworts are present. The southern slopes of Gebel Elba drain into Wadi Serimtai, one of the most extensive drainage systems within the whole district. The *Acacia* scrub of this wadi is much more open than that of Wadi Aideib. The most common type of vegetation within these runnels is a community dominated by *Commiphora opobalsamum*. On the higher altitudes, some shrubs of *Acacia etbaica* and *Moringa peregrine* are found. On the north and northeast slopes the vegetation is characterized by the preponderance of *Euphorbia cuneata* and *Euphorbia consobrina*. On the southern slopes *Aerva javanica* is dominant with only rare plants of *E. cuneata.* The most common annuals were *Chenopodium murale, Rumex viscarius, Rumex simpliciflorus.* The vegetation of the northeast slopes of Gebel Shindodai distinguishess four main zones from base to top: (1) a zone characterized by the abundance of *Caralluma retrospiciens*, (2) a zone characterized by the abundance of *Delonix elata*, (3) a zone of *Moringa peregrina* and (4) a zone with bushes of *Dodonaea viscosa, Pistacia khinjuk* v. *glaberrima* and *Euclea schimperi* and with numerous bryophytes and ferns including *Ophioglossum polyphyllum* and other moisture-loving species such as *Umbilicus botryoides*. The northeast slopes of Gebel Shillal are richly vegetated with a great variety of species. A number of zones may be recognized from base to top: (1) a zone of *Acacia tortilis* and *Commiphora opobalsamum*, (2) a zone of *Acacia etbaica* and *A. mellifera*, (3) a zone with patches of *Cordia gharaf, Dodonaea viscosa, Maytenus senegalensis, Grewa tenax, Rhus oxyacantha*, and a number of bryophytes and ferns (Zahran and Willis, 2009). In the upstream parts of these wadies, the density of perennial and annual medicinal species is shown in Figure 5.

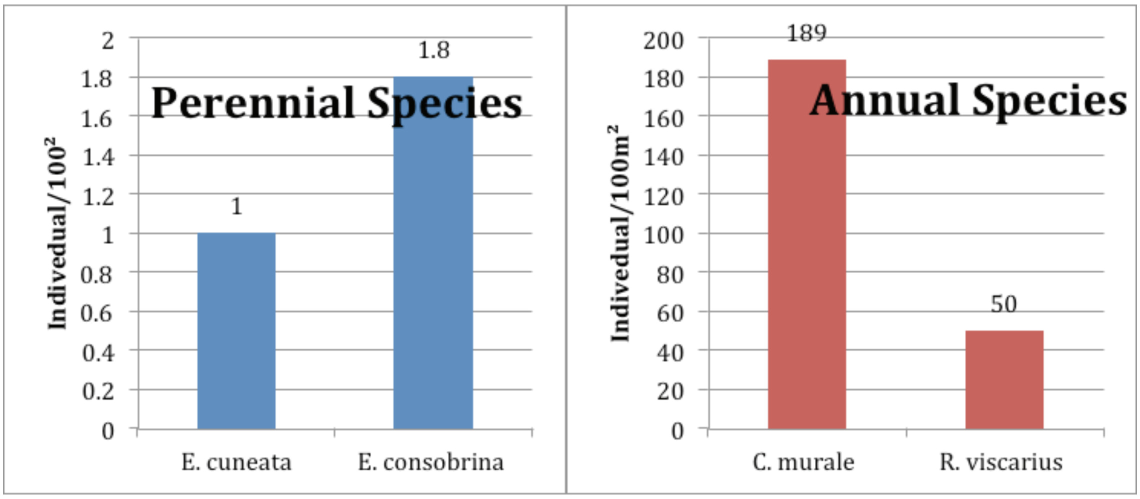

Figure 5. Average density of perennial and annual medicinal species in the upstream parts of wadies in the studied area.

Productivity of medicinal plants identified in the studied area

Figure 6 shows that *Rhizophora mucronata* had the highest productivity (2647 g/ individual) followed by *Lycium shawii* (1413.53 g/ individual) and *Avicenna marina* (968 g/ individual). *Chenopodium murale* had the lowest productivity (30.066%).

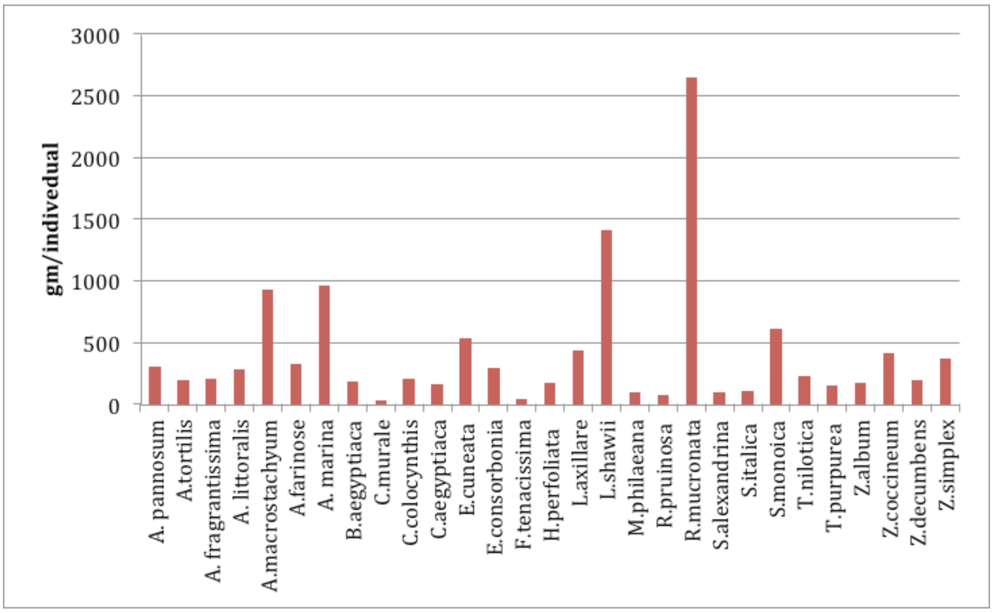

Figure 6. Productivity and water content of areal parts of medicinal species recorded in the studied area during the winter season.

Chemical constituents and active material of the medicinal plants

Glycosides, alkaloids, flavonoids and tannins were present in all plant samples under investigations (Table 2). Saponins were detected in sixteen species only. Figure 7 shows that the ash content ranged between 3.34% (*Balanities aegyptiaca*) and 32.86% (*Salvadora persica*). There was a wide range of tannin concentration in the analyzed medicinal plants (Figure 8). The highest content was in *Rhizophora mucronata* (5.178%), while the lowest was detected in *Plantago afra* L. (0.007%). The phenolic content of plant (Figure 9) ranged from 5.284% in *Rhizophora mucronata* to 0.039% in *Leptadenia pyrotechnica.* The highest concentration of alkaloid (10.943%) was in *Z. simplex* (Figure 10) while the lowest one was in *R. mucronata* (0.02%).

Marketing studies

In order to ensure the success of the introduction of a new product, 4 marketing factors were considered as follows: 1. Product – what am I offering to my customers? 2. Price – what are my costs and how to fix a competitive price? 3. Place – who are the intermediaries and what are my distribution tools? 4. Promotion – how to catch my customers' attention?

Below is the list of contacts made and responses received from each class of contacts:

Target	Contact	Response
Export Companies	77	25%
Pharmaceutical	70	10%
Herbalists	60	100%
Consumers	200	50%
Expert Interviews	2	

The main national market players of medicinal plants in Egypt are Royal, Isis, Sekem, Imtenan, Roots and Naturemann.

Table 2. Phytochemical screening of plants species (√ positive, - negative)

Species	Glycosides	Alkaloids	Flavonoids and / or Phenolics	Sap	Tan	Unsaturated Sterols and / or Triterpenes
Abutilon pannosum	√	√	√	√	√	-
Acacia tortilis subsp. Tortilis	√	√	√	√	√	-
Achillea fragrantissima	√	√	√	-	-	√
Aeluropus littoralis	√	√	√	√	√	√
Atriplex farinose	√	√	√	√	√	-
Avicennia marina	√	√	√	-	√	√
Cotula cinerea	√	√	√	√	√	√
Crotalaria aegyptiaca	√	√	√	√	√	-
Forsskaolea tenacissima	√	√	√	-	√	-
Forsskaolea viridis	√	√	√	-	√	-
Indigofera articulate	√	√	√	√	√	-
Leptadenia pyrotechnica	√	√	√	-	√	√
Limonium axillare	√	√	√	-	√	-
Morettia philaeana	√	√	√	-	√	-
Plantago afra	√	√	√	-	√	-
Reseda pruinosa	√	√	√	-	√	-
Rhizophora mucronata	√	√	√	√	√	√
Rumex vesicarius	√	√	√	√	√	√
Salvadora persica	√	√	√	√	√	-
Senna alexandrina	√	√	√	√	√	√
Senna italica	√	√	√	√	√	√
Suaeda monoica	√	√	√	-	√	√
Tamarix nilotica	√	√	√	-	√	-
Tephrosia purpurea ssp. apollinea	√	√	√	√	√	-
Ziziphus spina-christi	√	√	√	√	√	√
Zygophyllum album	√	√	√	√	√	√
Zygophyllum simplex	√	√	√	√	√	√

The quantities of medicinal herbs exported annually vary between 50 tons and 1500 tons. More than 50% of the herbs are sold in bulk. Most of the shipping is done by sea. EU and US represent the most important export markets. None of the most requested herbs are from Shalateen. Most of the companies conduct post-harvesting activities. The medicinal plants of interest from Shalateen were: Senna (*Senna alexandarina*), Kaf Mariam (*Anastatica hierochuntica*), Samgh Arabi (*Acacia arabica*) and Sugar Dates (*Balanitis aegyptiaca*). The plants of interests to herbalists in Shalateen were: Hargal (*Solnostemma argel*), Senna (*Senna alexandarina*), Kaf Mariam (*Anastatica hierochuntica*), Samwa (*Cleome droserifolia*), Halfa Bar (*Cymbopogon schoenanthus*), Shagrat ElGhazal (*Salvia spinosa*), and Sugar Dates (*Balanitis egyptiaca*).

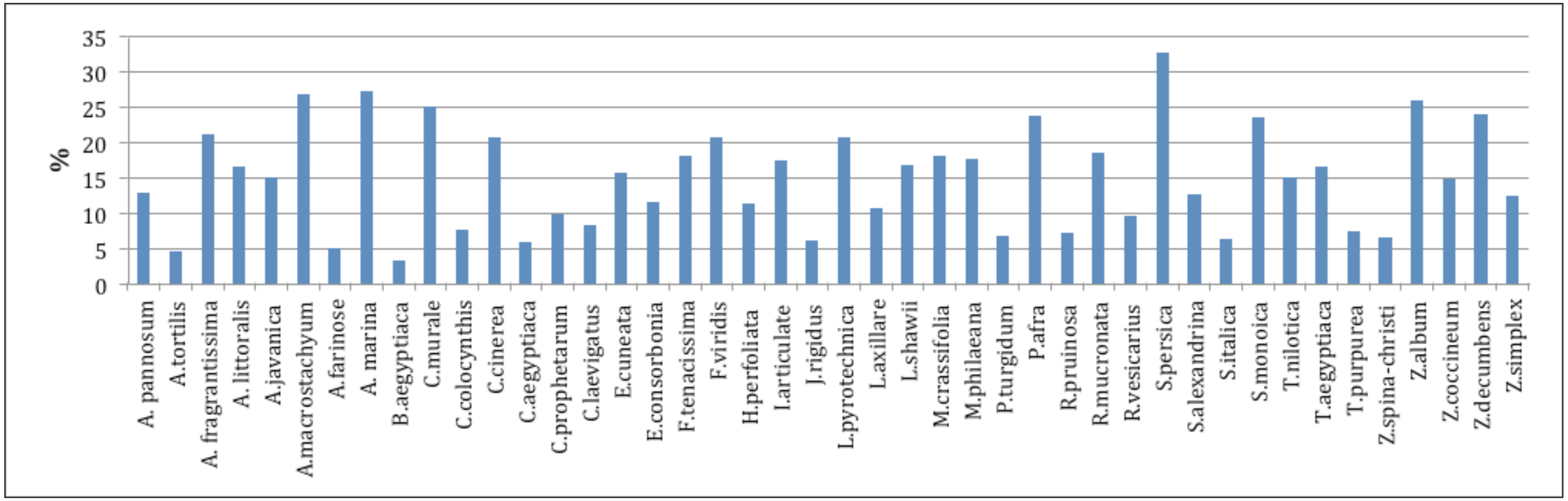

Figure 7. Ash content of the medicinal species recorded in the area studied during the winter season.

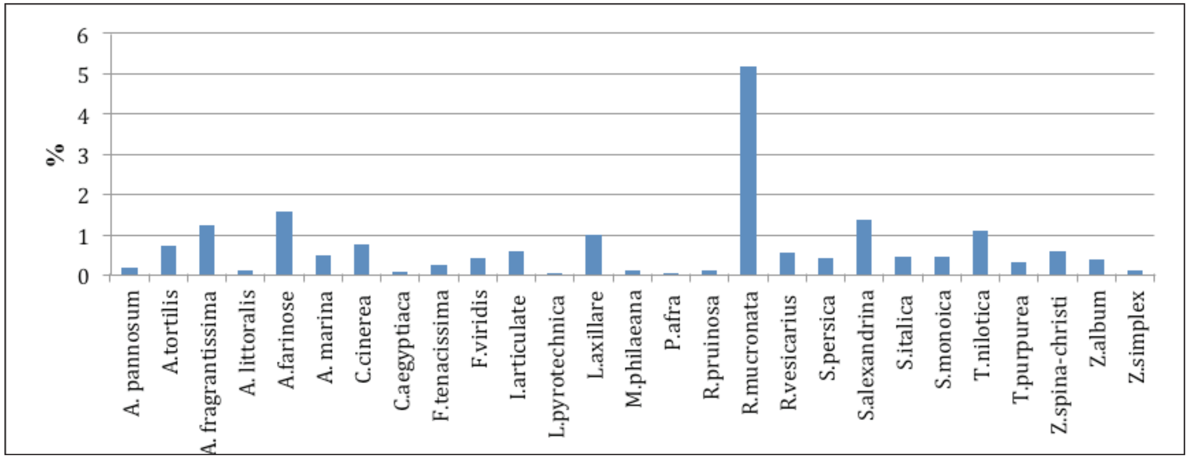

Figure 8. Total tannins of the medicinal species recorded in the area studied during the winter season.

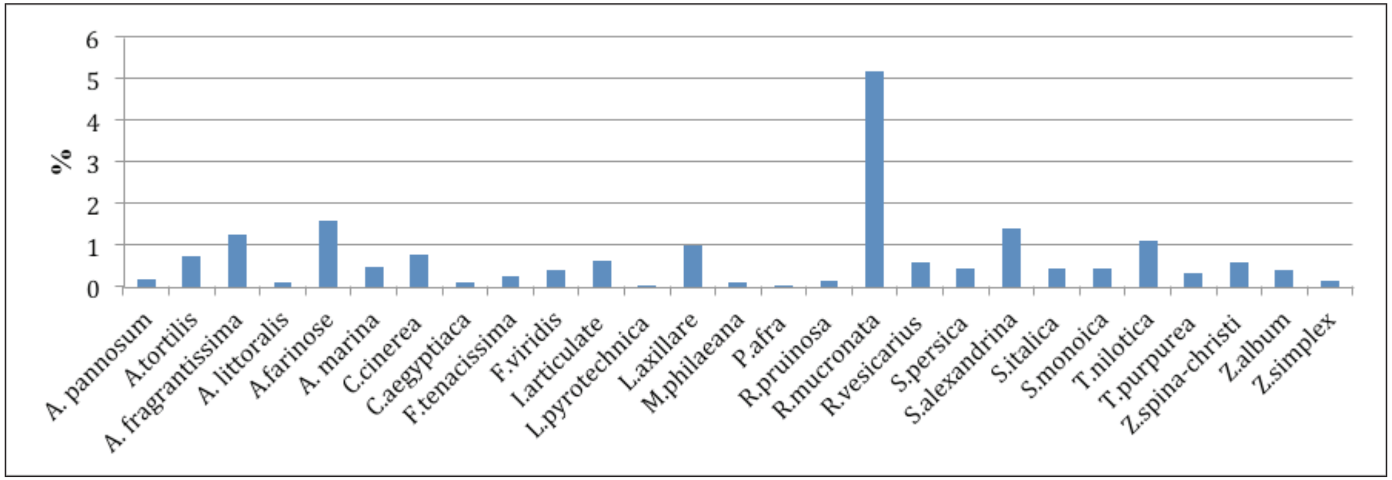

Figure 9. Total phenolics of the medicinal species recorded in the area studied during the winter season.

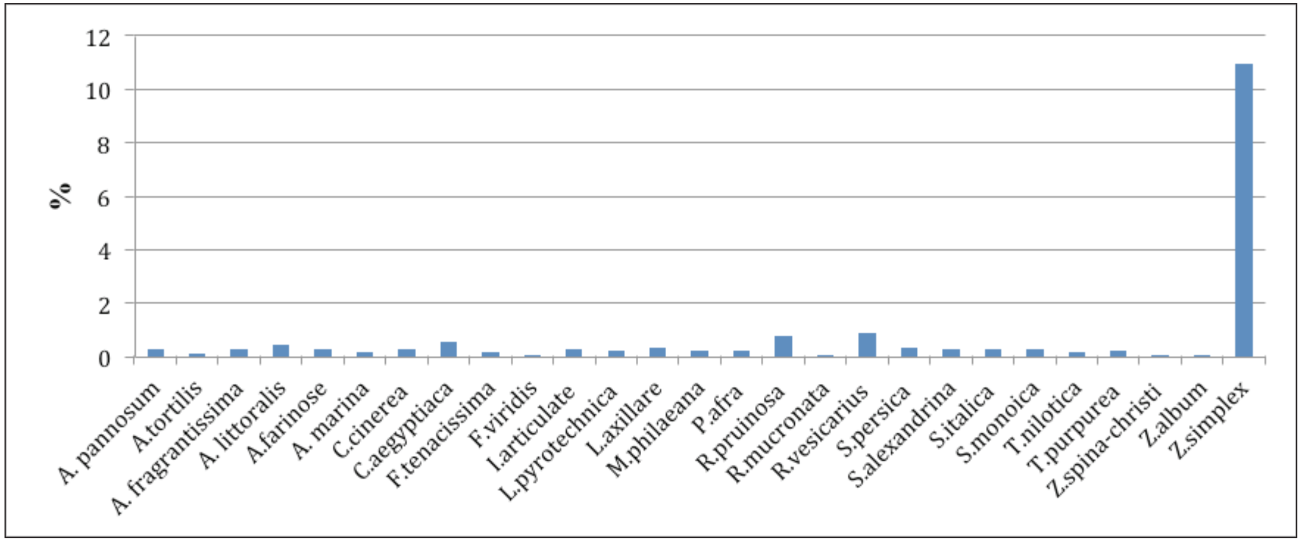

Figure 10. Total alkaloids of the medicinal species recorded in the area studied during the winter season.

Herbs exported are transferred from Shalateen to Cairo first then distributed to all the Egyptian vendors. Shalateen brokers make 200% profit from herbal transactions. There is no value-added and herbs are damaged because of the logistical problems.

In Hurghada, most of the tourists are German, Russian or English. Some 60% of tourists buy souvenirs, and 75% buy diet, energy and medicinal herbs from bazaars. Hibiscus is the most popular herb. Shalateen Hibiscus is only sold in a 3 month season. Lemongrass and Senna are also imported from Shalateen.

The product matrix is given below

Availability	High market demand	Low market demand
High	Senna (2 varieties) (*Senna alexandarina & Senna italica*) - DRC findings	Sugar Dates (*Balanitis aegyptiaca*) – DRC findings
Low	Hibiscus (*Hibiscus sabdariffa*) Kaf Mariam (*Anastatica hierochuntica*) Halfa Bar (*Cymbopogon schoenanthus*) Handal (*Citrullus colocynthis*)	DRC findings

Marketing plan

The product produced in Shalateen area are marketed by Shala-Tea. The medicinal and aromatic plants offered by Shala-Tea are: Senna or Sanamakky (*Senna alexandarina* & *Senna italica*), Lavender Cotton or Kiysome (*Achillea fragrantissima*), Desert Dates (*Balanitis aegyptiaca*), Bitter Apple or Handal (*Citrullus colocynthis*), Kaf Mariam (*Anastatica hierochuntica*) and Hibiscus (*Hibiscus sabdariffa*).

Shala-Tea's offerings are all medicinal and aromatic plants but each of the plants has a different usage and a different method of preparation. So, Shala-Tea's goods can be divided into 3 types: herbs ready for boiling and drinking, medicinal plants with physical usages and aromatic plants for decoration purposes. These goods are presented to the customers in two types of packages: Singles – the package will contain only one herb; and Packs – the package is designed to hold 3 to 4 different herbs. The materials used for packaging are: Burlap – to wrap fruits in a breathing bag – offered in two different sizes; Kraft bags – a type of paper bag – offered in two different sizes; Glass jars – either plastic or copper top – offered in two different sizes. The top will be covered with burlap/sackcloth to keep the all-natural look. Cardboards – to hold multiple herbs at once – are offered in 2 different sizes. It has been decided that Shala-Tea will offer its products in two major Egyptian markets: Cairo and Hurgada (the Red Sea area).Table 3 gives the suggested price for different types of packaging in Cairo or in the Red Sea.

Table 3. Prices suggested for different types of packaging of Shala-Tea products in Cairo and Red Sea markets

Package Type	Price in Cairo (EGP)	Price in Red Sea
Glass Jar	LE 20	2.99 Euros
Paper Bag	LE 15	1.99 Euros
4-Herbs Cardboard	LE 40	6.99 Euros
Bitter Apple in Jute Bag	LE 10	1.99 Euros

Discussion

Forty six localities were surveyed in Shalateen area, and forty-three medicinal plant species were recorded. *Acacia tortilis* subsp. *tortilis, Achillea fragrantissima* and *Aerva javanica* were the most abundant species in the area studied. The halophytic grasses had the highest density. El-Khouly and Abu-EL Nasr (2006) found that the density of Imperata clyndrica and Pharagmitis australis was higher than that recorded in *Alhagi graurcoum* in the dry season in Siwa Oasis. They stated that the first two species were less palatable to range animals than Alhagi graurcoum. The long term heavy grazing caused reduction in the density of the palatable species. The halophytic grasses are less palatable as fodders for range animals.

The annual species had a high density than the perennials especially in the wadies and in the mountain habitats due to the faster seed germination in the annuals than in the perennials, also, the germination percentage of annual seeds is more than in the perennial seeds.

The productivity of the mangrove species (*Rhizophora mucronata* and *Avicenna marina*) was more than that the other species. El-Khouly and Khedr (2007) recorded that the growth performance of R. mucronata was significantly higher in pure stands than in association with A. marina. R. mucronata in pure community grew twice as tall, had more main and lateral branches, and attain nearly 10 times the total number of leaves compared with those growing in mixed community.

The ash content ranged between 3.34% to 32.86%. This implies that all plant samples do not fall within the standard range for animal feed but can be used as ethno-veterinary products in all the regions. The highest value of tannins was observed in R. mucronata (5.178%), and the lowest in P. afra (0.007%). Tannin in plant is involved in defense mechanism to environmental attack (Okuda et al., 1992). It was reported to have potential antioxidant properties in faba beans mainly due to chain-breaking ability rather than to chelating activity with transition metals (Carbonaro et al., 1996).

The increased value of total phenolics in *R. mucronata* might be due to the presence of phenolic compounds like coumarins, flavonoids, lignans, neolignans, lignins, phenylpropenes. Flavonoids are low molecular-weight compounds. They are extremely important subclasses of phenolic compounds and widely distributed in plants such as vegetables, herbs, spices, and tea. Based on the presence of different substitutions on the rings and the degree of benzo-γ-pyrone saturation, flavonoids usually can be separated structurally into flavones, flavanones, and flavonols (Havsteen, 2002; Cai et al., 2004; Ncube et al., 2008; Samy, 2010; Romano et al., 2013).

Alkaloids have important eco-chemical functions in the defense of the plant against pathogenic organisms and herbivores or, as in the case of pyrrolizidine alkaloids, as pro-toxins for insects, which further modify the alkaloids and then incorporate them into their own defense secretions (Hartmann, 1991). In this study the highest concentration of alkaloid (10.94%) was in *Z. simplex*. The high alkaloid content in the desert plants serves as defense chemical to enable them to cope with insects and vertebrate herbivores. *Zygophyllum simplex* is not eaten by the range animals.

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7. Evaluating different policies to support organic agriculture adoption in Egypt

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Abstract

A very important pillar of the modernization of the Egyptian agriculture is the exportation of the high value added products such as organic products. In spite of the importance of the organic agriculture within the Egyptian agriculture sector, to best of our knowledge, there are no studies in Egypt that try to analyze the factors that determine the adaption of organic agriculture on the Egyptian farms. The main objective of this project, therefore, is to determine and analyze the importance of different public policies applied to support the adaption of organic agriculture and the social acceptance of these policies among Egyptian farmers. This will be helpful in designing suitable policies and strategies to support the extension of organic agriculture in Egypt and assure the social acceptance of these policies. In order to achieve this objective we carried out a survey with a representative sample of organic and non-organic farms in the Upper Egypt area, namely in Suhag, Assiut and Fayum governorates, which are considered as the main production area of organic products. The methodological approach is based on the use of choice experiments (CE) and the Analytical Hierarchy Process (AHP) techniques to examine the social acceptance of four policies to support the adoption of organic agriculture in Egypt. Our preliminary results suggest that the most accepted policy to support organic agriculture adoption in Egypt is the availability of subsidy followed by the establishment of a governmental certification body. Other policies such as reducing the certification cost and the availability of long contracts seem to be less effective in promoting organic agriculture adoption in Egypt.

Keywords: Organic farming, Policy support, Certification of organic products, Upper Egypt

8. Linking farmers to market in Upper Egypt: A case study

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Abstract

It is about the challenges and the lessons learned from SALASEL project, which started in January 2010 and shut down in June 2013. SALASEL is the short name of Pro-poor Horticulture Value Chains in Upper Egypt Project funded by MDG-F and implemented by 4 UN agencies, UNDP, UNIDO, ILO and UN WOMEN, with a total budget of $7.5 M in 6 Governorates in Upper Egypt. The Ministry of Industry & Foreign Trade (MIFT) and the General Authority for Investment (GAFI) represented the Government of Egypt. The presentation gave a brief about SALASEL, the main challenges of the project and what were the strategies to resolve these challenges. Then the lessons learned were presented under 5 main topics: start up, organization, community development, sustainability and technical issues. Most of the mentioned strategies and the lessons learned can be replicated in the new communities or new development programs.

Keywords: SALSEL project, Horticulture value chain, Upper Egypt, Community development

9. Linking small and marginalized farmers to markets: The importance and approaches

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Abstract

Small farmers around the world represent the largest proportion of the total farmers, and they also - with their families – represent the world's poorest people. On the other hand the total area of small farms is a significant proportion of total world agricultural area and it is considered as a main source of world food and food security for developing world population. Small farmers are facing severe difficulties - ecologically, socially and economically. An effective strategy is needed to cope with these difficulties to ensure good future. Today, international developmental agencies and organizations as well as donors have considered linking small farmers to modern markets as the most effective strategy to rescue small farmers around the world. There are different approaches to link small farmers to high value and modern markets, but there are some conditions to ensure the success of these. Small farmers' efforts to meet market deadlines, their group action and partnership with private sector, and governmental role in creating an enabling environment (policy, legal and institutional framework, supporting services and infrastructure) are some of these. Some trials and initiatives have been taken up in some countries. Lessons learnt could be taken into consideration for adaptive actions elsewhere.

Keywords: Agricultural development, Small scale farming, Market linkage

Introduction

Linking small farmers to dynamic and rapidly changing markets of the modern era is a relatively recent topic receiving growing interest from national and international organizations. Nowadays, there is a broad consensus from developmental organizations and agencies as well as developing country governments that the future of such farmers is dependent to a large extent on how their marketing system develops.

The vast majority of the farmers in dry land are small or marginalized. At the international level, about 85% of farms are considered as small farms (less than 2 ha holding) numbering about half a billion. The majority of small farmers is concentrated in developing countries and these fartmers account up to 60% of the total food consumed in those countries. Nearly one-half of the world population belongs to small farm households, with more than two-thirds of the global population under the poverty line.

In most developing countries, the average area of small farm units tends to decline, decreasing production efficiency and future livelihood of small farmers. For example, the average area of small farms decreased from 2.2 hectares in 1970/1971 to one hectare in 2002/2003 in India, from 0.6 ha in 1980 to 0.4 ha in 1999 in China, from 1.5 ha in 1977 to one hectare in 2001/2002 in

Ethiopia, from 2.7 ha in 1995 to 2.5 ha in 2002/2003 in Tanzania, and from 2.6 ha in 1950 to 0.9 ha in 2010 in Egypt. Thus, the future of small farms and small farmers is threatened not only by climate changes, but also by the negative impact of globalization, with its economic and world trade transformation, as well as severe competitiveness at national or international markets.

What are small farms?

There is no full agreement on the definition of small farms. The definition depends on a number of factors and considerations that differs from one country to another, but also from one region to another in the same country. Among these factors are:

- Population to arable land ratio.
- Availability of water for irrigation.
- Environmental and climatic conditions.
- Land and soil characteristics.

In general, small farm determination depends on some interrelated criteria such as land area of the farm, the share of family labor, importance of farm products in farm family food consumption, marketable ratio of farm products, degree of production specialization, level of technology, and availability of other production factors such as capital, knowledge and skilled labor. Considering these different criteria, the term 'small farm' refers to a small area of agricultural land where work depends mainly on farm family members who depend for their income and livelihood basically on the farm produce. On the other hand, the marginalized farm is a small farm with production conditions making it as a non-profitable farm. According the mentioned criteria, small farm area varies significantly from country to another.

In the U.S.A, the main criterion of small farm is Gross Cash Farm Income (GCFI). Accordingly, small non-commercial farm is one that has 10,000 $ or less revenue, where farmers depend mainly on non-farm income. In India, the farm is considered a marginalized one if its area is less than one hectare where it is not sufficient to absorb the family labor or to gain reasonable income. Farms less than one hectare in area comprise about 62% of all farm holdings. In many parts of Latin America, the farm with size smaller than the country average and operated mainly with the family labor is designated as small fgarm. In Egypt, about 70% of farms are less than about 1.25 ha (3 feddans), and about 40% of farms are less than 0.42 ha.

Fears about the future of small farms

During the last few decades, there have been different transformations at global and national levels which make the future outlook for small farms and farmers non optimistic. National and international economic and trade transformations, as well as accelerated changes in marketing and supply chain systems for food and agricultural products tend to add to the woes of small farmers in addition to the threats posed by the climate change.

Fears and threats from general vision

In developing countries, small farms are most negatively affected by globalization, world trade changes, economic reform and market liberalization. It is extremely difficult to small farmers to face the world competitiveness in exporting business. In many developing countries, there is considerable decrease in government interest and public expenditure on agriculture development in general and on small holding agriculture in particular. There has been decline in inputs subsidy, research and extension budget and the expenditure on agriculture services and infrastructure. Many of the transition economy countries consider agriculture as a minor sector with non-significant importance in supporting macro-economic growth and in creating new jobs. Comparing with large and medium farms, small farms have disadvantage of inaccessibility to skilled labor, technical knowledge, financial sources, improved inputs as well as research and extension services. Among small farm household, there is a trend of reluctance amongst youth to work on their farms and an ambition to get better opportunities in other sectors. The huge agriculture subsidy fund in OECD countries represents a heavy pressure on developing world agriculture in general and on its small farmers in particular as it reduces their competitiveness in the global trade.

Fears and threats from trade and marketing perspective

Traditionally, the marketing systems for small farm products in most developing countries have been and remain under-developed. Some of the characteristics of such systems are: high percentage of waste and losses, less attention to quality and safety measures, poor post-harvest operations, *ad hoc* production decision without adequate marketing information and unfair farm gate prices. National and international economic and trade changes and transformations have doubled the marketing problems for small farmers to compete in markets. Food processing and agro-industry, food retailing systems and food supply chains have distanced themselves from small farmers because of the strict requirement of quality standards, timelines of supply, big quantities, regular and consistency of supply, which are very difficult to meet for small farmers. It seems more difficult for small farmers to be involved in agriculture export chains where tough conditions are applied, not only for quality and safety measures but also for exporters' requirements to inspect the conditions of production in terms of pesticide use, organic cultivation, and post-harvest practices. Small farmers lack of market information prevents small farmers to respond to big and rapidly improving food consumption patterns and consumer attitudes, especially in relation to quality, safety, freshness, post-harvest practices, packaging and other improved marketing services.

Linking small farmers to market, concept and importance

Marketing and innovation are the basis of business success and competitiveness. Market tells the producer what to produce (species, variety), how much (quantity), when (season), how to produce (pre and post-harvest practices), where (climate, water and soil condition), for whom (local consumer, foreign consumer, processing firm). On the other hand marketing governs the production decision, inputs sources, knowledge needed, agricultural practices, post-harvest operations. The small farmer can not achieve profitable and competing farming business without involvement in an efficient and dynamic marketing system, through effective linkages to modern and high value markets.

The concept linking small farmers to markets in its simplest meaning is establishing a closer and long-term business relation between small farmers and their products' buyers. The concept also means shifting from *ad hoc* producers to market oriented producers, from the culture of selling what they produced to emphasis on produce what sells, and also from dealing with open traditional markets to direct sales through integrated commodity chains.

Linking small farmers to modern high value markets has become an essential strategy. But it seems not a substitute for strategy of increasing production efficiency and development of product quantitatively and qualitatively. Indeed, both strategies are closely interdependent. It may be impossible to improve crop productivity and crop quality if there is no proper access to modern markets with fair and rewarding prices, and encouraging and motivating dynamics. On the other hand, low production efficiency and non-adequate quality or quantity of products may put rigid barriers to linking small farmers to modern high value markets.

Types of linkages of small farmers to emerging high value markets

Attempts at linking small farmers to rapidly changing markets and their involvement within high value supply chains are relatively recent efforts. So, there is no specified framework of the approaches and types of such linkages. Instead there are some related projects, ideas, experiments or plans which are still not properly evaluated to determine their potential, or to decide which type is more advantageous to small holders, and suitable for a certain socio-economic and cultural environment.

The known types are as follows:

- Direct relation between small farmers and retailers (supermarkets, restaurant chain).
- Contract farming.
- Direct relation between farmers and agro-processing companies.
- Direct relation between farmers and exporters.
- Linkages promoted by leading small farmers.
- Linking through group action bodies (cooperatives, NGOs, farmer associations, marketing boards etc.)
- Direct sales to local institutions (hotels, schools, military, hospitals)
- Marketing through government procurement and governmental boards.
- Initiatives by agricultural extension officers to arrange proper direct marketing opportunities.
- Initiatives promoted by medium and large scale farmers to enter in partnership with small farmers.

It is important to clarify that the above types are not mutually exclusive; cooperatives or any other form of farmers associations can play a significant role for linkage with retailers, exporters or agro-processors. Also the direct marketing linkages could be through formal contracting, and so on.

Advantages of linking small farmers to markets

There are numerous benefits and outcomes of linking small farmers to modern and high value markets. Foremost is to maximize the contribution of small farmers in food production for the growing billions of world's population. Second important advantage is to improve the livelihood of billions of small farmers and their families with the great opportunities to reduce the high rates of poverty prevailing among them. Efficient and successful linking of small farmers to markets could be the most effective strategy to make the future of worldwide small farmers more optimistic.

Marketing linkages in advance would secure marketing and agreed prices. Equitable involvement of small farmers in supply chains of different commodities would secure fair farm gate prices and higher farm return, especially with the improvement of product quantity and quality. Through some of above mentioned linkages, small farmers can obtain inputs, technical assistance and extension services and marketing services (packaging, grading, storage, transport…etc.). In some cases buyers may provide partial finance in advance to small farmers depending on the terms of contract or the nature of the crops.__

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10. Enhancing faba bean production and productivity through the demonstration of innovative technologies on farmers fields

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Abstract

Faba bean (*Vicia faba* L.) is the most important food legume crop in Egypt, being a good source of quality protein in the diet of people, and for animal feed. Increasing faba bean production and improving its nutritional quality is thus crucial to meet the demand of the increasing Egyptian population. Five high yield-potential faba bean cultivars were tested along with integrated management techniques for key diseases, insect pests and *Orobanche* at five locations of Delta region in three seasons (2012/13 to 2014/15). Results showed that the productivity was highest in Dakahlia in all the three seasons (5.59, 5.23 and 4.56 t ha^{-1} respectively). The test of *Orobanche* control package in the demonstrations on *Orobanche*-infested soil at Dakahlia, Sharkia and Assiut indicated that the yields of two tolerant cultivars ('Giza 843' and 'Misr 3') exceeded those of farmers' varieties by 11.1 to 35.7%. The mean increase in seed yield of demonstration fields over those of the neighboring farmers' fields were 22.5, 22.5 and 28.8%, respectively, in the three seasons. Average seed yield increase of the tolerant cultivar 'Giza 843' in the three seasons compared to neighboring fields was 0.83 and 1.48 t ha^{-1} at Assiut and Dakahlia, respectively, whereas the increase for 'Misr 3' was 0.37 and 1.07 t ha^{-1} at Sharkia and Assiut, respectively. The average increase of seed yield of the demonstration fields was 0.29 t ha^{-1} at Nubaria and 1.24 t ha^{-1} at Sharkia in 2012/13, and the respective values were 0.50 t ha^{-1} and 1.06 t ha^{-1} in 2013/14, and 0.49 t ha^{-1} and 1.04 t ha^{-1} in 2014/15. In 2013/14 the control of chocolate spot and rust diseases was also investigated through the demonstrations of resistant cultivars 'Sakha 1' and 'Sakha 4' as well as the drought tolerant cultivars 'Nubaria 2' and 'Nubaria 3'. The paper presents the results of these demonstrations.

Keywords: Faba bean, Field demonstrations, Productivity, Orobanche, Chocolate spot and Rust resistant cultivars

11. Institutional reform of Egyptian agricultural cooperatives development

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Abstract

In most African countries 'modern' cooperatives were introduced by colonial powers who sought to replicate their domestic cooperative structures throughout their colonies and protectorates. After independence, and until the beginning of the structural adjustment era, cooperatives received massive state support, both financial and technical; they were given marketing and supply monopolies for agricultural commodities and inputs, which *de facto* meant that farmers were obliged to seek membership. As a result of structural adjustment program applied by Egypt and most African countries, cooperatives were subject to sudden removal of state support, the abolition of monopolies and other privileges. The situation in Egypt was very difficult for cooperatives, where the government removed all types of support while continued its interference in their operation and had not taken serious steps towards their reform. Such situation brought to light a set of triple crisis: (1) A crisis of *identity*: the existing cooperatives were cooperatives by name only, not by nature; (2) A crisis of *environment*: the legal, institutional and administrative context was preventing, not supporting, the emergence of genuine, self-managed cooperatives; and (3) A crisis of *mmanagement*: The existing cooperatives were unable to survive without subsidies, and state protection. By 2014, the Government of Egypt realized the importance of amending the cooperative law as measure for institutional reform, to give the cooperative the chance to grow and participate in achieving the objectives of the sustainable agricultural development strategy 2030. The paper presents the situation analysis of the Egyptian agricultural cooperatives and legislative changes introduced through amendment of the existing law. The new amendments have been designed to enable cooperatives to be economically more viable and service-oriented, protect farmer's interest through creating cooperative companies, encourage collaboration with private enterprises, minimize the governmental intervention, and promote joint-use of capital and facilities.

Keywords: Cooperatives, Structural reforms, Legislative changes, Sustainable agriculture

12. Lessons learnt for settlement in reclaimed lands in arid zones: The case of Egypt

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Abstract

Egypt, a part of the most arid zones in the world, relies on the Nile River to satisfy more than 95% of its water needs that are increasing substantially due the high growth rate of its population. With increase in population the demand for food is increasing while cultivable land remains limited. Hence, land reclamation in Egypt is indispensable to expand the cultivated areas and to resettle the growing population in new communities. Yet, the fixed quota of 55.5 billion m^3 of Nile water allocated to Egypt from the Nile basin lets the land reclamation plans face real challenges. The conflicting need of water for economic activities, including agriculture, and household uses in reclaimed lands puts additional pressure on already scarce water resources.Under such conditions the process of creating new and sustainable human settlements in reclaimed land in the arid zones becomes very crucial. When any agency plans for establishment of new human settlements in newly reclaimed lands it should consider, very carefully, the various long-lasting social, economic, environmental and geopolitical goals of land reclamation as well as the future dimensions of human settlements. The planning of land reclamation should consider adoption of specific development paradigms with an emphasis on the sustainable livelihood and territorial approaches to ensure sustainable human settlements in reclaimed areas. The different societal assets and capitals, whether natural, human, social, physical or financial, needed for sustainable development, should be fully considered from the very beginning of planning of establishment of such settlements. This would save huge investments and invaluable efforts likely to be spent in such endeavor.

Keywords: Reclamation of lands, Resettlement of population, Water scarcity, Sustainable development

13. Prospective role of smallscale farmers in agriculture development in Egypt

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Abstract

Smallscale farmers (SSF) are still considered to be one of the most important elements in agricultural and rural development in Egypt. This study focused on the characterization of SSF and their economic and social contributions to agriculture sector and food security in the country. The data from agricultural censes form 1929-2010 were used for this study. The holders of less than 3 feddans of land were considered as SSF generating an income to cover the UN-specified poverty line of 1.25 US$/day/capita. The study revealed that SSF families represent 38% of the total population in Egypt, and 69% of the rural population. They provide most (about 71%) of the permanent and temporary agriculture work force and are the main producers of field crops and livestock products; but their contribution to fruit production is very limited. Despite several challenges facing the SSF that hinder their active participation in the sustainable agricultural development, such as severe land fragmentation, high rate of land transfer to non-agricultural activities, and continuous and rapid increase in input prices and land renting value, SSF have prospects and opportunities to improve their livelihood, and enhance their participation in sustainable rural and national development, because they possess traditionally accumulated knowledge in agriculture and risk mitigation, have high level of crop intensification, have integration between family and farm business and consider farming as a way of life, practice integrated crop-livestock farming system and are generating jobs for new generations.

Keywords: Small scale farmers, Agricultural development, Challenges and opportunities for livelihood improvement, Egypt.

Introduction

Agriculture is a key pillar of the Egyptian economy because of its multiple roles. It is a major source of national income, contributing to 11.3% of the Gross National Production (GDP). Agricultural sector has achieved a growth rate of about 3% (Egypt, 2014-2015). It contributes largely to commodity exports, provides work opportunity for a large proportion of the national labor force, and plays a role of safe guard for food security.

More than 85% of agricultural holders in Egypt are smallscale farmers. This farming community is very important for agricultural and rural development in Egypt, especially with the growing phenomenon of land fragmentation, and the consequent negative impact on agricultural production, efficiency use of natural resources, and food security on one side, and the living conditions of small farmers and their families on the other.

Although smallholders in agricultural sector represent more than 85% of agricultural holders in Egypt, and the new Egyptian constitution of 2014 includes a number of articles that emphasize the need for giving more attention to agriculture sector, farmers in general, and small farmers in particular, there is no common agreement on the definition of small agricultural holding, or small-scale farmers among various stakeholders, and there are limited studies related to their contribution to agricultural sector in Egypt.

Objective of the study

This study aimed to determine the prospective role of small-scale farmers in the agricultural and rural development in Egypt. This involved getting a clear definition and characterization of small-scale farmers and determining their economic and social contributions to agricultural sector and food security.

Methodology and data source

The study used descriptive analysis of secondary data available of agricultural sector, especially the data available on agriculture cencus (1990 and 2010) which issued every ten years and available until 2010 only.

Results and discussion

Definition of small-scale farmers (SSF)

Review of literature showed 36 definitions of family farm, referring to one or more elements such as labor, management, size, family livelihood, residence, family ties and generational aspects, community and social networks, subsistence orientation, patrimony, land ownership and family investment. Family farming, according to FAO is a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production managed and operated by a family and predominantly reliant on family labor. The family and the farm are linked, co-evolve and combine economic, environmental, social and cultural functions (FAO, 2014).

The agricultural census in Egypt classified its farmers into two groups. 1. Individual land holdings: Total area about 8.9٧million feddans, representing nearly 92.1% of total farmland area and 99.95% of total number of farms. 2. The corporate farms: Farmland owned by companies, cooperatives, agrarian reform and other entities, amounting to 766 thousand feddans, representing only 7.9% of total cultivated area and 0.1% of total number of holdings (Agricultural Census, 2010).

This study defines the small scale farmers (SSF) as the ones owning farms of less than 3 feddans because with the income generated from such small farms does not fulfill the poverty line of US$ 1.25 /day /capita. This type of farming is usually characterized by intensive labor and, in most cases, using animal as a source of drafting power, limited use of chemical fertilizer and supplying most of the production to the surrounding markets.

The SSF include two main groups of farmers. A. The landless farmers: There were some 565 thousand holders (16.3% of the total holders) in 1990 (Agriculture Census, 1990). The number rose to about 965 thousands holders (17.9% of the total holders) in 2010 (Agriculture Census, 2010). B. The small agricultural landholders: This group included about 2.3 million holders in

1990; the number has risen by 60% in 2010. Table 1 shows the evolution of agricultural landholders within this category over the twenty years (1990-2010). The proportion of smallholders in the total number of holders in Egypt has increased from 77.9% to 84.3%, while the average holding area has declined from 1.14 feddan to 0.91 feddan from 1990 to 2010. The largest proportion of small scale farmers are the holders with less than one feddan, their proportion has risen from 36.1% in 1990 to 48.3% in 2010

Table 1. Number and area (fed) of holdings within the SSF class (<3 fed)

Holding size (fed)	1990					2010				
	number	%	Area	%	Average Area	number	%	Area	%	Average Area
<1 fed	1050.9	36.1	508.1	6.5	0.48	2143.9	48.3	923.6	9.5	0.43
Fed(1-<2)	713.8	24.5	941.1	12	1.32	1068.6	24.1	1322.1	13.6	1.24
Fed(2-<3)	502.1	17.3	1137.4	14.5	2.27	531.5	12	1177.9	12.1	2.22
SSF total	2266.8	77.9	2586.6	33	1.14	3744	84.3	3423.6	35.2	0.91
Grand total	2910.3	100	7849.2	100	2.7	4439.5	100	9730.8	100	2.19

Source: compiled and calculated from agricultural censuses of 1990 and 2010

Legal entity of holdings in national statistics: The majority of individual agricultural holdings are small holdings: about 38.2% of the individual holdings are less than 3 feddans, 51.0% less than 5 feddans, and approximately 66.7% are less than 10 feddans (Table 2).

Table 2. Distribution of land holding (%) 2010 census

Area (fed)	Individuals	Organizations	Area (fed)	Individuals	Organizations
Landless	0	0	10-20	12.78	0.25
< 1	10.30	0.007	20-50	10.66	0.76
1-2	14.75	0.012	50-100	3.62	0.98
2-3	13.14	0.013	100-500	3.92	8.08
3-5	12.86	0.034	500-1000	0.93	7.19
5-10	15.70	0.111	> 1000	1.35	82.56

Source: Ministry of Agriculture and Land Recl a mation, consolidated results of Agriculture Census 2009/2010.

Farm holding fragmentation: The most important phenomenon in Egyptian agriculture is the fragmentation of holdings. Table 3 shows that nearly one third of the small holding farmers have more than 2 parcels. It is obvious that small farms with more than one parcel will have more difficulties to utilize modern technologies by their own means. The land fragmentation leads also to an inability to control pests and to regulate irrigation water to meet real requirements of different crops. The land fragmentation is one of the most important obstacles facing the country in organizing agricultural production services and applying collective agricultural rotation, which is necessary for the conservation of natural resources. It is the main obstacle to the development of organizing value chain marketing systems, which can improve the ability of these farmers to bargain collectively to get fair share of the consumer price especially in the case of perishable crops.

Table 3. Distribution of small scale farms by holding size and number of parcels (%)

Land holding	One parcel	Two parcels	Three parcels	More than three parcels
< 1 fed	90.22	9.48	0.29	0.01
1-2 fed	57.02	34.96	7.40	0.62
2-3 fed	41.79	38.73	16.89	2.59
3-5 fed	38.89	33.85	21.14	6.12
5-10 fed	52.02	24.52	15.79	7.67
Total	70.02	22.09	6.54	1.36

Source: Ministry of Agriculture and Land Reclamation, consolidated results of Agriculture census 2009/2010.

Land tenure: It has changed through time. It declined from 2.7 feddan in 1990 to 2.2 feddan in 2010. The area of large landowners category (50 feddans or more) has declined about 19.1% between 1990-2010 (Table 4).

Table 4. Change in average area (fed) of land holding of farms of different categories of land holders from 1990 to 2010

Farm size	1990	2010
< 1 feddan	0.483	0.431
1-5 feddan	2.126	1.893
5 - 10 feddan	6.28	6.09
10-20 feddan	13.03	12.65
20-50 feddan	28.22	27.07
50-100 feddan	63.91	61.48
>100 feddan	568.6	450.1
Average	2.7	2.2

Source: Compiled and computed from agricultural censuses (1990, 2010)

In conclusion, the smallscale holders' category in Egypt is expanding in numbers and there is further decline in the area of their holdings. This has a negative impact on the socio-economic situation of Egyptian agriculture as a whole, from the perspective of technical and economic efficiency, economies of scale, and farmers' living condition and poverty.

General characteristics of small-scale farmers

A recognition of the characteristics of SSFs from different aspects (social, economic, cultural aspects, etc.) is very important in designing supportive policies and programs. Small scale farming is usually characterized by intensive labor and, in most cases, using animal as a source of draft power. There is limited use of chemical fertilizer. The most of the production is disposed in the surrounding markets.

Family labor: The number of family labor engaged on SSF has increased from 3.48 to 3.60 million permanent laborers (Table 5). This number has doubled for temporary family labor (from 5.62 to 11.12 million). Women were 14.4% of the total permanent employment, and 40.9% of the total temporary employment in 2010. The SSF is the category that provides most of the permanent and temporary employment opportunities for the family. In 2010, this category involved 71.3% of total permanent family employment, and about 69.5% of total temporary family employment, despite the fact that agricultural land held by this category represents only 35% of the total land area. If the medium and large farms (more than 3feddans) are taken as a basis for comparison, the average (permanent and temporary) labor per feddan in this category was about 0.72 individual / feddan in 1990 and 0.70 in 2010. The corresponding figure for SSF is about 3 labors/feddan. This number considerably increased in less than 1 feddan category reaching 5.8 labors/feddan This involves a significant reduction of the efficiency of human resource in the small farms, which means a decline in the level of productivity/ unit of labor component (Table 6). The rate of permanent family labor /feddan is declining, in all the categories of farms, especially for SSF. Agriculture activity is no longer attractive to family members for permanent work and farm family members generally. Especially, young members prefer to move towards the non-agricultural activities as permanent work where ever it exists.

Table 5. Number of family labors working in their own holdings (thousands) (2010)

Farm size	Permanent			Temporary		
	Male	Female	Total	Male	Female	Total
Landless	95.2	33.1	128.4	1089.3	831.9	1921.1
SSF	2206.1	374.0	2580.2	4598.8	3128.1	7726.9
≥3	795.7	115.8	911.2	887.9	582.3	1470.3
Total	3097.0	522.9	3619.8	6576.0	4542.3	11118.3

Source: Compiled and calculated from agricultural censuses of 2010 census.

Table 6. Family labors per feddan for each farm size in 1990 & 2010 censuses

Farm size	Permanent labors/Fed.		Temporary labors/ Fed.		Total labors /Fed.	
	1990	2010	1990	2010	1990	2010
<1 fed.	1.29	1.06	2.61	4.72	3.90	5.78
1- 2 fed.	0.93	0.74	1.18	1.69	2.11	2.43
2-3 fed.	0.66	0.53	0.72	0.96	1.38	1.49
SSF	0.88	0.75	1.37	2.26	2.25	3.01
≥ 3 fed.	0.26	0.16	0.46	0.54	0.72	0.70
Total	0.49	0.37	0.79	1.14	1.28	1.51

Source: Compiled and calculated from agricultural censuses of 1990 and 2010

There is a clear rise of temporary labors/feddan among the different categories of land tenure, especially for SSF. Egyptian agriculture did not see untraditional changes between 1990 and 2010 either in crop structure or technological methods to justify these significant increases in temporary employment per feddan. Therefore other factors need to be considered; one of these could be the low interest of family members in agricultural work and the attractiveness of other off-farm activities like governmental jobs for income security or private sector jobs for income generation.

Age structure of smallholders: According to the censuses of 1990 and 2010, the proportion of the age group < 45 years tends to decrease in all landholders, while the percentages for age groups > 50 years tends to increase. This reflects a decline in ratio of young holders who have better ability for productive work (Table 7). This can be explained by various factors such as the low interest of young generations in agricultural activities and an improvement of living conditions, especially in life expectancy.

Table 7. Age distribution of land holders (1990 and 2010 censuses)

Class of Age	Total holders (%)		Landless holders (%)		Holders < 3 fed (%)	
	1990	2010	1990	2010	1990	2010
<25	0.59	0.52	0.99	0.87	0.53	0.43
>25	2.53	1.89	4.12	3.20	2.17	1.71
>30	4.97	3.56	7.79	5.53	4.14	3.34
>35	12.71	8.95	17.94	12.36	12.30	8.63
>40	14.20	11.97	1724	14.56	14.20	11.84
>45	20.56	20.02	21.02	21.24	20.91	19.96
>50	15.63	17.59	12.88	16.45	16.10	17.84
>55	12.15	14.61	8.49	13.05	12.44	16.62
>60	16.41	19.23	9.18	12.84	15.87	19.60
< 45	35.00	26.77	48.08	36.52	33.34	25.95
45 & above	64.75	71.45	51.57	63.58	65.32	74.02

Source: Ministry of Agriculture and Land Reclamation, bulletin Agriculture census

Irrigation and drainage systems: About 95% of the SSF depends on the Nile water. Only 5.0% have other irrigation sources such as underground water, agricultural drainage water, blended water. About 99% of the SSF continue to apply the traditional irrigation system, which is the least efficient.

Cropping pattern in smallholding: Egyptian agriculture shows a trend towards an increase in the cultivation of cash crops at the expense of traditional field crops. SSF category grew mainly field crops (90.3%), with fruit and vegetables representing only 9.7% of their land in 1990 (Table 8). In 2010, the cultivation of field crops still dominated as they provide sustenance food for SSF communities.

Table 8. Cropping pattern changes between 1990 and 2010 censuses (%)

Holding size classes	Field crops		Vegetables		Fruits	
	1990	2010	1990	2010	1990	2010
<1fed	91.8	93.5	5.5	4.6	2.7	1.9
1- 2 fed	85.9	91.6	10.0	5.99	4.1	2.4
2-3 fed	91.8	89.5	5.9	70	2.3	3.4
SSF	90.3	91.4	6.9	6.0	2.8	2.6
>=3fed	81.9	71.4	10.1	13.9	8.0	14.7
Total	84.6	79.6	9.1	10.6	6.3	9.7

Source: Ministry of Agriculture and Land Reclamation, Agriculture census 1990 and 2010

SSFs and their small holdings are the main producers of the main food and fodder crops for the domestic consumption. According to the 2010 census, about 50.5% of the total wheat area, 56.4% of rice, 55.0% for maize, 53.8 % of sorghum, and 54.2% of clover, and 46.7% of cotton areas was cultivated by SSFs although they cultivated only 35% of the total agricultural land (Table 9).

Table 9. Major field crops (%) cultivated on small holdings

Crops	1990	2010
Wheat	42.25	50.47
Maize (corn)	49.00	55.00
Sorghum	47.66	53.80
Cotton	41.44	46.66
Clover	43.75	51.33
Green fodders	31.50	32.00
Total field crops	90.30	91.40

Source: MALR, Agriculture census – consolidated results, 1990 and 2010

Possession of animal production in smallholdings: The contribution of SSFs in livestock production has risen from 52.6% to 61.3% for the large ruminants, and from 50.2% to 59.3% for small ruminants, compared to the decline in the contribution of the medium and large farmer category (Figure 1).

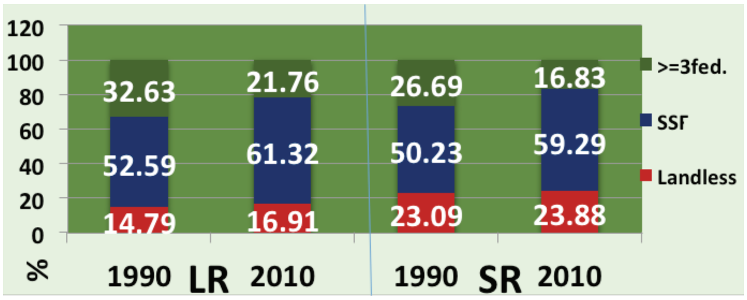

Figure 1. Percentage of livestock (LR large ruminants; SR small ruminants) population in each holding size.

Strengths and opportunities

Despite all the problems and obstacles facing small-scale farmers, this category still has some strengths and opportunities that could help in the improvement of their livelihood, and enhance their participation in sustainable rural and national development. This includes cumulative knowledge in agriculture and risk mitigation, high level of crop intensification, integration between family and farm business, and their considering farming as a way of life, and use of integrated crop livestock farming system. The new laws have been issued by the government that serve the small farmers, i.e. farmer's health insurance law, small farmers and agricultural laborers pension law, agricultural cooperatives amendment law, and the contract farming law.

Challenges

Small farmers face several challenges which hinder their active participation in the agricultural sustainable development: severe land fragmentation, high rate of transforming lands to non-agricultural purposes, continuous and rapid increase in input prices and land rent value and limited access to credit, especially for the landless category.

Prospective and recommendation

Applying collective cropping pattern and crop rotation, development and enhancement of small farmer's agricultural associations, designing and applying a package of direct and indirect supporting policies tailored specifically for smallholders, allocating adequate investment to the development of agriculture sector and to agriculture research, extension of basic services and developing adequate credit policy and system for SSF are the avenues which can improve the livelihood of these farmers and enhance their contribution in the sustainable development of Egyptian agriculture.

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14. Strengthening the seed industry policies in Egypt; opportunities to support the sustainable agriculture in dryland countries

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Abstract

The Egyptian seeds industry has been established more than hundred years ago, a legacy of policies liaised with global agriculture growth trends. In the last 30 years it has been subjected to major reforms to empower this industry to meet the local needs of high quality seeds. The role of private sector, however, needs to be increased in order to supply the market with new varieties that secure high-productivity, especially to those small-scale farmers that practice agriculture in the draylands. The modernization for seed industry in Egypt will promote the current efforts to support the sustainable agriculture. However, sustainable agricultural development seeks not only to preserve and maintain natural resources, but also to develop them, as future generations will have much more demand for agricultural and food products in terms of both quantity and quality. Egypt exports seeds to many countries especially those located in dryland area. However, it also imports seeds of many crops due to its climatic conditions. The paper will explore the current situation of seed industry in Egypt, with a quantitative analysis, within the scope of Egyptian Agriculture Strategy 2030, with its reflections on the future outlook in combating the food insecurity and promote the biodiversity in the face of ecosystem challenges.

Keywords: Seeds, Policies, Agriculture, Drylands, Sustainable development, Food security, Small-scale farmer

15. Supporting policies to combat desertification in Egypt

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Abstract

Egypt is located in one of the driest regions of the world, with full reliance on Nile and ground water for different economic activities, including agriculture. Regulating policies for better utilization of these resources are of particular importance to combat desertification. Those policies can become a major tool to expand the green area in Egypt, supporting activities with high economic returns as well as limited risk in investment. These policies are: a. Develop plant varieties that are tolerant to drought or can be cultivated on low quality water; b. Provide incentives for investment for activities supporting value chains; and c. Adoption of agricultural insurance policies and risk mitigation. The paper will discuss these policies, the mechanisms to implement them and the expected positive effects of these on combating desertification in Egypt.

Keywords: Policies, Combating desertification, Value chain, Agricultural insurance

16. Sustainable water management and eco-healthy prevention process among rural communities in semi-arid region of Tunisia

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Abstract

The irrigation development in the Sidi Bouzid region embodies both the sustainability issues of the water resources management and the question of the eco-health resiliency system among the rural communities. Indeed, the intensification of the irrigated agriculture is marked by continuous pressure on water resources and strong difficulties of the collective management process. Furthermore, studies showed that the development of irrigation is a factor that increases the spread of certain diseases among the rural households. Within this context, the community of El Hechria, based around the public irrigated area of Sidi Sayeh I, showed an important risk of exposure to the Zoonotic Cutaneous Leishmaniasis (ZCL) disease. In addition, the increase of the water demand constrains irrigators to practice overnight irrigation during the intense activity of the sandfly as main vector of the disease. Hence, this research aims to identify development alternatives that reconcile a sustainable and rational use of the water resources, an effective prevention of the ZCL disease by minimizing the risk of the exposure and an improvement of the farming profitability. In order to reach this objective, field surveys were carried out among the half of the concerned farmers. By using positive mathematical programming, the farming system was modelled in order to simulate scenarios that meet the farmers' purposes. The results showed that irrigators extend their irrigable potential outside the public irrigated area through using their quota of water. This practice increases not only the pressure on water resources but also the irrigation costs. The simulation of supply chains improvement scenario suggests the opportunity to rethink the farming system leading to the consequent decrease in water demand and allowing irrigator to set up daily irrigation. Moreover, the new cropping system provides a significant increase in income that might strengthen the prevention of the disease by reducing the risk of exposure.

Keywords: Irrigation, Zoonotic Cutaneous Leishmaniasis, Sandfly, Rational use of water

17. Introduction to regional and industrial development project, International Platform of Dryland Research and Education, Tottori University

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Abstract

International Platform for Dryland Research and Education (IPDRE), Tottori University is an organization for university-wide interdisciplinary research and education in collaboration with leading scientists and stakeholders around the world, and focuses attention on a wide range of problems over the natural, agricultural, industrial and social sectors in drylands and developing countries. As problems similar to ones in drylands and developing countries arise often in our local area, problems and solutions associated with IPDRE can be shared with both drylands and developing countries, and our regional society. One of our missions is to contribute to the sustainable development of drylands and developing countries in the world as well as our local area through transfer and implementation of knowledge and technologies invented in Tottori University. The Industrial Development and Promotion Group of Regional and Industrial Development Project aims at industrial development and regional vitalization by taking advantage of our local and international networks. This paper provided an introduction to the group, our local networks among industry, local government, finance, and academia, joint researches with various sectors, and technology transfer from our university to companies including a local venture company, which is expanding its business in the dryland regions.

Keywords: IPDRE, Industrial development, International network, Technology transfer

18. Restoration of the coastal geo-environment along Tottori Sand Dunes

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Abstract

Objectives of this study are to trace natural restoration processes of the coastal geo-environment in the humid climate over 50 years along the coast of Tottori Sand Dunes, South-west Japan. Along the coast, dimensions of offshore bars were illustrated from aerial photos taken in 1968-2008 at 5-year intervals, and the grain size distributions at berm crests on the beach have been investigated over half a century since 1955. The results show that beach environments have been restoring naturally after damages induced by human activities, such as sand and gravel harvesting in the Sendai River during 1960-1975, which had caused diminishing of offshore bars, coastal erosions and beach sediment coarsening (>1.0 mm) in 1980's and finally vegetation covering of the Tottori Sand Dunes. After stopping sand and gravel harvesting, large floods occurred in 1998 and 2004. These floods transported lots of sediment from upper parts of the drainage area to the main Sendai River. Around 2000, offshore bars along the coast became larger and grain sizes on the beach changed to become finer (<0.4mm) after 2011. These grain size values are similar to those in 1955. We are expecting that weeds on the Tottori Sand Dunes will regrow naturally by activating blown sand. These phenomena are a good story to let visitors notice: a well-coordinated natural system as a geo-park site in the San'in-kaigan UNESCO Global Geo-Park.

Keywords: Natural restoration, Coastal geo-environment, Tottori sand dunes

19. STEM Project-based learning in designing and making products for developing countries

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Abstract

It is generally agreed that education in the fields of science, technology, engineering, and mathematics (STEM) is vital for fostering innovative human resources. To achieve effective STEM education, interdisciplinary and applied approaches are necessary. The four disciplines should be integrated into a cohesive learning rather than teaching each as separate and discrete subject. We introduce the Project-Based Learning (PBL) as a well-suited method to STEM education. In PBL program, students can learn STEM through the experience of project solving inter-disciplinarily and practically. Innovation Center for Engineering Education (ICEE) of Tottori University, in Japan, provides STEM PBL programs for students in the Faculty of Engineering. In the program, students try to design products and make prototype models under specific subjects. The subjects are offered from collaborating organizations. Usually, they are mainly local companies including NPOs and, sometimes, local governments. So far, educational staff of ICEE have developed and improved the educational programs, instructions, materials and tools. Based on those educational resources, we have just started the new program in cooperation with Jomo Kenyatta University of Agriculture and Technology (JKUAT) of Kenya. In that program, students deal with social problems in Kenya and they work on problem analysis, idea development, product design and prototyping. The cooperating organization JKUAT presents problems and gives feedbacks to our students. In return, JKUAT can get the outcome of the project. The outcome may be useful as feasibility studies or prototypes. Moreover, the educational methods developed through this program can be applied to develop innovative human resources in JKUAT. Trial classes were conducted using this program. In the trial classes, some students developed a water-filtering system and an animal-detection system. This poster will introduce the details of PBL programs, the results of trial classes with JKUAT and the future plans.

Keywords: Project-based learning, Educational methods, Human resource development

20. Rapid renewable wood substitute from palm midribs

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Abstract

JEREED (an Arabic expression for rapid renewable wood substitute from palm midrib and trade mark of the organization) uses palm midribs to produce wood-substitute boards, marketable furniture items parquet and decorative accessories to satisfy local, national, and international demands for green products. The machines used are especially designed for production in regular village households, requiring no additional utilities or special investments. This creates income sources for the poor villagers and reduces the negative impact on the environment from burning the palm midribs, or poor maintenance of the palm trees.

Keywords: Palm trees, Wood substitute, Farm income, Environmental protection

21. New promising cash crop halophytes for dry lands farming

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Abstract

Dry areas currently occupy over 40% of the total land surface. These areas are facing a series of challenges: severe fresh water scarcity, land degradation, low agricultural productivity and increasing level of poverty. In addition, the negative effects of these factors would increase as a result of climate change. In our study we have tried to introduce productive new promising cash crop halophytes into cropping systems in the marginal dry areas to raise agricultural productivity and support food and feed security as well as reduce the pressure on limited fresh-water resources. There is no doubt that it will lead to improved quality of life of the rural poor in the dry areas. The newly introduced plants belong to different families and are: *Sesuvium portulacastrum* (Aizoaceae), *Leptochloa fusca* (Poaceae) and *Chenopodium quinoa* (Amaranthaceae). These plants can grow using land and water unsuitable for other conventional crops, since they are highly tolerant to harsh conditions and have potentials to provide food, fodder, medicines, landscaping and soil covering under conditions of dry regions. The efficiency of such new crops under high saline soil conditions (ECe=27 $ds.m^{-1}$) was evaluated in comparison with normal soil conditions (ECe=1.9 $ds.m^{-1}$). Vegetative growth parameters, productivity, grain yield, proximate analysis and feeding values as well as nutritive values were recorded. The results showed that *Sesuvium* can tolerate and grow under extremely high salinity concentrations. The highest forage yield recorded was 12.0 t ha^{-1} with 8% protein content. However, the Na content in *Sesuvium* shoots is 10 times higher than K and P. Concerning chemical compositions of *Leptochloa* shoots, salinity led to an increase in protein, ash, fat and carbohydrates contents, while fiber content was decreased as a compared with non-saline conditions. In quinoa grains the concentration of the total carbohydrates significantly decreased whereas the concentration of protein, Fe, Na and ash increased significantly. No significant differences were found for oil, fiber, P and K contents under saline conditions. These new cash-crop halophytes have highl potential as forage crop (*Sesuvium* and *Leptochloa*) and grain crop (quinoa) due to their high nutritional values and quality of grains under dry regions.

Keywords: *Leptochloa, Sesuvium*, Quinoa, Salinity, Proximate analysis, Feeding values & Nutritive values.

22. Exploration and practice on the sustainable development of World Heritage Site - a case study of the Mogao Grottoes, Dunhuang, China

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Abstract

The Mogao Grottoes of Dunhuang are a world famous treasure of the Buddhist art, located between the Kumtag Desert and the eastern piedmont of Mount Mingsha. Researchers and managers in this site always insist on an all-round sustainable development, including tourism development, cultural inheritance, resource utilization, cultural heritage conservation, ecology health and environmental coordination. This kind of approach has brought economic and social benefits for the local region. Based on a review of research issues and experiences related to sustainable development of heritage sites, with in the perspectives of environment protection, exploitation and utilization, impact on the economy, we have summarized the status of the development of the Mogao Grottoes, and analyzed the process of sustainable tourism development, identifying the opportunities and challenges in the coming days. After discussion on forging cooperation, an agreement has been reached, between our academy and other institutions for sharing the protection of cultural relics resources. However, there are still many problems, such as the frequent breaking of the limit of maximum tourist bearing capacity fixed considering the fragile ecological environment of grottoes, biodiversity capacity, continued control and monitoring of natural and man-made environment, the landscape change because of infrastructure construction and modification, and the rapid development of heritage sites and buffer zone. The solutions include proper planning, integrated protection and diverse exploration etc., following the principle of preservation and scientific conservation, by real-time environment monitoring, alternated opening of caves, increased technological investment, visitors reservation services and maximum capacity control, scientific management, digital display technology and new media transmission, socialization of activities of Dunhuang culture, new models of touristic publicity by local residents, and transparent and effective cooperation between all stakeholders. In conclusion, the development of Mogao Grottoes tourism must be based on respecting the ecological environment as well as the local social and cultural environment, by the pursuit of the harmonious development among tourism, nature, culture and human living environment, as a new mode of tourism development that can benefit the future generations.

Keywords: Cultural heritage site, Sustainable development, Protection of cultural relics

Theme 9. Renewable energy

1. Opportunities and constrains of renewable energy deployment in Egypt

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Abstract

Energy is a critical factor to Egypt's immediate economic recovery plan and broader vision of private sector development. Egypt's historic energy security has faced a number of challenges during recent years. In the last few years, this situation has particularly serious. The gap between the production and consumption of petroleum products and electricity has been expanding, which, combined with lack in energy infrastructure, has resulted in serious outages of electricity, particularly during summer months. Subsidies to the energy sector are fiscally unsustainable, while low prices have decreased energy production and boosted demand growth, leading to an increase in energy deficit. Achieving Egypt's vision will require sustained economic growth of about 6-7% per annum with a corresponding acceleration in energy demand. Meeting this demand will not be possible without diversifying energy supply and thorough transformation of the energy sector. The New and Renewable Energy Authority (NREA) was established in 1986, to act as the national focal point for expanding efforts to develop and introduce renewable energy (RE) technology on a commercial scale and implementing the energy conservation programs. The main barriers for deploying RE in Egypt are: securing the required huge finance for RE projects by the public and private sector; the average cost of each kWh generated from RE projects is still higher than the same produced from conventional power plants due to Low Energy Tariff; and there are technical risks on the grid stability due to implementation of RE projects.

Recently, Egypt has set a target of 20% of its electricity generation coming from renewable sources by 2022 and the private sector investment will play a critical role to achieve this strategy. To meet this target, the Egyptian Government has already taken key steps to implement renewable energy strategy, which includes a major subsidy-reform program to remove the subsidy through 5 years up to 2019. Consequently, the price of the electricity generated from RE will be increased annually with same rate of the wholesale electricity. The other step is issuing the new Renewable Energy Law to provide clarity on Feed in Tariff procedures and enabling legal provisions and announcing an interim target for the first regulatory period through Feed In Tariff program (2015-2017) with total capacity of 4300 MW of both solar and wind energy. To achieve this ambitious target of renewable energy in Egypt, there is a necessity to promote the participation of the private sector in this program through providing governmental support, clear incentives and guarantee. In addition, steps will be taken for enhancing the cooperation with both industrial & educational partners to transfer and adapt to local conditions the wind and solar technology in Egypt. This paper will focus on the future of RE and the current situation, main barriers of deployment of renewable energy and the actions being undertaken by the government to overcome these barriers.

Keywords: Renewable energy (Solar and Wind), RE Law in Egypt, Transfer and adaptation of RE technology

2. Production and water use efficiency of *Jatropha curcas* irrigated with agricultural drainage water: A case study of Ismailia, Egypt

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Abstract

Jatropha (*Jatropha curcas* L.) is a renewable source of biodiesel and it is a valuable multipurpose crop. A field experiment was carried out on marginal soil in El- Mhsama, 30 km away from Ismailia, in eastern Egypt from August 2010 to June 2014. Three levels of water application (100%, 97% and 95% of control as I_1, I_2 and I_3, respectively) were tested at regular plant spacing of 2.5m x 2.5m. The water used for irrigation was agriculture drainage water. In addition, two plant spacings (2.5m x 2.5m and 2.5m x 1.25m) were compared at I_2 and I_3 irrigation levels. Three levels of NPK fertilizer (100%, 120% and 140% of recommended rates) were also evaluated at the regular plant spacing and I_2 moisture regime. The productivity of Jatropha shrubs, oil yield and water use efficiency was evaluated. The highest seed and crude oil yields were recorded with Jatropha shrubs that received I_3 irrigation treatment, at both standard and narrow plant spacings. The yield of extracted oil was 130, 233 and 283 kg ha^{-1} at I_1, I_2 and I_3, respectively. The treatment I_3 with standard plant spacing gave highest oil content in the seeds and water use efficiency in terms of yield of seeds, and squeezed and extracted oil yield (0.29, 0.04 and 0.089 kg m^{-3}, respectively). The highest seeds and oil yield was obtained when the shrubs were given 100% of the recommended rate of fertilizer and yield reduced when fertilizer rates were increased. Thus, irrigating the shrubs with agriculture drainage water at an irrigation regime of I_3 (95% of the control), using standard plant spacing (2.5m x 2.5m) and 100% of recommended rate of NPK fertilizer was best under the tested marginal soil conditions.

Keywords: *Jatropha curcas*, Agricultural drainage water, Biofuel, Plant spacing, Fertilizer, Water use efficiency

1. Introduction

Jatropha curcas L., a multipurpose, drought resistant, perennial plant, belonging to Euphorbiaceae family, has gained a lot of importance for the production of biodiesel (Behera *et al*., 2010). The availability of biofuel, in a sustained manner, from Jatropha with an added advantage of less emission of greenhouse gases is the ideal option for mitigating climate change (George *et al.,* 2005). The plant is native of tropical America, but is widely distributed in the wild or semi-cultivated areas in Central and South America, Africa, India and South East Asia (Cano-Asseleih *et al.,* 1989).

Jatropha plant has been successfully grown in southern Egypt using primary treated municipal wastewater for irrigation (El- Diwani *et al.,* 2009). It is cultivated on more than 400 ha in desert areas of Egypt (Ministry of Agriculture and Land Reclamation, 2009). The non-edible oil produced by this crop can be easily converted to liquid biofuel (Azam *et al.,* 2005; Tiwari *et al.,* 2007). Additionally, the pressed seedcake can be digested to produce biogas (CH_4) (Lopez *et al.,* 1997). The cake contains curcin, a highly toxic protein similar to ricin in castor, making it unsuitable for animal feed. However, it can be used as an organic fertilizer (Staubmann *et al.,* 1997; Gubitz, 1999) because of its high nitrogen, phosphorous and potassium content (Riyadh, 2002).

Jatropha shows a wide variation in growth, production and quality characteristics (Jongschaap *et al.,* 2007). It is a hardy crop that can grow in marginal soils and reclaim the wasteland (Spaan *et al.,* 2004). It has low nutritional requirements and grows on soil with pH up to 9 (Tewari, 2007; Biswas *et al.,* 2006). Being drought tolerant, Jatropha can be grown as a boundary fence or live hedge in the arid and semi-arid areas. With extremely low water requirement, it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss (Riyadh, 2002). But Fujimaki and Kikuchi (2009) determined its stress response functions and indicated that Jatropha may not be more tolerant to drought or salinity as compared to other major crop such as soybean or wheat.

Jatropha plants start yielding from the second year of planting, but in limited quantity. If managed properly, the plants can start yielding 4 to 5 kg seeds per tree from 5th year onwards and remain productive up to 40 to 50 years. In rain fed conditions and in wastelands, a Jatropha plant can give only limited seed yield. The Jatropha plant stand may range from 1600 to 2200 per ha; wider spacing is reported to give a larger yield of fruit (794 kg per ha) (Heller, 1996).

The dry seed of Jatropha would yield about 30–38% of crude oil using a motor-driven expeller (Forson *et al*., 2004). In semiarid regions, low rainfall and low soil fertility are the main factors responsible for low yields of many crops used for the extraction of vegetable oil destined to biodiesel production and Jatropha is no exception. The use of optimum level of essential macro nutrients (N,P,K) is critical for *Jatropha* to evolve as a commercial crop (Mohapatra and Panda, 2011). Also, efficient management of moisture supply and use of optimum plant stand are essential to increase productivity of Jatropha. Therefore, the present study was undertaken to develop appropriate agronomic practices for producing Jatropha, using agricultural drainage water, in peripheral desert of the Nile delta.

2. Materials and methods

An experimental field of 0.75 ha was set up in a farmland by the side of Ismailia drainage canal in the El-Mhsama village in Ismailia governorate (N 30.5397^o, E32.0625^0). The ground level was about 2.5 m higher than the drainage canal. The soil was sandy loam. The chemical analysis of the agricultural drainage water used for irrigation was as follows: pH 8.8; EC 1.93 dS/m; Ca^{++} , Mg^{++}, Na^+, and K^+ 4.5, 4.0, 10.8, and 0.33 meq/L, respectively; HCO_3^-, Cl^-, and $SO_4^=$ 5.5, 12.0 and 2.65 meq/L, respectively; SAR 5.25; available N, P and K 17.5, 0.154 and 12.9 mg/L, respectively; and Fe, Pb, and As, 0.2, 0.66, 0.0008 mg/L, respectively. The concentration of available heavy metals (Fe, Cu, Pb, As and Cd) was measured by Atomic absorption spectrophotometer after acidifying with nitric acid (APHA, 2000).

The six-month old seedlings, raised in the nursery of Agriculture Research Center, were transplanted on the soil of the experimental site in August 2010. Plants were spaced 2.5m x 2.5m for standard plots. Spacing was 2.5m x 1.25m for narrow spacing plots.

Three levels of irrigation were tested with standard spacing and recommended fertilizer application. These were: water application at 100% (control), 97% and 95%, designated as I_1, I_2 and I_3, respectively. Since no crop coefficient data is available for Jatropha at different age and season, the daily amount of application was adjusted based on visual monitoring for control treatment, i.e. we raised the rate when leaves looked wilted and lowered it in autumn when leaves looked fresh. Two levels of irrigation (I_2 and I_3) were tested at standard and narrow spacing to study the interaction of these two variables. The amount of water of control (100%) was estimated on the basis of the shrub's wilting point. Three levels of NPK fertilizer (100%, 120% and 140% of recommended rates) were also evaluated, by injecting required amount of liquid fertilizer weekly, at the regular plant spacing and I_2 moisture regime.

Randomized complete blocks design was used. There were three replicates and each replicate had ten plants. Data were analyzed as described by Snedecor and Cochran (1989).

Water was applied through a drip irrigation system almost every day from transplanting the seedling until the end of the experiment, except during the period of dormancy (period from January until April) when the shrubs dropped their leaves. A button type emitter with a standard discharge rate of 2 L/h was used; each plant was irrigated with one emitter. To implement different application levels, an automatic solenoid-valve controller was developed. It operated according to a program of Campbell CR10X. There were two cycles: the first was to apply liquid fertilizer and the second was to apply water. A dose of 166 g of soluble fertilizer (recommended rate), which contained 19% of N, 19% of P_2O_5 and 19% of K_2O, was applied every time to whole area, where fertilizer rates were not a test variable.

Meteorological conditions, i.e. air temperature, humidity, solar radiation, wind velocity and direction, were measured with a Campbell Weather Hawk station. Soil moisture, temperature and salinity at 20 cm away from the plant and at the depths of 3, 10, 20, 40, 80 cm were observed with Decagon 5TE probes.

Growth study for plant height and stem diameter was carried out in June and October, while the mature fruit weight and the percentage of fruiting shrubs were studied twice a year, on February and September, till the end of the experiment in June 2014. The dry matter was determined by drying a representative sample of the plant at 80ºC for 24 hours in an oven (Kalannavar *et al.,* 2009). Seeds were squeezed by a compressor (KT23-100EL) to get squeezed oil yield. Extracted seed oil was determined by using Soxhlet apparatus and n-hexane (40-60 ºC) as solvent, then oil yield was calculated (AOCS, 1981). Oil yield per 100 g seeds was measured and then calculated per hectare. The crop water use efficiency (CWUE), expressed as kg seed per m^3 water applied (Begg and Turner, 1976), was also used to compare various treatments.

At the end of the experiment (June 2014), the soil physical and chemical analysis was carried out according to Black *et al.* (1965). Available Fe, Cu, Pb, As and Cd were extracted by DTPA-reagent (Lindsay and Norvell, 1978) and measured by atomic absorption spectrophotometer. Pesticide residues in drainage water and in soil were determined by chromatographic technique.

3. Results and discussion

The effect of different irrigation levels, plant spacing and fertilizer levels on Jatropha height is shown in Table 1. The treatments did not affect the height significantly although there was an indication of increased height with 100% irrigation level. Evangelista (2009) indicated that fertilizer types and plant spacing significantly affected the growth and development of Jatropha. The stem diameter was significantly higher with standard spacing as compared with narrow spacing (Table 1). Other treatment effects were not significant. Fagam *et al.* (2012) studied the effect of spacing on the canopy diameter and observed that it was not significantly affected.

Table 1. Jatropha shrub height (cm), stem diameter (cm), fruit weight (kg/plant), total fresh and dry weight (kg/ plant), squeezed crude oil (%) and extracted crude oil (%) at the end of experiment in June 2014

Treatments	Plant height	Stem diameter	[a]Fruit weight	Total fresh weight	Total dry weight	Squeezed crude oil	Extracted crude oil
Effect of irrigation levels:							
100% (I_1)	162.1	8.97	0.119	8.50	2.49	10.23	22.92
97% (I_2)	149.9	8.72	0.278	5.42	1.61	12.38	27.88
95% (I_3)	148.6	8.84	0.311	11.10	3.21	13.79	30.89
Sig.	N.S	N.S	N.S	**	**	**	**
L.S.D 0.05	—	—	—	0.022	0.023	0.158	0.014
Effect of irrigation levels and plant spacing (2.5mx2.5m: S1; 2.5mx1.25m: S2)							
I_2, S1	149.9	8.73	0.278	5.42	1.61	12.45	27.88
I_2, S2	141.3	8.17	0.0916	7.06	1.78	11.50	25.76
I_3, S1	148.6	8.85	0.311	11.10	3.21	13.79	30.89
I_3, S2	147.17	7.89	0.187	5.42	1.932	14.27	31.96
Sig.	N.S	N.S	N.S	**	**	N.S	N.S
L.S.D 0.05	—	—	—	0.097	0.099	—	—
I_2 mean	145.6	8.45	0.185	6.24	1.695	11.972	26.82
I_3 mean	147.9	8.37	0.249	8.26	2.571	14.03	31.43
Sig.	N.S	N.S	N.S	**	**	**	**
L.S.D 0.05	—	—	—	0.069	0.07	0.73	1.634
S1 mean	149.3	8.79	0.295	8.26	2.41	13.12	29.38
S2 mean	144.2	8.03	0.139	6.24	1.86	12.89	28.86
Sig.	N.S	**	N.S	**	**	N.S	N.S
L.S.D 0.05	—	0.439	—	0.069	0.07	—	—
Effect of fertilizer levels:							
100%	149.883	8.725	0.278	5.42	1.61	12.45	27.88
120%	137.496	8.266	0.085	7.29	1.96	19.78	44.31
140%	132.873	8.256	0.078	8.77	2.38	11.04	24.73
Sig.	N.S	N.S	*	**	**	**	**
L.S.D 0.05	—	—	0.158	0.022	0.134	2.132	4.782

** Highly Significant, * Significant , N.S Non Significant; [a] Fruit weight in Feb 2014

There were no significant effects of different irrigation levels, spacing and their interaction on the fruit weight at the end of the experiment (Table 1). The fruit weight was, however, significantly affected by fertilizer rates, and the 100% of recommended rate of N,P,K fertilizers gave highest fruit weight. Applying more than the recommended rate resulted in significant decrease in the fruit weight. Data on fresh and dry weight of whole plant indicated that these parameters were significantly increased by higher plant spacing and increased rates of fertilizer application. These results are consistent with results obtained by Evangelista (2009), Krishna *et al.* (2008) and Saxena *et al.* (2001), who indicated that the growth parameter like dry matter yield were significantly affected by fertilizer types and levels and population. The increased total biomass yield in our study did not reflect in increased fruit yield. It may be because of an imbalance between the vegetative and reproductive growth triggered by higher rates of moisture supply and fertilizer rates.

The pattern of fruiting was studied from January 2013 to April 2014. The fruit weight per plant was higher in February and it gradually decreased till September when it started increasing again till February 2014. It means that the main yield of Jatropha is obtained in February as compared with September in the area. The percentage of fruiting shrubs was higher in autumn season (September) as compared with winter season (February), a trend opposite to that of the fruit weight / shrubs. Nahar and Ozores-Hampton (2011) indicated that most fruit production is concentrated from midsummer to late fall with variations in production peaks where some plants have two or three harvests and some produce continuously through the season. There may be several crops during the year if soil moisture is good and temperatures are sufficiently high.

The crude oil content in Jatropha seeds, determined both by squeezing and solvent extraction, significantly increased with a decrease in irrigation levels and increased with intermediate level of NPK fertilizer (Table 1). On the other side, there was no significant difference between the two plant spacings and the interaction between irrigation levels and plant spacing was also not significant. The average oil content obtained by solvent extraction in our study is comparable to that reported by others (Achten *et al.*, 2008; Deng *et al.*, 2010; Heller, 1996).

Table 2. Fruit, seed and oil yield (kg per ha), total amount of water applied (m^3 per ha) and water use efficiency (kg per m^3 of water) for all treatments from 5-10-2012 to 15-6-2014

Treatments		Fruit yield	Seed yield	Oil yield		Water applied	Water use efficiency			
				Squeezed oil	Extracted oil		Fruit	Seed	Squeezed oil	Extracted oil
Irrigation and plant spacing										
100%	S1	970.36	594.44	58.106	130.122	3305.13	0.293	0.1798	0.0175	0.0393
97%	S1	1367.77	837.89	104.275	233.603	3205.99	0.426	0.2613	0.0325	0.0728
97%	S2	1085.30	664.85	76.457	171.260	6413.43	0.169	0.1036	0.0119	0.0267
95%	S1	1497.17	917.16	126.47	283.310	3158.02	0.474	0.2904	0.0400	0.0897
95%	S2	2195.76	1345.12	191.948	429.900	6317.47	0.347	0.2129	0.0303	0.0680
Fertilizer levels										
100%		1367.77	837.89	104.27	233.603	3205.99	0.426	0.2613	0.0325	0.0728
120%		417.35	255.66	50.569	113.28	3205.99	0.130	0.0797	0.0157	0.0353
140%		414.86	254.14	28.057	62.848	3205.99	0.129	0.0792	0.00875	0.0196

Table 3. The pesticides residues in El-Mhsama drainage water and the soil at the end of the experiment

Sample	Residue of organochlorene pesticides (ng/g)					
	α-HCH	β-HCH	γ-HCH	Heptachlor	Aldrin	Heptachlorepoxide
Water sample	ND	0.56	ND	ND	ND	ND
Soil sample	ND	5.2	ND	ND	ND	ND

ND: Non detectable

Table 2 presents the results on total fruit, seed and oil yield (kg per ha), total amount of water applied (m^3 per ha) and water use efficiency (kg per m^3 of water) for all treatments from 5-10-2012 to 15-6-2014. The yield of fruit, seed and oil increased as water application rate decreased and plant spacing narrowed. The highest values of water use efficiency of fruit, seed, and squeezed and extracted oil yields of Jatropha (0.474, 0.290, 0.040 and 0.089 kg m^{-3}, respectively) were achieved at the lowest level of water use with standard spacing (2.5m x 2.5m). Increasing the rate of fertilizer application decreased the WUE. Abdrabbo and Nahed (2009) reported that the highest water use efficiency in terms of seed and oil yields of Jatropha (0.44 and 0.13 kg m^{-3}, respectively) was achieved with irrigation at the rats of 100% of potential ET. WUE reflects the ability of the crop to assimilate carbon while limiting water loss through the stomata, and that this depends on the capacity for CO_2 assimilation, photosynthetic efficiency and the type of plant. Jatropha seems to optimize these functions under minor stress that might have been experienced with irrigation at 95% of control while under higher moisture supply there might have been a wasteful use of water, lowering the WUE.

General inference from these studies is that the lowest irrigation level (95%) — water applied (3158 $m^3 h\bar{a}^1$) — and the lowest level of NPK fertilizer (100% of standard recommendation) would be suitable for planting Jatropha using a narrow spacing (2.5m x 1.25m).

As the crop was grown with El-Mhsama drainage water there could be a concern about the pesticide residues building up in the soil. Therefore, the irrigation water and the soil after the end of the experiment were analyzed for pesticides residues. The data in Table 3 indicate that there should be no concern about the pesticide residues as per the standard given by WHO (1992 and 1993) and as stated by Tomlin (2000) about DDT. The chemical analysis of the soil was as follows: pH 7.69; EC 0.23 dS/m; Ca^{++} , Mg^{++}, Na^+, and K^+ 0.3, 0.3, 0.5 and 0.08 meq/100 g, respectively; HCO_3^-, Cl^-, and $SO_4^=$ 0.13, 0.6 and 0.46 meq/100 g, respectively; available N, P and K 28.0, 1.98 and 45.35 mg/kg, respectively; and Fe, Cu and Pb , 10.56, 0.12, 0.169 mg/kg, respectively. The levels of heavy metals in the water and in the soil at the end of the experiment were still with in the limits set by FAO (1992) and cadmium was not detectable in the samples.

Conclusion

Jatropha cultivation under marginal land conditions of El-Mhsama desert of Egypt, using drainage water, would be promising in terms of seed and oil yields and water use efficiency if the crop is irrigated at an irrigation level of 95% of control, narrow spacing (2.5m x1.25m) or standard plant spacing and 100% of recommended rate of NPK fertilizer. It should however be noted that Jatropha cultivation is labour intensive, particularly for collecting the fruits, and the yield levels

Residue of organochlorene pesticides (ng/g)						Residues of PCB, s (ng/g)
γ chloredane	pp-DDE	Endrim	pp-DDD	pp-DDT	Methoxychlor	PCB-178
ND	ND	ND	ND	0.86	65.4	ND
ND	ND	ND	0.02	ND	92	32.4

are very low as compared to castor bean. Therefore, more studies may be needed to come up with detailed recommendations for profitable and sustainable production of Jatropha under Egyptian conditions.

Acknowledgements

The authors would like to thank the scheme 'Science and Technology Research Partnership for Sustainable Development' funded by JST and JICA. Under this scheme the Project "Sustainable System for Food and Bio-energy Production with Water-Saving Irrigation in the Egyptian Nile Basin" was implemented, from 2009 to 2015, collaboratively by the scientists from University of Tsukuba and Tottori University, Japan and Cairo University, National Water Research Center, Ministry of Water Resources and Irrigation, and Agricultural Research Center, Ministry of Agriculture and Reclamation of Egypt.

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3. Development of mobile stand-alone solar driven reverse osmosis desalination plants for sustainable development in Egypt

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Abstract

Egypt is experiencing a fresh water crisis. Many large and small communities in Egypt are suffering an acute shortage of fresh water that complies with minimum health requirements. Water desalination projects based on reverse osmosis technology are being introduced in Egypt to combat drinking water shortage in remote areas. Reverse osmosis (RO) desalination is a pressure driven process. This work focuses on the design of an integrated brackish water and seawater RO desalination and solar Photovoltaic (PV) technology. Small mobile PV driven RO desalination plants prototype were designed and tested. Solar-driven reverse osmosis desalination can potentially break the dependence of conventional desalination on fossil fuels, reduce operational costs, and improve environmental sustainability. Moreover, the innovative features incorporated in the newly designed PV-RO plant prototype are focusing on improving the cost effectiveness of producing drinkable water in remote areas. This is achieved by maximizing energy yield through an integrated automatic single axis PV tracking system with programmed tilting angle adjustment. Mobility of the systems provides potable water to isolated villages and population as well as ability to provide good drinking water to different number of people from any source that is not drinkable.

Keywords: Reverse osmosis, Photovoltaic, Desalination, Northwest Coast

4. Economic analysis of a stand-alone reverse osmosis desalination unit, powered by photovoltaic, for possible application in the North West Coast of Egypt

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Abstract

The availability of fresh water and energy is the key factor of the development of many countries particularly those of over-populated arid areas. Potable water supply shortage and recent technological development have led to wider application of conventional, and yet advanced saline/brackish water desalination plants. Today, desalination methods require large amounts of energy, which make them costly both in terms of environmental costs and in money terms. This study defines the main economic parameters used in estimation of desalination costs and limitation of the stand-alone, small size SWRO plants powered by photovoltaic at the North West cost of Egypt. Moreover, techno-economic study is made to estimate the actual cost of per m^3 fresh water production on real field measurements. All cost estimations are based on the prices prevailing during 2012-2013. The average unit cost of desalted water with the desalination unit powered by photovoltaic battery is 9.3-5.6 LE/m^3, which is very high, but when using the unit without battery, the cost is reduced to be between 2.3 – 1.7 LE/m^3 by increase working hours to 24 hours. Economical strategies should be developed for more reduction in cost taking into account all phases from site selection and design to operation and maintenance and, most importantly, increasing the local manufacturing.

Keywords: Production cost, Economic analysis, Stand-Alone, Reverse osmosis, photo voltaic, Desalination, Egypt.

5. Innovations for long term resilience and sustainable nexus of food, energy and water system

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Abstract

The majority of wastewater treatment facilities in the United States and around the world partially treat the organic solids generated as a byproduct of the wastewater treatment process by anaerobic digestion. Anaerobic digestion generates Class B biosolids which can contain millions of fecal coliforms bacteria and other enteric pathogens per gram of solids. Anaerobic digestion requires heating and keeping the organic solids above 35°C for at least 15 days as per U.S. EPA rule 503 requirements. Approximately 7.1 million tons of dry wastewater sludge are generated each year in the U.S. The wastewater sludge is usually in the form of liquid at percent total solids of less than 10% (> 90% water). This amounts to more than 64.5 million m^3 per year of Class B sludge; of which, 15% is incinerated, 28% landfilled and 36% applied to agricultural land. Huge cost and environmental problems are associated with this practice. The problems range from the release of billions of enteric pathogens into the environment to the emitting of tons of greenhouse gases into the atmosphere contributing to the climate change. It requires more than 650 KWH per wet ton of cake to dry sludge from 15% total solids to 90% total solids. We have adopted, and are in the process of improving on, a treatment technology that dehumidifies the sludge to 90% solids with the consumption of 175 KWH per wet ton of sludge in a pilot project. We constructed a controlled environment greenhouse adjacent to the sludge dehumidification pilot system. The dehumidification system produces disinfected organic pellets that are used as rich energy and fertilizer sources. We are also producing high quality condensate water, electric power, waste heat, and CO_2. All those products are being used in the green house to enhance production and yield of agricultural crops.

Keyword: Waste water, Sludge dehumidification, Greenhouse gases, Electricity generation

Introduction

The majority of wastewater treatment plants in the United States partially treat the organic solids generated as a byproduct of the wastewater treatment process through using anaerobic digestion processes (Figure 1). This process generates Class B biosolids which can contain millions of fecal coliforms bacteria and other enteric pathogens per gram of solids. Anaerobic digestion requires heating and keeping the organic solids above 35°C for at least 15 days as per U.S. EPA rule 503 requirements (U.S. EPA, 1993). This necessitates the construction, operation and maintenance of huge expensive reinforced concrete digesters that generate odors and require air scrubbing at a huge cost to public utilities. Treating and pumping water and wastewater is at the top of energy needs for municipalities across the United States (Corum and Lovely, 2006). According to the

California Energy Commission, 56% of energy usage by municipalities is spent on water and wastewater treatment facilities. Energy efficiency in water and wastewater facilities would make huge savings benefiting water and wastewater utilities and taxpayers.

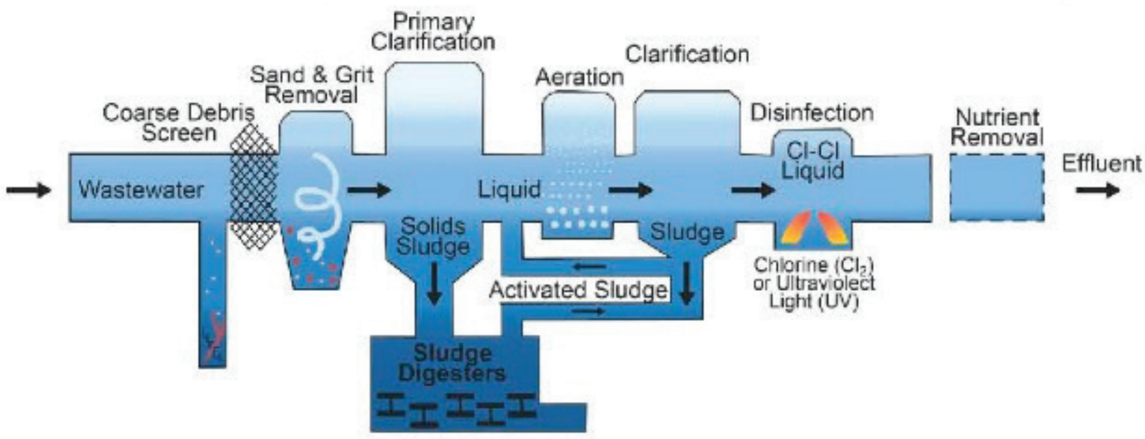

Figure 1. Wastewater treatment process.

Approximately 7.1 million tons of dry wastewater sludge is generated each year at approximately 16,000 municipal wastewater treatment facilities in the U.S. (Water Environment Federation, 2010). The wastewater sludge is usually in the form of liquid sludge with percent total solids less than 10%. This amounts to 64.5 million m^3 per year (Figure 2), of which 15% are incinerated, 28% are landfilled and 36% are applied to agricultural land (Center for Sustainable Systems, 2015).

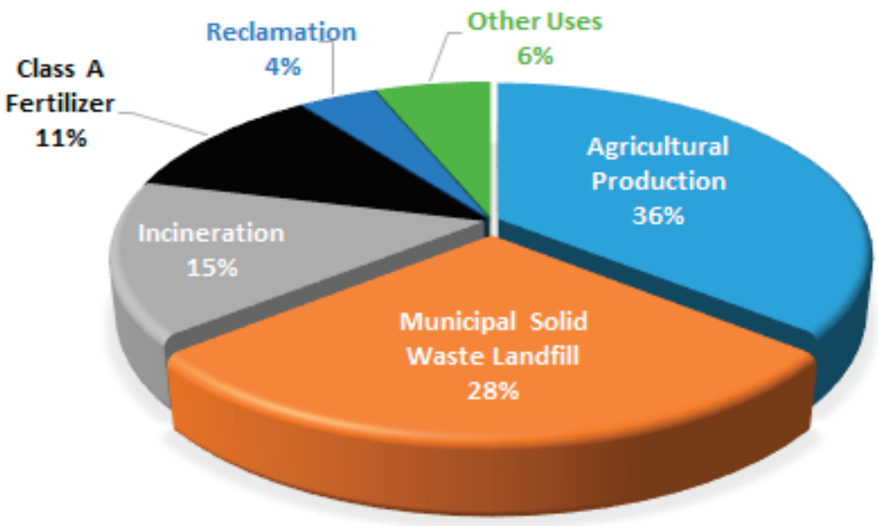

Figure 2. Uses of wastewater sludge in the USA.

When the generated sludge is at a total solids content of less than 10%, that requires the hauling of 18.2 million m^3 of sludge to landfills and 23.1 million m^3 of sludge to land application sites on yearly basis, amounting to millions of hauling and trucking kilometers.

Huge problems are associated with this practice: 1) the release of a minimum total of 1.3×10^{18} fecal coliforms bacteria and enteric pathogens per year into landfills; 2) the release of a minimum total of 4.7×10^{18} fecal coliform bacteria and enteric pathogens per year into agricultural lands and potentially to ground water; 3) emitting millions of tons of greenhouse gases, such as CO, CO_2 and CH_4, into the atmosphere due to releasing and/or flaring digester's methane gas into the atmosphere and from extensive hauling and trucking; and 4) the destruction of US highways and bridges due to the repetitive loading and unloading by the heavy trucks and tankers hauling the mostly water sludge to landfills.

The objective of this study was to:

- Introduce a new transformative low cost technology for converting liquid organic waste such as wastewater sludge to dry disinfected product that has no odor; and has high caloric and nutrient content. The process also produces reusable condensate water.
- Demonstrate the reduction of hauling liquid organic waste through increasing percent total solids to 90% (10% water content).
- Demonstrate the use of the generated treated byproducts in energy generation and agricultural production.

Material and methods

To demonstrate the new technology, a system design for a treatment plant is introduced here and the technology is explained and demonstrated through the design.

Input design parameters

Influent rate to Wastewater Treatment Facility "A" is 15,520 m^3 per day (4.1 million Gallon Day). The treatment facility is located in south west part of United States and it serves a community of 30,000 people. In 2015, the treatment facility generated 15,484 m^3 of untreated stabilized liquid sludge per year with an average total solids content of 3.46% (50 m^3 per day based on 6 days per week operation). The liquid sludge was hauled 48 km for treatment to class B level as per U.S. EPA Rule 503 (U.S. EPA, 1993) and was reused for land application. The dry solids present in the liquid sludge can be calculated as 537 tons per year or 1.7 tons per day based on 6 days per week operation. The hauling and treatment cost totaled $383,536 for year 2015 which represents a cost of $0.0248 per liter of liquid sludge.

Description of the new technology

The new sludge treatment system consists of two integrated modules: the first is a spiral filter dewatering system that dewaters liquid sludge from 3.46% to 20.0% total solids; and the second is a heat pump dehumidification module that dries the 20.0% dewatered cake coming out of the spiral dewatering system to 90.0% total solids resulting in Class A biosolids that meet vector attraction reduction as per EPA 503 rule (U.S. EPA, 1993). Figure 3 shows a schematic of the new sludge treatment system.

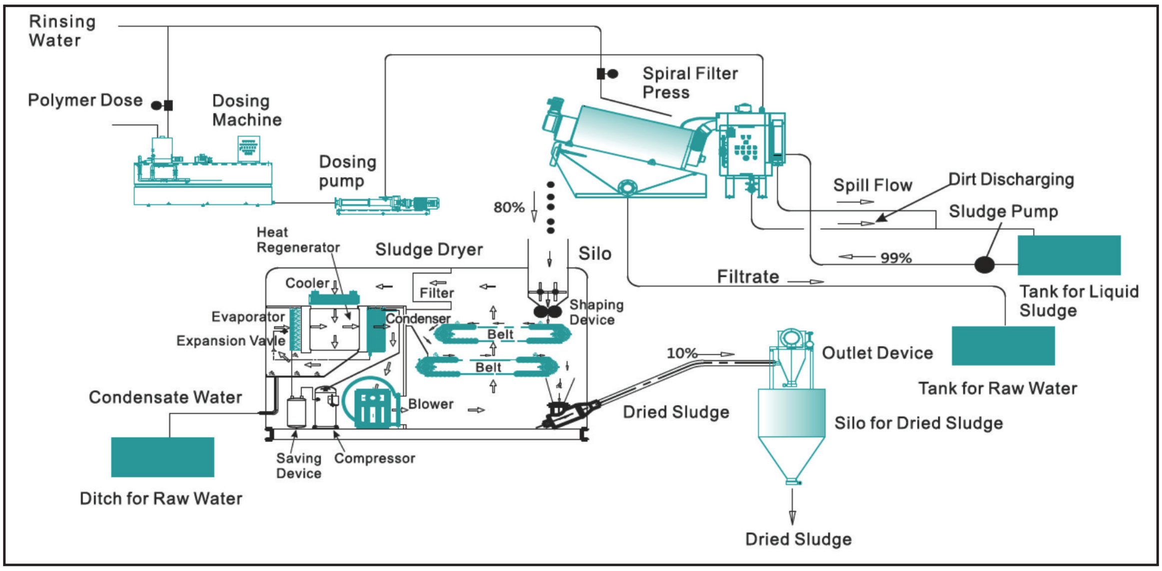

Figure 3. Schematic of the spiral filter press dewatering module and the dehumidification module in the new sludge treatment technology.

Spiral filter dewatering system

The spiral filter dewatering system can dewater sludge from 3.46% to 20.0% total solids with less than 1 KWH per dry ton of sludge, it also requires about 5 Kg of polymer per dry ton of solids. The thickened sludge cake is then dropped into the dehumidification module for drying.

Low heat dehumidification heat pump

The dehumidification heat pump installed in the new sludge treatment system utilizes the refrigeration principal to cool and dehumidify hot wet air. Through the heat pump principal, the heat pump recycles the latent heat released from steam congealing to liquid water. A dehumidification heat pump is equal to the dehumidification process (moisture removal or moisture dehumidifying) plus a heat pump process (energy recycling). A dehumidification heat pump can internally collect all the latent heat and sensible heat during air exhaust, bringing no waste heat to the outside.

The evaporation of sludge moisture absorbs latent heat; and the condensation of the generated vapor on the heat pump cycle releases latent heat. The evaporation process absorbs the same quantity of latent heat that the condensation process produces, according to the laws of thermodynamics and the law of conservation of energy. As a result, the drying process does not require additional heat capacity, resulting in the reduction of energy costs. The energy consumed during the process is only the electricity needed to operate the compressors and the fans or air handlers in the dehumidification system. The new system adopts a belt type closed cabinet dehumidification drying system. There is no need for a treatment system for odor or gas buildup. The sludge cake is shaped as thin spaghetti before it is placed on the mesh belt increasing the sludge surface area to enhance the evaporation of the water entrapped in the wet sludge cake.

The dry air coming into the system, shown in Figure 4, starts at 80°C, the temperature is reduced as the air is moving upward and as its moisture content increases the temperature decreases to reach a temperature of 50°C at the top of the drying module where it enters the dehumidification heat pump. Sludge cake stays on the two drying mesh belts for a total period of two hours.

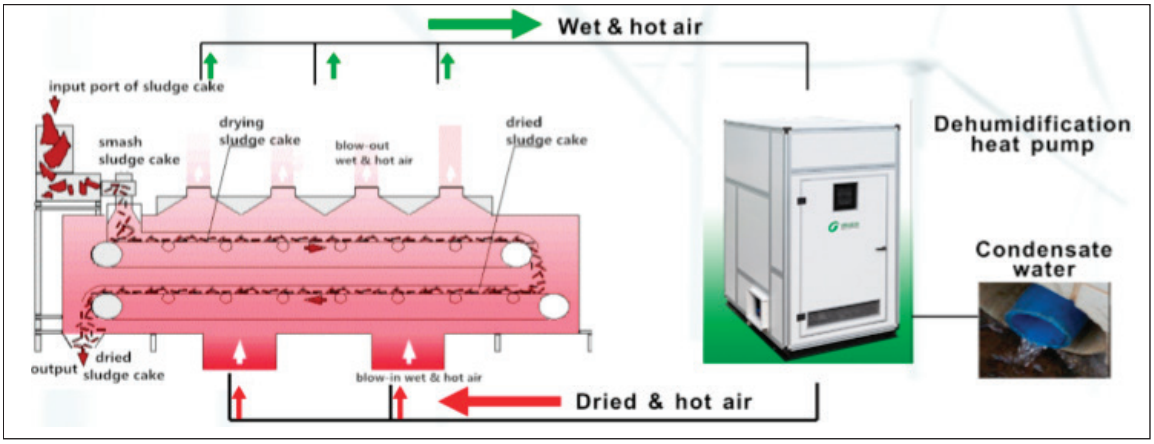

Figure 4. Process flow of the dehumidification and drying module.

Mesh belts

Mesh belts are used in the new sludge dehumidification system with a variable frequency control to vary the belt speed. The speed is adjustable to enable the adjustment of the moisture content of output (dried biosolids). The speed can be reduced to arrive at drier biosolids or it can be increased to arrive at wetter biosolids. During the sludge dehumidification process the dehumidification heat pump dries, by means of hot air, the wet sludge killing all viral, bacterial and parasitic pathogens, hence producing Class A biosolids that have no odor with all nutrient and caloric contents intact. The hot air and the condensate water are captured within the system.

Energy requirement

To dewater 50 tons of sludge per day at Wastewater Treatment Facility “A” from 3.46% to 20% total solids, the spiral filter dewatering system requires one Kilo Watt Hour (KWH) per dry ton of sludge. The 50 tons of liquid sludge at 3.46% total solids contain 1.73 tons of dry solids. Therefore, the spiral filter dewatering system requires about two KWH per day. When the 50 tons of sludge per day are dewatered from 3.46% to 20% total solids, their weight is reduced to 8.6 tons of untreated sludge cake per day. The dehumidification system requires an average of 175 KWH to dehumidify one ton of sludge cake from 20% to 90% total solids. Therefore, to dehumidify 8.6 tons of sludge cake per day from 20% to 90% total solids the dehumidification system requires 1,505 KWH per day.

Results

To treat the 50 m³ of liquid sludge generated at Wastewater Treatment Facility "A" per day using this patented efficient dewatering and dehumidification treatment system, the 50 m³ (equivalent to 50 Tons) per day are reduced to 1.9 tons of Class A biosolids at 90% total solids. Figure 5 shows the drastic reduction in the weight of sludge after dewatering and dehumidification as a function of percent total solids. For Wastewater Treatment Facility "A", the reduction of the weight in sludge goes from 15,484 tons per year to 595 tons per year representing a weight reduction factor of 26. In addition, an estimated volume of 5,389 liters of condensate fresh water at ambient temperature are generated every day.

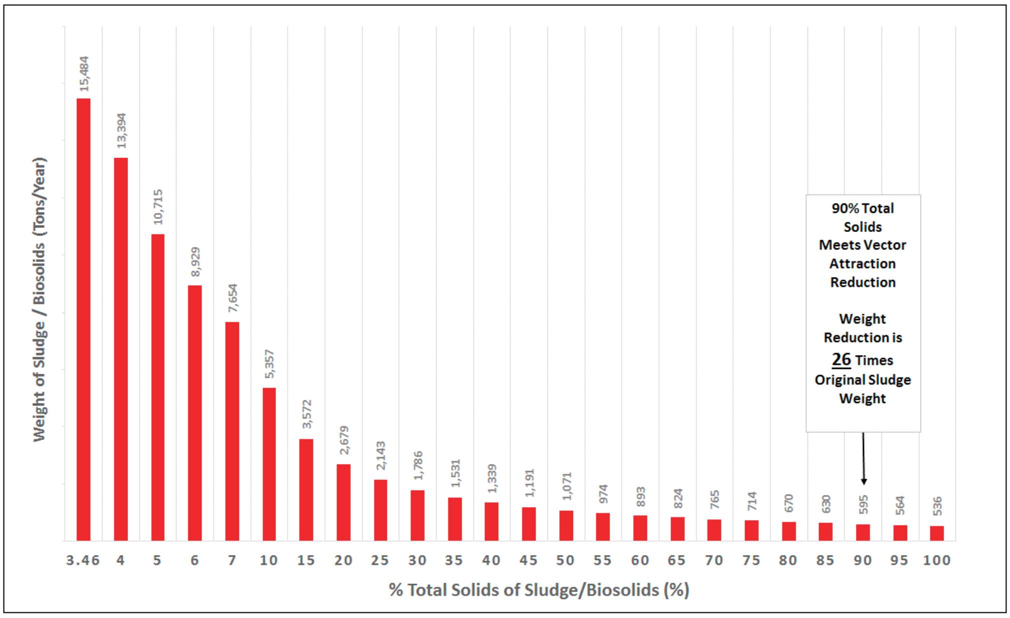

Figure 5. Weight reductions in sludge as a function of percent total solids.

The 2015 cost to haul and treat the liquid sludge generated at Wastewater Treatment Facility "A" was calculated earlier to be $0.0248 per liter of liquid sludge. Capital and financing costs, and operational, maintenance and electric costs of the New system over 3 years, with municipal interest rate of 5.0% per year, result in total revised cost of $0.0232 per liter of liquid sludge, resulting in a saving of $0.0016 per liter for the first three years. This represents a total savings of $24,775 for the first three years.

For years 4 through 15, the cost of drying, dehumidification, electrical cost based on $0.08 per KWH, operational cost and maintenance cost will be in the order of $0.011 per liter of liquid sludge. This represents a saving of $214,834 per year over the current practices used in Wastewater Treatment Facility "A". The savings over 11 years (years 4 through 15) represents a total of $2,363,174 assuming 15 years as the operational life of the dewatering and dehumidification systems.

Conclusion

The food, energy and water nexus system is comprised of a Genset to generate electricity, waste heat and CO_2 gas; a controlled environment green house and a dewatering-dehumidification module. All are installed in a wastewater treatment facility that produces preferably undigested stabilized liquid sludge. Undigested stabilized liquid sludge is treated to Class A fertilizer and energy pellets using the dewatering-dehumidification treatment system. The energy pellets are used to generate energy to run the Genset. The Genset generates electricity and waste heat that can be used to run the dewatering-dehumidification system. The condensate fresh water can be used to irrigate agricultural crops in the controlled environment greenhouse. The generated electricity can also be used to light the controlled environment green house at night and for cooling and heating the green house. The CO_2 gas generated from the Genset can be pumped into the controlled environment greenhouse to provide more efficient agricultural growth and yield.

The tangible savings in implementing a food, energy and water nexus system are huge. Those savings can be reflected by the drastic reduction of the high cost of treating and hauling sludge at wastewater utilities.

The intangible savings are reflected in eliminating the release of greenhouse gases into the atmosphere, the reduction of contaminating agricultural soils and potentially ground water, saving roads, bridges and highways from repetitive loading and unloading of heavy trucks and tankers, and improving public health.

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6. Current situation and prospects for solar drying and biofuels in Central Africa: Laboratories, research teams and experiences

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Abstract

The work reported here gives the state of research and prospects on solar drying and biofuels in Central Africa. It happens every day without governments' involvement in the renewable energy and biofuels. Indeed, these disciplines affect several sectors. The work of University focuses on the development of sources of renewable energy and biofuels to solve the problem of energy deficit. In this part of Africa, the solar energy is the main source for drying and is the traditional type of energy used for drying, either as direct, indirect, mixed and hybrid. To this effect, we can have biomass energy source and finally the conventional power source. The themes pursued by the research teams are focused on the development of local technologies using local materials. Each country has at least one laboratory for energy and biofuels. Central Africa has ten research laboratories in this field and majority of them respond to calls for tenders. We have identified around ten varieties of products for drying in Central Africa, on which researchers are working. The energy source used here is the sun to adapt to the realities of Africa.

Keywords: Solar energy, Solar dryers, Laboratory team, Central Africa

Introduction

Drying is an important operation in the agricultural industry. For a given application, the drying process should be allowed to dry up the wet product to the desired level within an acceptable time, to give an acceptable quality and size of the product. The process should be appropriate to the equipment being used and its cost, safe and without impact on the environment.

The selection of a drying process can be done by an iterative process based on: defining needs and constraints; pre-selection of possible technologies; defining the hypothesis and conduct tests to identify need for any adjustments and building a schematic plan. The choice of a drying technology might involve making compromise between technical and economic aspects and should be referred to a specialist. Drying is now widely used around the world, with a very broad scope; it is not just about the food products, but also pharmaceutical, wood, plastics and others. By itself, drying accounts for 8% of the energy spent by industry. In the developed countries it is about 12 to 25% (Kapsue *et al.,* 2011; Kapsue *et al.*, 2012 a,b,c,d; Kapsue *et al.,*2014). It should be interesting to find out the situation of use of different drying techniques in Central Africa with respect to development issues and the fight against poverty. Some good indicators that enable the capacity of drying in the region to be assessed are: a) Researchers: who are they and what do they do? b) Laboratories: where are they located and what are their characteristics? This paper provides the answers to these questions and examines the prospects.

Research teams

The research teams are made up of researchers of different ranks (Assistant, Senior Lecturer / Lecturer, Associate Professor, Professor). Research topics are varied and they use processes needing expensive equipment. Given the geographical location of the countries of Central Africa and the fact that they are developing countries, research topics are restricted in their scope because of the limitations on import of equipment and the environmental protection problem. By encouraging the use of local materials and sources of local energy, these problems are averted.

Research teams interested in drying are present in many Universities and at the National School of Agro-Industrial Sciences (ENSAI) of the University of Ngaoundere.

Laboratories

They are located in various regions of Central Africa. These laboratories have on-the- shelf equipment such as ovens and cold preservatives (freezer, refrigerator) that often are expensive. The devices for measuring various parameters (thermometer, hygrometer, anemometer) used in drying are available in the market at reasonable price. Depending on their scope, the drying technologies are different, but based on what has to be dried one can determine the types of dryers that might be useful. The area of interest for all the countries is the drying of agricultural and livestock products. Table 1 presents a few laboratories in the Central Africa region.

Table 1. Some renewable energy and biofuels laboratories in Central Africa

Countries	Institution	Laboratory name	Laboratory head
Cameroon	Faculty of Sciences, Yaounde 1	Technologie de l'Energie et de l'Environnement (LATEE)	Prof. Ndjomo
	National Advance School of Agro-industrial Sciences (ENSAI), University of Ngaoundere	RESH (Reaction extraction, sugar drying and oils)	Prof. Kapseu Cesar
		Energ. Laboratory and Processes	Prof. Kuitché Alexis
		Food Technology and Bio-processes	Prof. Nso Emmanuel
	Advanced National Polytechnic School (ENSP), Yaounde 1	Energe. Laboratory	Prof. Meukam
	Sahel Advanced Institute (ISS, Maroua	Renewable Energy Laboratory	Prof. Djonyang Noel
Central African Republic	ISDR	Advanced Institute of rural Development University of Bangui	
Congo	Faculty of Sciences	Département of Physics, University of Marien Ngouabi, Brazzaville	
Gabon	University Omar Bongo	Faculty of Sciences	
Chad	Faculty of Basic and Applied Sciences	Laboratory of Applied Physics	Prof. Yacoub

Experience

The drying technologies in Central Africa are still less developed compared to countries of North and West Africa. Also, laboratories in universities and independent organizations have set up prototype dryers. Some have already been used in several sectors such as drying of cocoa and coffee. Given the difficult to have access to conventional power sources, developing countries focus on improving the old method of preservation, which is drying in the sun. Thus, traditional solar drying techniques are disappearing in rural areas. Today, there are indirect and direct solar dryers, mixed dryers and hybrids; biomass dryers and a few electric dryers. The prevailing poverty and need for cash has encouraged the people to turn to newer method of drying. Table 2 shows advantages and disadvantages of dryers. Table 3 shows, specification, advantages and disadvantages of different power sources.

Table 2. Advantages and disadvantages of different types of dryers/drying methods

Drying methods/dryer	Advantages	Disadvantages
Traditional air dryer (natural drying)	Drying soft things round the clock; No qualified personnel needed; Low moisture gradient in the thickness; Free source of energy; Small change in product colour.	Exposure time is high; Risk of contamination; Dependent on the weather condition; Needs much space to spread product; Difficulty to get completely dry product.
Direct solar dryer	No contamination; Temperature can rise; Less time needed to dry	Direct exposure of product to sun; Dependent on the weather condition; Initial investment is needed.
Indirect solar dryer	More hygienic quality; Drying is fast; Lesser organoleptic effect.	Dependent on the weather condition; Not suitable in tropical humid zones; Consumes more electrical energy.
Mixed solar dryer	Choice between indirect and direct drying available	
Hybrid dryer	High quality output since any of the above systems can be used	

Table 3. Power source: specification, advantages and disadvantages

Power source	Specification	Advantages	Disadvantages
Gas	Continuous solar energy supply dryers.	Drying time is less when drying is done using solar energy.	Has direct contact with the gas which can cause combustion
	Non-continuous energy supply dryers.		
Electricity	Drying by heating using electrical resistance system.	Temperature can be controlled; Lesser drying time; High quality of the dried product.	Not possible to dry large amount; Temperature limits the product type that can be dried
	Drying using a heating pump	Can be used in tropical humid zones; Can dry large quantity of material;	High cost of dryer; High managing costs
		High quality output.	
Biomass burning	The main source of energy is biomass	High temperature; Smoking is possible.	No control on the process; Biomass collection leads to deforestation

Products that need drying

The major products that need drying in the region include the following:

1. The high water content fruits: mango, banana, pineapple.
2. The low water content fruit: fig, date, safou.
3. Nuts: cashew, peanut, coconut, shea nuts.
4. Leaves: senna, Jew's mallow, baobab, jute, sorrel, moringa.
5. Vegetables: tomato, onion, mushroom, pepper, eggplant, sorrel.
6. Meat and fish.
7. Cereals, tubers and legumes: maize, cassava, sweet potato, peas, beans, yams, millet, all to be transformed into flour, couscous or gari.
8. Cash crops: coffee, cocoa, tobacco, sugar.
9. Spices and condiments: pepper, cardamom, local spices, garlic

Conclusion

Central Africa has ten research laboratories involved the field of drying and the majority of them apply their efforts to the food. There are some ten kinds of products undergoing drying process in Central Africa on which researchers work. The main energy source is either the sun or biomass given the economic realities of Africa.

Acknowledgment

The International Dryland Development Commission (IDDC) and Bibliotheca Alexandrina, Alexandria, Egypt are thanked for their invitation and support to participate in the Twelfth International Conference on Development of Drylands.

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7. Reducing post-harvest losses by solar drying: Case of Central Africa

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Abstract

The drying of food products is now almost mastered under many works to show improving the efficiency of solar dryers. As regards the indirect solar dryers used in single, mixed or hybrid combination, an analysis has shown that they are all of crossing mode and a temperature gradient exists between the trays in the dryer. An indirect solar dryer has been developed in which the airflow is manually guided in the drying chamber. The collector also offers the possibility to change the absorber and store heat through the use volcanic stones found locally. The insulation is made of wood. CESAM has praised the design as it takes into account the needs of the user. This new dryer allows three air circulation patterns in the same equipment as follows: the licking, crossing, and mixed mode. It also helps to have constant temperature reaching 68 ° C in the drying chamber. In the absence of sunlight, heat accumulated in the collector continues to create a difference of 5 °C between drying chamber temperature and that outside for up to 8 hours. The set is mainly made from local materials easily found on site and it depends solely on solar energy.

Keywords: Indirect solar dryer, Post-harvest losses, Heat conservation

Introduction

Solar dryers are the oldest and the most used dryers in developing countries (Karekezi, 1997; Ekechukwu, 1999). But, new drying technologies have also been developed as they, although more expensive, reduce the selling price of the dried products (tobacco, coffee, onion, etc.). Several researchers (Ekechukwu, 1999; Sharma, 2009; El-Sebaii, 2011) have presented design, advantages and disadvantages of currently existing condensed solar dryers to permit selection of a dryer suitable to a given product. The appropriate choice of a dryer affects the drying time, the quality of the dried product and its cost (Matason *et al.,* 1998; Lahmari *et al.,* 2012). Indeed, from one model to the other, the drying parameters differ. For example, a good quality of dried tomato could be achieved at 50 ° C in an indirect solar dryer where exposure to air did not reach 22.5 °C for consistent quality. Management of energy in the dryers allowed good quality drying.

Drying is an operation aimed to eliminate, by partial or complete evaporation, any volatile substance from a wet body (Bimbenet, 1984). It remains one of the least expensive options for farmers to protect post harvest losses, next to techniques such as cold storage, particularly with the use of coolers and refrigerators. Drying is primarily intended to extend the storage life of the produce; but, it also aims to reduce the costs of transportation and storage or to give a special appearance to the product (Leon, 2002; Murthy, 2009; Fudholi *et al*., 2010).

There are several methods of classification of dryers. Some authors classify them according to the source of energy (Mujumdar, 1998; Ekechukwu, 1999. Aleon et al, 2002) and others follow the mode of transfer of energy governing the drying operation. The later refer to the solar dryers with different configurations depending on whether they are of mono, mixed or hybrid modes.

The traditional drying (exposure to air) directly uses the sun and air, with no control on the action. In this form of drying, the product can be spread on mats or arranged on the floor or in cribs installed in a position perpendicular to the prevailing wind (Sharma et Adulse, 2007). Figure 1 shows the principle and the energy flows exchanged in this case.

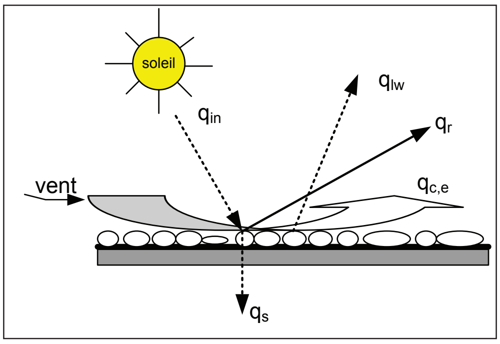

Figure 1. Schematic of natural drying principle (Belessiotis *et al.,* 2010).

In direct solar dryier the material to be dried is placed in a chamber with a transparent cover (Figure 2) for exposure to the sun. Heat is generated by absorption of solar radiation on the product itself (Sharma *et al*., 1990; Gikuru *et al.,* 2005; Belessiotis *et al*., 2010; El-Sebaii, 2011). The greenhouse effect created because of the transparent cover can lead to quick degradation of quality. Many vitamins are not resistant to photo-oxidation.

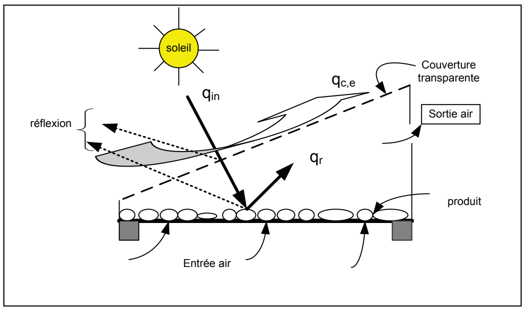

Figure 2. Schematic of direct solar drying with transparent roof (Karathanos and Belessiotis, 1997).

Indirect solar dryer, in contrast to direct drying, uses a solar collector to focus and capture the solar rays to raise the temperature. The heated air in a solar collector is then led into the drying chamber, either by natural or forced convection, to dry the product (Rabl, 1985). Radiation does not arrive directly on the product to dry. There are a wide variety of forms for this type of dryer. Figure 3 shows the principle of operation of this type of dryer. The air enters through the collector, where it gets heated, and rises by convection to the product. Generally, the capacity is low. Convection is natural but in some models, such as those of Figures 4 and 5, there is forced ventilation in order to optimize the system. The drying time varies depending on weather conditions and airflow in the dryer (Rozis, 1995). The temperature in the chamber depends on the weather.

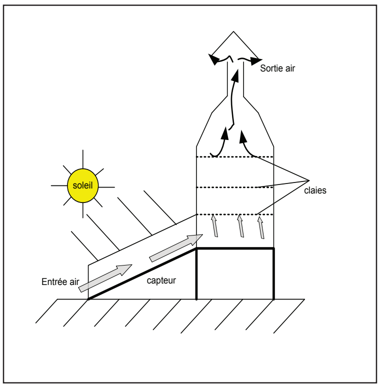

Figure 3. Schematic of operation of indirect solar dryer (Roger and Gregoire, 2006).

An example of a hybrid dryer is shown in Figure 6. It consists of a brick structure (2.3m × 1.1m × 2.2m), two concurrent drying cells — each provided with an air inlet, a burner and a drying duct. There are 10 trays of 0.7 m^2 each. Jain (2005) modeled the system performance of multi-tray crop drying using an inclined multi-pass solar air heater with in-built thermal storage.

Figure 4. Indirect solar dryer (Rozis, 1995).

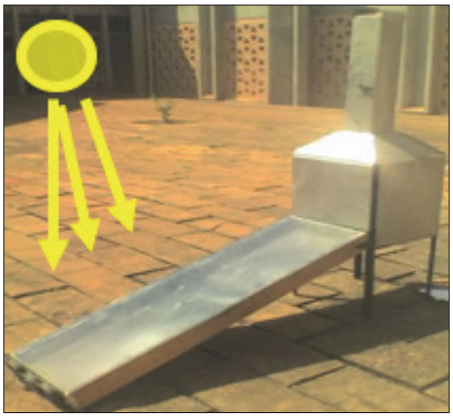

Figure 5. Indirect solar dryer (Bup, 2010).

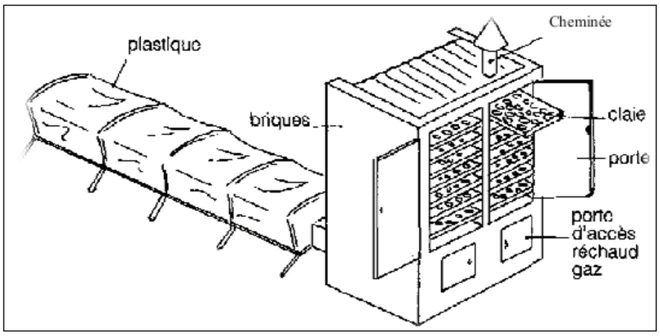

Figure 6. Schematic hybrid solar-gas dryer (Dudez, 1999).

An indirect solar dryer has been developed (SSIFO) in this study in which the airflow is manually guided in the drying chamber and the collector offers the ability to change the absorber and store heat through the use of volcanic stones found locally in Camaroon.

Materials and methods

The heat storage system with excellent performance has been achieved using phase change materials (PCM) (Alkilani *et al.,* 2011). Such material is difficult to obtain reported a problem in rural areas. Aboul-Enein *et al.* (2000) and others proposed storage of heat in rocks or in water. Our choice was black pumice (volcanic black stone) which is a volcanic rock locally available, and enables the solid-air exchange. Disposed in bed, in order to have a continuous supply of temperature, volcanic stone has a theoretical heat capacity between 1000 and 1200 J / kg / K. (Kirirat et al., 2006; Alkilani and al., 2011).

To power the fan and the controller in the design a panel (NP50G, max power: 50 W, current: 3 A, Voltage: 16.7 V Manufacturer: Naps Systems Oy Finland), available in the Cameroonian market, was used.

AHLBORN measuring devices were used to make measurements. The central data acquisition system called ALMEMO 2390-8, capable of recording 200,000 measurement values and simultaneously recording 5 variables and allowing easy transfer of data in an Excel was used. An Almeno (FUA9192) pyranometer was used for the measurement of sunshine in W / m² or direct radiation, with a measuring range from 0 to 3 mW / cm² for a spectral sensitivity of 310 nm to 400 nm.

Results

The equipment developed is presented in Figure 7. The dimensions of the whole equipment (front view) are shown. This drawing, developed using 2010 AutoCAD software, shows the dimensions of different parts of the dryer.

Work done with the dryer in order to characterize it occurred without any produce in the drying chamber. Two experimental areas were pursued to compare the effectiveness of the equipment, the absorber of radiation and storage of heat. In the following Figures, temperatures and irradiance versus time for each are shown. According to the literature, the steel or aluminum absorber is painted matt black. In the case of storage, the volcanic rocks are black.

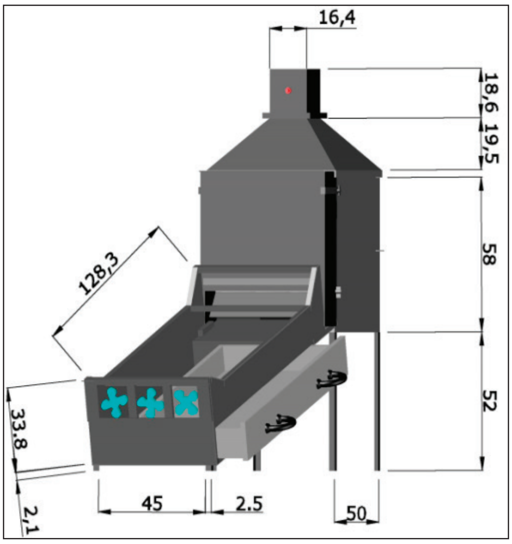

Figure 7. Design of the indirect solar dryer showing the flux orientation.

Storage is done with black volcanic stone rock in our system. As shown in Figure 8, the temperature rise is slow; because at first the absorber stores and saturates before beginning to release but the period of saturation depends on the sunlight received. After this phase, the temperature of the absorber is up to its maximum (80.70 ° C) and no longer follows the irradiance. This is what represents the flattening on both temperature curves (output absorber and absorber). The saturation of the material takes place after an hour of time to a higher irradiance (800 W / m²) and the temperature profile remains constant up to 15 hours. It is noted that the drop in solar radiation does not influence the temperature up to 15 hours. Here, this inertia lasted for 3 hours during the day, before the fall begins. Temperature measurements during discharge showed that once charged to 82.2 ° C, the absorber falls in 3 hours to 73.3 ° C in the absence of sunlight. The temperature at the sensor output in the absence of sun for 16 hours is 55 ° C while ambient temperature is 38 ° C.

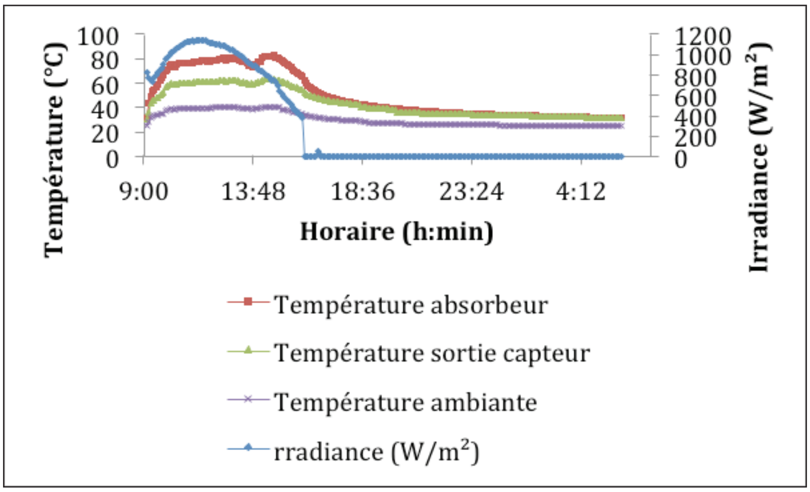

Figure 8. Temperature profiles (ambient, absorber and output absorber) and irradiance with energy storage system.

Characterization of the drying chamber

In the following Figures (Figure 9, 10 and 11), we present the temperatures on the three racks/screens in the room and irradiance over time time for each mode of circulating air: 'flow through', 'licking' and 'cross' mode.

'Flow through' mode (Figure 9): Temperatures on the three screens in the room are similar to the top, as there is no input of energy; thereafter, there is a temperature gradient across the three racks and finally, as the chamber is empty, the temperature becomes homogeneous. The rack positioned at the entrance of the air shows highest temperature, and the farthest the least. The average temperature was 52 ± 6 ° C, 51 ± 6 ° C and 49 ± 5 ° C, respectively, on the tray 1, 2 and 3.The ANOVA on inter racks temperatures shows that there is a significant difference.

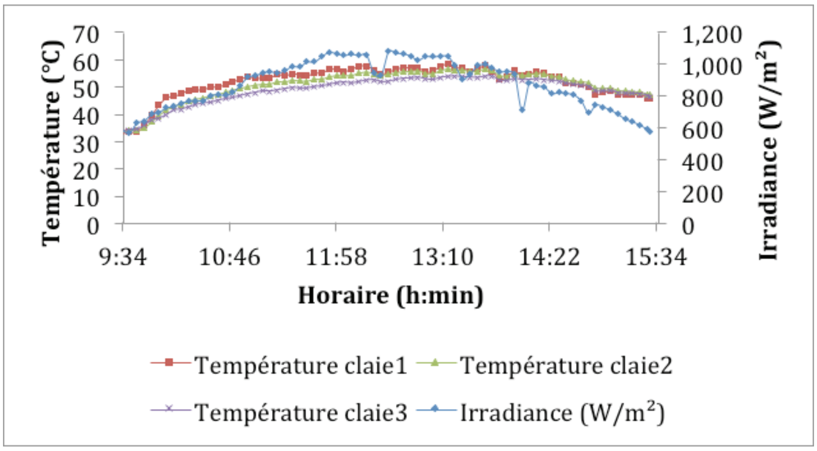

Figure 9. Temperature profiles and irradiance in the 'flow through' mode.

'Licking' mode (Figure 10): The temperature difference on the three screens is low; average temperature values are 48 ± 5 ° C, 49 ± 5 ° C and 49 ± 5 ° C, respectively, on the tray 1, 2 and 3 in the room. The temperature profile does not follow the trend in irradiance because of the absorber interface, which adjusts the processing. The ANOVA showed that there was no statistically significant difference.

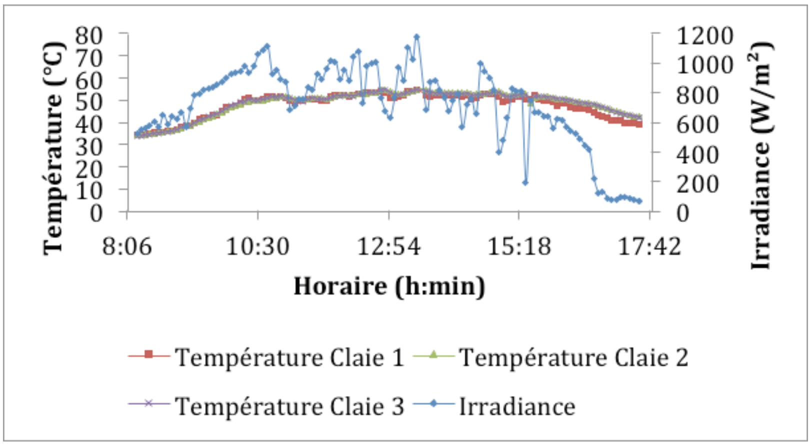

Figure 10. Temperature profiles on the three racks in the room and irradiance in flow through mode 'licking'.

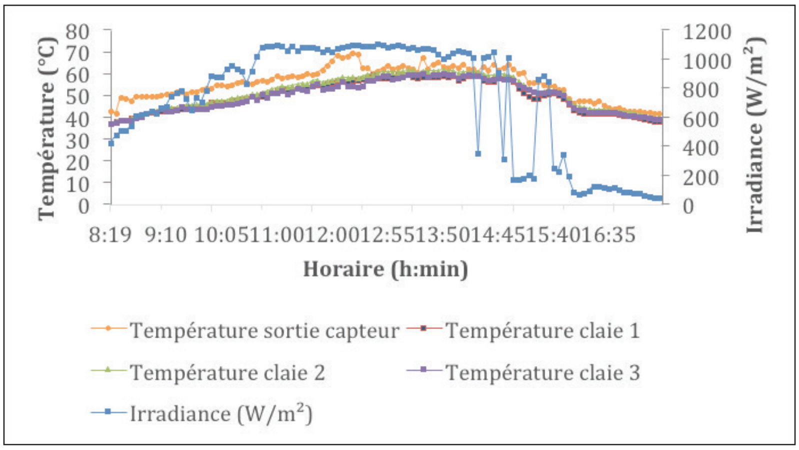

Figure 11. Temperature profiles at three racks in the room and irradiance in the 'mixed' air flow mode.

Table 1 presents a statistical analysis to compare the three airflow modes in the present SSIFO. It is found that the mode 'cross-flow' gives good result because there is not a significant difference at the 5% threshold in the temperatures at racks 1, 2 and 3. In addition this mode combines the two other airflow patterns.

Table 1. Testing of comparative study ANOVA airflow modes

Airflow mode	Average temperature at each tray (°C)			Probabiliy	Irradiance average (Wm^{-2})
	Tray 1	Tray 2	Tray 3		
Through flow	52± 6^{a}	51±6^{ac}	49 ±5^{c}	0,0042	781
Licking	48±5^{a}	49±5^{a}	49±5^{a}	0 ,3890	708
Mixed	50±7^{a}	51±7^{a}	49±7^{a}	0,1846	723

Conclusion

The designing and characterization of an indirect solar dryer with directed air flow has shown that the choice of material in the manufacture of the absorber is most important as it has an influence on the temperature profile in the sensor output even when there is no irradiance. The position of the absorber relative to the glass rapidly raises the temperature thereof. We optimized the absorber with respect to its position in the sensor. Without loading the trays/racks with material to dry, the temperatures are substantially equal on all the three screens in the 'licking' mode, followed by the 'cross' mode. Thus, 'licking' fashion products spread over the three racks can dry simultaneously. The product of high quality can be obtained also by applying the 'mixed' mode that allows the product to dry on both sides simultaneously and having the temperatures on three racks are substantially equal.

The volcanic rock is widely available in rural areas and is less expensive to store the energy in a dryer to ensure a continuous dehydration even in the period when there was no sunshine. Its presence has created a difference of more than 5 ° C for 12 hours between room temperature and the sensor output. To allow proper implementation, it is important to give a mathematical model of the dryer design.

Acknowledgment

The International Dryland Development Commission (IDDC) and Bibliotheca Alexandrina, Alexandria, Egypt are thanked for their invitation and support to participate in the Twelfth International Conference on Development of Drylands.

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8. Utilization of renewable energy sources in dryland systems

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Abstract

Use of renewable energy is becoming essential as a strategy to mitigate greenhouse-gas emission, and reduce energy use and cost of operations in Indian agriculture. Intensive research and development activities have been, therefore, undertaken by the research institutions of the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), and other State and Central Government organizations, to develop technologies for agricultural operations using renewable energy. Several novel solar devices and systems e.g. solar drier, non-tracking solar cooker, animal feed solar cooker, three-in-one solar device, solar PV pumping system, solar PV duster, PV winnower cum drier, solar PV sprayer, solar distillation unit etc. have been developed at the ICAR- Central Arid Zone Research Institute (CAZRI) since last four decades. The ICAR-Central Research Institute for Dryland Agriculture (CRIDA) has also been engaged in developing simple renewable energy based devices and systems for the benefit of smallholder farmers. Experiments have also been conducted with biomass-based herbal dryer using biogas as auxiliary source. Biogas plant of 85 m^3 digester capacity have been designed and promoted for installation in dairy farms with 100 cows. In this paper, all these renewable energy based devices developed at CRIDA and CAZRI are discussed.

Keywords: Small holder farmers, Solar thermal devices, Solar PV based devices, Solar-powered farm devices, Biogas plant, Solar PV pumping system

Introduction

In rural areas of India most of inhabitants have agriculture as their main occupation. Since electricity is essential to meet the day-to-day activities it is necessary to ensure its availability for keeping the pace of development. Although there is several fold increase in electricity production in India since independence in 1947, the shortage continues because of the growing needs for development. About 60% of electricity production is by coal-based power plants, which emit about 800-960 g CO_2 per kWh of electricity production having serious implications for the climatic. On the other hand, the general practice in the absence of electricity is to use kerosene oil for lighting and diesel for operating pumps and agricultural machinery. The greenhouse gas emissions associated with the use of these fossil fuels are also a serious concern for the environment. Moreover, use of firewood, agricultural waste and cow dung cake for cooking food and heating water is causing irreparable damage to the fragile eco-system of arid and semi-arid zone. Due to lack of energy resources, the villagers are not able to process their agricultural produce leading to increased post-harvest losses and reduced income. In this context the most preferable option is to harness free and abundant solar energy.

On an average, irradiance on horizontal surface in India is 5.6 kWh m^{-2} day^{-1}. The solar resource map of India shows that western India receives maximum amount of solar irradiation whereas major portion of India (~140 million ha) is receiving solar irradiation of 5-5.5 kWh m^{-2} day^{-1} (Figure 1). The cold arid region of the country (Leh and Ladakh region) receives highest amount of radiation, which is about 7-7.5 kWh m^{-2} day^{-1}. At Jodhpur, Western Rajasthan, the maximum amount of radiation is received during the month of April (7.17 kWh m^{-2} day^{-1}), and the minimum during the month of December (5.12 kWh m^{-2} day^{-1}).

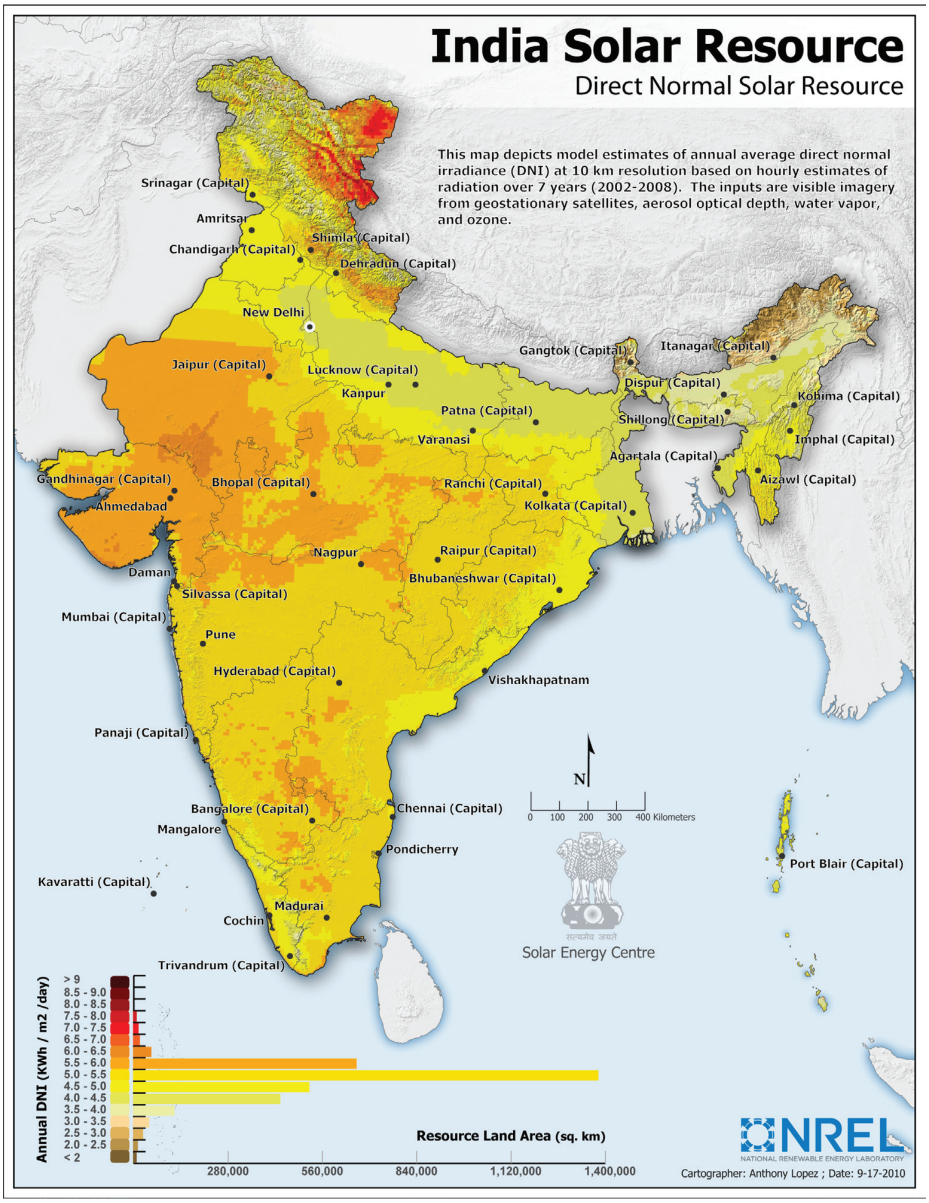

Figure1. Solar resource map of India.

Globally, renewable energy share to produce electricity is about 22.8% (by the end of 2014) out of which 16.6% is contributed by hydropower, 3.1% by wind energy, 1.8% by biomass-power and 0.9% by solar photovoltaic (PV) (Renewable Energy Network for 21st Century, REN21). Cumulative renewable installed capacity in the world is 1712 GW including hydropower installation of 1055 GW. Annual growth rate of cumulative renewable energy installed capacity in 2014 was about 8%, whereas the annual capacity addition grew by 24% in 2014 as compared to 2013.

India ranks 7th in the world in total renewable energy installed capacity while China tops the list followed by USA and Germany. About 13% of energy generation in India is met through renewable sources e.g. wind, solar, biomass etc. whereas coal is still the main source contributing to about 60% of total generation (Singh *et al*., 2002). During the last few years, a great stride has been made in increasing the use of renewable energy; the installed cumulative capacity has been increased from 24,914 MW in 2011-12 to 42,752.21 MW by the end of 2015-16 with an annual growth rate of 17.8% (Figure 2). By the end of March 2016, wind energy installation's share of total renewable energy installed capacity in India was about 62% (26,769.05 MW) whereas that of solar PV installations was 15.8% (6,762.85 MW). Rajasthan and Gujarat have ~58% of the total solar power installed capacity in the country. The National Solar Mission (NSM) has been in operation in India since 2010, setting the targets for three phases as shown in Table 1. The targets have been revised in 2015 to a total grid connected solar power generation of 1,00,000 MW comprising 40,000 MW roof top generation and 60,000 MW grid connected solar power plants (Resolution of MNRE, Govt. of India, No. 30/80/2014-15/NSM dated 1st July 2015).

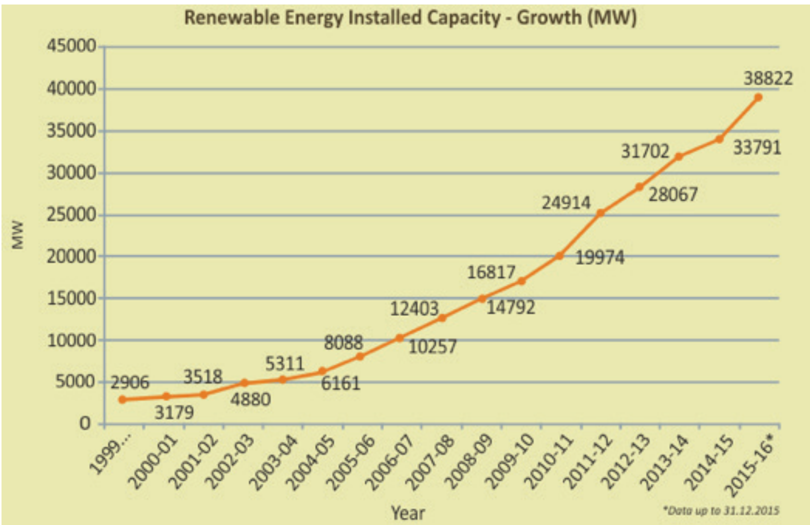

Figure 2. Renewable energy installation capacity in India.

Renewable energy use is always beneficial as it reduces CO_2 emission and thus protects the environment. For example, Dincer and Zamfirescu (2012) reported that the cogeneration (solar based heat, hot water, cooling, hydrogen etc) increases GHG mitigation about 2 to 4 times, whereas the payback time decreases about 2.8 times with respect to the single-generation case (solar based power only). It may certainly depend on energy efficiency of solar-based system. In India and China, renewable–resource–management estimated a carbon mitigation potential of

64.8 MtC yr^{-1} from 5.5 Mha area (Pretty *et al.,* 2012). Secondly, prices of energy, particularly of crude oil, are increasing which adversely affect profitability of dryland farming with existing tools and machinery. In the last two decades it is observed that use of commercial energy (crude oil) in agriculture has increased by four times due to change in energy consumption pattern, for example, shifting from bullock power to tractor for farm operations and diesel pump sets for irrigation (Jha *et al.,* 2012). Thirdly, hydroelectric power is a major source of electricity production in India but it is monsoon dependent. In recent years, hydroelectric power plants are badly affected due to in-sufficient water storage in reservoirs (Amitabh Sinha, 2016). Frequent drought across the agro ecological zones is a major reason for lower water storage in reservoirs and ultimate reduction in electric power. Thus, from environmental, technical and economical points of view, the use of renewable energy source is one of the necessary options in India for sustainable agriculture.

Table 1. National solar mission targets

Sr. No.	Application segment	Target Phase I (2010-13)	Target Phase II (2013-17)	Target Phase III (2017-22)
1.	Grid connected solar power generation	1,100 MW	4,000 MW	1,00,000 MW*
2.	Off-grid solar applications (includes solar PV pumps)	200 MW	1,000 MW	2,000 MW
3.	Solar thermal collectors	7 million m^2	15 million m^2	20 million m^2
4.	Solar lighting systems	5 million	10 million	20 million

*The revised target (Source: Ministry of Renewable Energy Sources, Govt. of India)

Several ICAR institutions, State Agricultural Universities (SAUs) and other State and Central Govt organizations are conducting research to develop various technologies for agricultural operations using renewable energy. This paper highlights some these technologies and their possible applications in Indian agriculture with focus on dryland system. The paper also presents the scope for developing novel technologies based on renewable energies for clean and safe agriculture from the perspective of green house gas mitigation.

Among the renewable sources, solar energy, both in the form of solar thermal and solar PV, has a special role in agriculture. For examples, solar PV based electricity generation can be used in agriculture for: (i) operating pumps for irrigation, (ii) running duster and sprayer for application of agricultural chemicals in field, (iii) co-generation of food and electricity, (iv) winnowing and drying, (v) protected cultivation, and (vi) mobility. Apart from these PV based devices, several solar thermal based devices have also been developed in India, specifically for post-harvest processing of agricultural produces and domestic usages e.g. cooking, water heating etc. These are (i) inclined solar drier, (ii) PCM based solar dryer, (iii) non-tracking solar cooker, (iv) animal feed solar cooker, (v) solar water heater, (vi) integrated three-in-one device for cooking, drying and water heating, (vii) passive cool chamber, (viii) solar preservator for enhancing shelf life of fruits and vegetable, (ix) solar distillation unit, (x) solar thermal based decentralized milk processing system, etc. Biogass generated energy also has potential to meet some of the energy demand in rural areas for domestic needs and other specific applications. All these devices are discussed briefly below.

1. Solar PV pumping based irrigation: Irrigation to the crop at right stage is important for sustainable production in agriculture. Even in dryland situation, one or two protective irrigations can save the crop from damage during dry spells and maintain crop yields. Pressurized irrigation systems, e.g. drippers, sprinklers etc., are of great importance in 'more crop per drop' mission but need ensured power supply. Solar PV pumping systems can be of great help in operating the pressurized irrigation system, specifically in low head situations like water lifting from canals, shallow wells and dug wells, farm pond etc. These pumping systems are more effective in terms of distribution. At present, ~16 million electric pumps and 7 million diesel pumps are in operations in the country for irrigation purpose; however, they are highly energy intensive and therefore, if replaced with solar pumps they can greatly contribute to country's energy security (Santra and Pande, 2015). Till December 2015, some 29,669 pumps have been installed in the country, mostly of 2 or 3 HP capacity. Recently, 5 HP pumping systems have been added as they have the capacity to withdraw water from a depth of about 75 m In arid and semi-arid regions operational efficiency of solar pump is high because of clear sky and good irradiance (5-6 kWh m^{-2} day^{-1}). In these regions, solar pumps can be operated for six hours a day, nearly the year round. A solar PV system mainly comprises of i) PV panels (ii) mounting structure (iii) pump unit (AC/DC), and (iv) tracking system. The size of PV panel depends on the capacity of pump to draw water. If the suction head is about 4-5 m, which is applicable in case of a surface water reservoir, 1 hp capacity pump is sufficient needing a 900 W_p panel in case of DC pump and 1400 W_p panel in case of AC surface pump. An example of 1 hp solar pumping system with AC and DC pump is shown in Figure 3. Drawing water from wells or for running tube-well, will need panel of larger size. The pumps to be used in a solar pumping system can be either DC or AC type and surface or submersible type as per the situation. To keep the panel perpendicular to the sun, tracking system is required. Both manual and auto tracking systems are available in the market. Solar PV pumps can be best used with pressurized irrigation system. Small size solar PV pumps of 1 HP capacity are best suited to irrigate crops from surface water reservoir in to greenhouses, poly houses, shed net houses for high-value vegetable production. Larger size solar pumps (e.g. 3 HP and 5 HP capacities) can be used in canal command areas to irrigate crops with sprinklers. With good solar irradiation, even a 5 HP pumping system can withdraw groundwater from 75 m depth. However, in many parts of India ground water is becoming deeper. A solar pump in such situation may not be effective option. Solar PV pumps have a great potential for irrigating high value crops such as pomegranate through drippers (Santra *et al*., 2014).

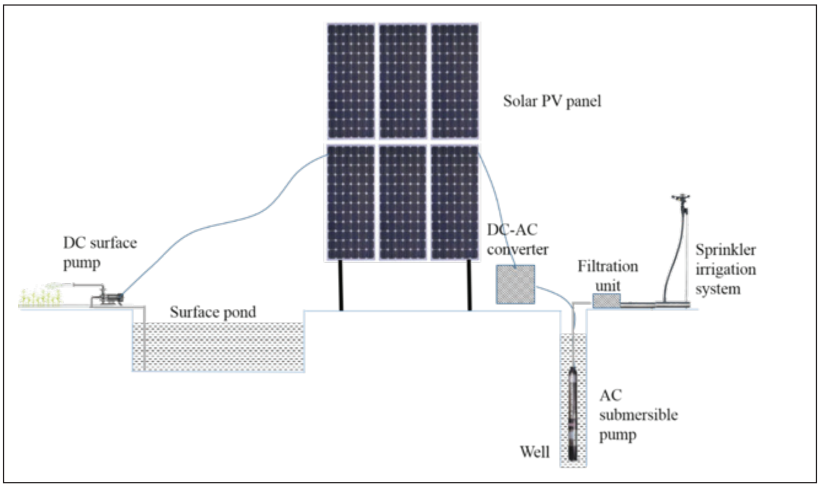

Figure 3. Schematic diagram of a solar PV pumping system.

2. Mini solar pump for lifting water from farm ponds: Farm ponds constitute a viable technology for harvesting and storing rainwater for life-saving irrigation under prolong dry spells common in dry areas in India and it has been promoted in the dry areas in India. A solar PV pumping system is a good device to lift water from these ponds and distribute it in the field through pressurized irrigation system. To suit to small holders in dryland a low head, low cost solar based micro irrigation system was developed for lifting farm pond water. The system uses small solar powered pump (110 Wp) to lift water from pond to a overhead tank of 1000 l capacity. This water is then redistributed through gravity-fed micro tube irrigation system to the crop (Figure 4). Kumar *et al.* (2015) reported that such system could irrigate an area up to 0.2 ha with distribution efficiency of 90 per cent. In case of low solar radiation, the hybrid energy system based on concomitant use of diesel/electricity and solar energy can be used.

3. Solar PV duster: Developed by CAZRI, the solar PV duster (Figure 5) essentially comprises a photovoltaic panel carrier, storage battery and especially designed compatible dusting unit. The PV panel is carried over the head with the help of a light PV panel carrier, which provides shade to the worker and simultaneously charges the battery to run the duster even after the sunset. The battery is stacked in a bracket, which is fixed in situ to the panel carrier. The unit also has the lighting facility for use during the night. It has been successfully tested for dusting sulphur dust and malathion powder. Approximate cost of this device is about Rs. 9,000/- (US $ 150). CAZRI has signed a memorandum of understanding (MOU) with a private manufacturer for its manufacture and sale.

4. Solar PV sprayer: Solar PV sprayer developed by CAZRI is shown in Figure 6. It consists of an energy conversion unit for generating electricity from solar irradiation using solar PV module (120 W_p capacity), an energy storage unit in the form of battery (a bank of two batteries, 12V, 7Ah each), a DC motor to operate the pump (60 W) of the sprayer and the sprayer unit. National Institute for Plant Health Management (NIPHM), Hyderabad has also developed a solar sprayer useful for dryland farmers (Figure 7). The equipment is mounted on a trolley foe easy movement of loaded tank. It has a boom having three spinning discs on which spray fluid is dripped. Solar powered battery is provided to energize the spinning disk nozzles. It covers a swath of three meter in one swipe. This equipment is useful for safe and effective spray of pesticides for low height field and vegetable crops.

5. Agri-voltaic system: Since there is a big plan for land-based solar PV installation in the country, solar PV modules for generating electricity are likely to compete for land with agriculture sector. In this context, agri-voltaic land utilization system or 'solar farming' is proposed to ensure that a portion of land used for erection of PV modules in a famers' field is available for cropping (Figure 8). By adopting such a system, the risk of loss due to crop failure during aberrant weather events may be reduced and may even prove as an effective drought proofing strategy. In a conventional solar PV power plant, PV modules are generally placed in long rows with sizeable areas left blank between two rows to avoid shading of one row by another. These inter-panel areas and the area below the panels can be effectively utilized for growing crops that can tolerate shade to some extent. In the arid zone, partial shading provided by the panel may even be helpful for the crops as it would reduce evapotranspiration losses. In larger solar power plants, the panels are regularly washed to keep them clean. The wash water can be used for growing plants in the inter-panel area of the PV array. This would enable farmers to use their part of the land as an assured source of

Figure 4. Solar based micro irrigation system for lifting farm pond water.

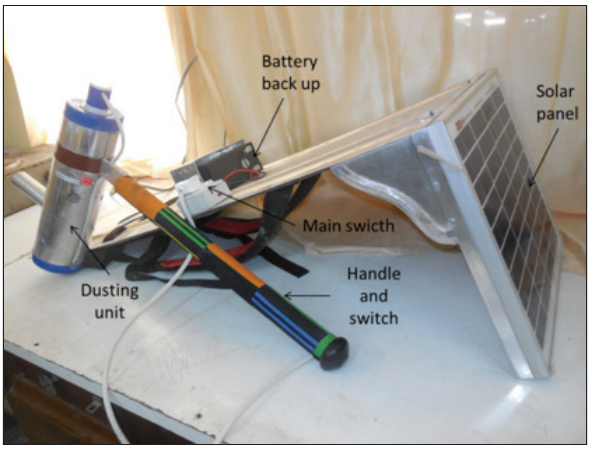

Figure 5. Solar PV duster.

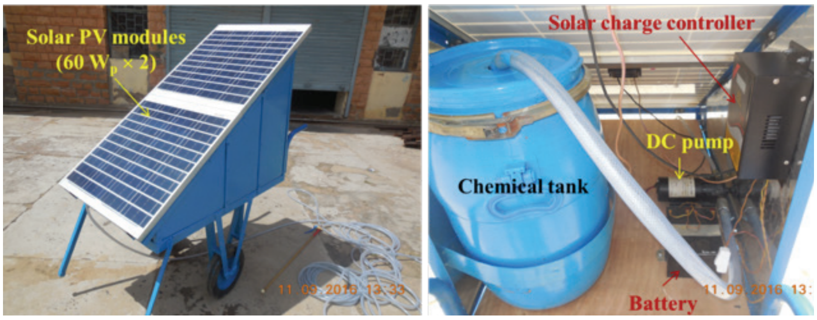

Figure 6. Solar PV sprayer.

Figure 7. Solar Sprayer developed by NIPHM, Hyderabad.

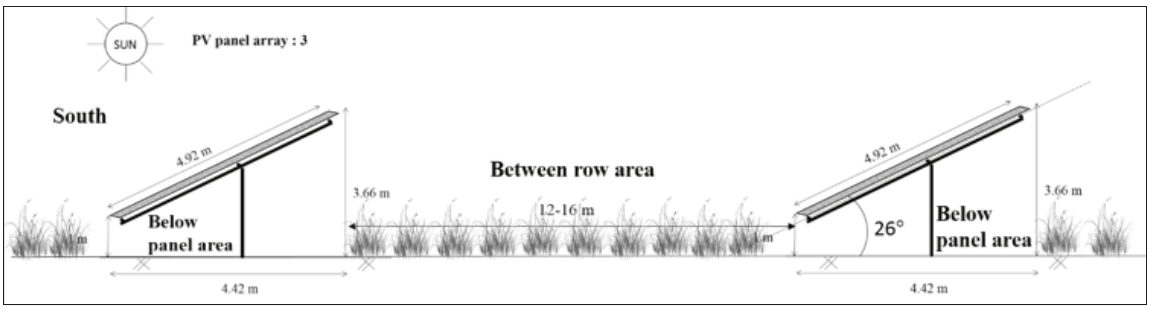

Figure 8. A typical sketch diagram of agri-voltaic system.

earning by selling the generated electricity as well as the produce from the inter-panel land. At the same time, the system will contribute to mitigation of climate change as each square meter of PV panel saves about 1330 kg of CO2 emission per year.

6. Solar PV based winnowing and drying: The PV winnower cum dryer shown in Figure 9 can be used for winnowing threshed materials in the absence of erratic and unreliable natural winds and also for dehydrating fruit and vegetables effectively and efficiently. The system comprises of PV module connected to an especially designed winnower with DC motor - fan assembly. Some 35 to 50 kg grain can be separated in 1 to 1.5 hours from threshed materials of pearl millet, mustard and cluster bean. The fan of the winnower can also be used in a dryer for dehydrating fruit and vegetables under forced circulation of air. Drying of mint, spinach, onion, mushroom, *ber* etc. was accomplished with good retention of colour and aroma.

7. Solar PV based protected agriculture: Protected cultivation of fruits and vegetables is gaining importance, specifically with climate change. However, it requires thermal regulation inside the protected structure for optimum crop growth. A protected agriculture system was developed using a PV clad enclosure (ground area 15.3 m^2) with fiber glass sheets. Two interconnected PV arrays of amorphous silicon solar cells (60 W_p each), placed on the roof, provided the power to operate a fan for forced aeration through a earth embedded pipe network for creating a controlled environment within the enclosure (Figure 10a). Studies showed that there was a reduction in the air temperature at the exit of the fan by 6-10 °C in summer and a rise of 2-4 °C in winter, compared to the temperature at inlet. The observed values were close to the ones predicted through a mathematical model developed for the purpose (Pande *et al.,* 2013). Performance of the PV clad enclosure with forced circulation of air through earth embedded pipes, combined with PV supported mister, indicated a reduction in the inside temperature by 4-6 °C below the ambient temperature during extreme weather conditions in summer (Pande *et al.,* 2012). Tomato plants were grown successfully (Figure 10b), as the inside temperature could be maintained within a desirable range. The system is useful for raising nursery of fruits and vegetables in areas where ambient temperatures are too high for raising such nurseries in the open.

8. PV mobile unit: A multipurpose self-propelling PV mobile unit (Figure 11) was designed and developed for various domestic and small agricultural applications in isolated cluster of rural houses (*Dhanis*) in the arid region. The unit carries two PV modules (70W_p each), facing south at 26 degree from horizontal, to receive optimum solar radiation and also to provide shade to the subcomponents as well as to the user. Made of rectangular iron angle frame, with four wheels and a flexible metallic pulling sling, the structure can be moved with ease through a DC motor. A multi crystalline silicon PV array (140 W_p) output is fed to a battery (12V 120Ah) through a regulator and a maximum power tracker to charge the battery and then to derive power through an in-built inverter for operating various devices for use at home level (for illumination, or running a radio or a small TV). The unit can also be used for cottage scale applications, through both AC and DC devices, for different post-harvest processing operations (e.g. aloe vera gel extractor, ber grader, butter churns, blower for winnowing, etc).

9. Solar drier: Drying freshly harvested agricultural produce like paddy, wheat, pulses, chillies etc. is essential for safe storage. Also, drying at 50-55^0 C becomes necessary to make them ready for secondary processing. Solar tunnel driers can be used for this purpose as the heat load

Figure 9. PV winnower cum dryer.

Figure 10. PV clad structure for multipurpose agricultural applications.

Figure 11. PV mobile unit developed at CAZRI, Jodhpur.

Figure 12. Solar dryer developed by ICAR-CIPHET, Ludhiana.

Figure 13. Solar dryer developed by ICAR-CAZRI, Jodhpur.

Figure 14. A flat plate absorber with thermal storage natural convective solar crop dryer.

requirement is less compared to the other drying systems. Agricultural waste and biomass stoves can be coupled with these driers as auxiliary heating devices in case of inadequate sunshine. A solar tunnel dryer, developed by ICAR-CIPHET, Ludhiana, is shown in Figure 12. Up to two tonnes of produce can be dried at a time and the drying time is only 60% of that needed for the open sun drying. Solar dryer is a convenient device to dehydrate vegetables and fruits faster in a hygienic manner. CAZRI has designed and tested a tilted type solar dryer, costing about Rs. 3500 per m^2 of drying area, for drying vegetables (onion, okra, carrot, garlic, tomato, chillies, spinach, coriander, etc.) and fruits (*ber*, date, salt-coated *amla* etc.). Local entrepreneurs have adopted such dryers (Figure 13) of variable capacities (10–100 kg). Farmers can save about 290 to 300kWh/m^2 equivalent energy by using such solar dryers and get higher returns from the dried products because of superior quality.

High value crop and horticultural products can be easily dried using solar power with convection and conduction type heating systems. CRIDA conducted experiments with biomass-based herbal dryer using the biogas as auxiliary source. Henna, senna, *amla,* figs etc. dried in this dryer at 55^0 C retained good aroma and color. Solar cabinet dryers and hybrid solar driers can be used for value addition of the horticultural products before going for tertiary processing.

10. PCM-based solar dryer: A PCM (phase control material)-based solar dryer overcomes the disadvantages of traditional open sun drying and permits maximum utilization of available solar radiation (Figure 14) as it provides storage of thermal energy in the form of latent heat and sensible heat during sun shine hours to be released thereafter, maintaining a drying temperature of 40 – 45^o C over an extended period of time. Considering the increased returns from dehydrated products, the PCM-based solar dryer is financially viable with payback period of 1.5 year.

11. Non-tracking solar cooker: A double glazed non-tracking solar cooker with reflector was designed and fabricated at the workshop of CAZRI. The cooker is based on the hot box principle with dimensions of 1090 × 490 × 290 mm (Figure 15). The length to width ratio of the cooker has been fixed as 3:1 to maximize the amount of radiation falling on the glass window any time during the day, eliminating the need for azimuthal tracking essential for a simple hot box solar cooker towards the sun every hour. The thermal efficiency of the non-tracking solar cooker was 25.4% for the wet load of 3.0 kg (Nahar, 1998). The payback period varied from 1.58 to 6.00 years depending upon the fuel (firewood, electricity, charcoal, LPG and kerosene) it replaced. The estimated life is about 15 years.

12. Animal feed solar cooker: The cooker is capable of boiling 10 kg of animal feed, sufficient for five cattle per day (Figure 16). The efficiency of the cooker is 21.8%. The cooker saves 6750 MJ of energy per year (Nahar *et al.,* 1996). The cooker is fabricated using locally available materials such as clay, pearl millet husk, horse droppings and such commercial material as plain glass, mild steel angle and sheet, wood and aluminum sheet.

13. Solar water heater: Substantial amount of fuel can be saved by using such heaters for domestic purposes and in textile and dairy industry. The natural circulation type solar water heaters with flat plate collector have been installed in hotels and guesthouses. Collector-cum-storage solar water heaters (Figure 17) reduce the cost, almost to half, of the cost of conventional solar water heater, and provide 100-litre hot water at 50-60^oC in the evenings and 40-45^oC next day mornings (winter season) after covering the device with insulating cover (Nahar, 2003).

Figure 15. Installation of the non tracking solar cooker.

Figure 16. Improved solar cooker for animal feed installed in the field.

Figure 17. Collector cum storage type solar water heater.

Figure 18. Integrated three in one solar device.

Figure 19. Improved passive cool chamber.

Figure 20. Solar preservator developed by CRIDA, Hyderabad.

14. Integrated three-in-one solar-based device for cooking, drying and water heating: With a view to using the same device throughout the year for one or other purposes, dual and multipurpose solar energy appliances have been developed at CAZRI. A solar cooker cum dryer can cook food for 4-5 persons without sun tracking and in this dualpurpose device fruit and vegetable can also be dehydrated (Pande and Thanvi, 1988). The Integrated Solar Device (Figure 18) is a unique three-in-one solar device used to cook food round the year (Pande *et al.,* 1980). The geometry of the device enables cooking without sun tracking. Further, the device can produce hot water (50-60^{o}C0 utilising the low altitude position of sun during winter and thus having energy gain both from top and front windows. The device can also be used for drying fruit and vegetables. The main feature of the device is that during dehydration the water also gets heated, the dehydration process continues even in night and the temperature is regulated for optimum dehydration of fruit and vegetables.

15. Passive cool chamber: The low cost passive cool chamber (Figure 19) is useful to preserve different kinds of vegetables for short period. It consists of a double walled chamber made of baked bricks and cement, and the space between the walls is filled up with coarse sand. The water filled up in the annular sidewalls helps to maintain high humidity (> 90%) inside the inner chamber and reduces temperature. Provision made for water evaporation from the bottom side of the cool chamber further reduces temperature (up to 15^{o}C). High humidity and reduced temperature in the chamber enhance the shelf life of the vegetables and fruits (Nahar *et al.,* 1999). The passive cool chamber is, therefore, becoming very popular with vegetable growers.

16. Solar preservators for enhancing shelf life of fruits and vegetable: Solar preservator is developed by CRIDA for preserving foods, fruits and vegetable (Figure 20). It works on evaporative cooling principle. It has storage chamber, small pump for water circulation, and fan for air circulation. Pump and fan are operated by power from15 Wp solar panel. In peak sunshine hours, the temperature inside the chamber can be maintained ~18^{0} C with 60-80 per cent humidity. The temperature inside the preservator is 25-30^{0} C lower than ambient temperature in the peak summer, which could reach 45^{0} C in some regions hampering the shelf life of fruits and vegetable in normal stores. Fruits and vegetables can remain fresh for 10 days in this preservator as against 2-3 days in the normal store.

17. Solar distillation unit: Solar still is a convenient device for producing distilled water, and for making saline water potable. Step basin tiled type solar stills of different sizes (capacity 3 to 3.5 liter/m^{2}/day) have been adopted by railways, army units, schools, etc. The production of distilled water is independent of season due to its special design. Rose water can also be prepared using such solar. An improved solar still (Figure 21) with 2 m^{2} glass area has been designed, developed and fabricated by using 3 mm thick steel plate so that its life is more than 15 years. It consists of seven trays and its tilt can be varied as per declination of the sun so that maximum solar radiation can be captured on its surface. A channel is provided at the bottom for collection of distilled water. The still can provide 8 to 10 litres of distilled water per day on clear sunny days. With the use of this still 20 lit/day of potable water (1500 ppm TDS) can be made available in a day from raw water containing 3000 ppm TDS.

Figure 21. Multi basin tilted type solar still.

18. Solar thermal based decentralized milk processing unit: The energy requirement and type of energy used in dairy industry depends highly on the level of production and technological interventions used at the production unit. For example, in cheese and curd production at home level, thermal energy used to heat the milk comes from bio-residues. However, the system efficiency is low, in the range of 10-15%. In industrial sector, it is quite possible to replace high cost systems like steam heaters with simple solar water heating system to avoid technological complexity. A moderate solar water heating system of 2500 l per day capacity generating feed water for boilers would save 20-25 l of furnace oil per day and reduce GHG emissions. Solar thermal systems can greatly contribute to energy savings during the production processes in the dairy sector that needs water temperatures of above 80^0 C for various operations. The illumination of the plant is also essential for indoor operations. A typical lighting system for this would consist of a PV module of 74 W capacity, a flooded lead–acid battery of 12 V, 75W capacity, and a CFL of 11 W rating. The cost of one single unit is about Rs 30,000/- including wiring and installation.

Biogas as a renewal energy source

Biogas based small-scale dairy farming: India is largest milk producing country in the world having nearly 70 million milk producers. Nearly 48% of rural households keep milk animals (National Sample Survey Organization's (NSSO) survey). Many dairy operators rely on the utility grid for their power for running water wells, milking machines, heating water for cattle maintenance, running refrigerators for preserving dairy products, and operating feed grinders and other equipment for daily dairy farm management. Since, the electricity supply in rural areas is poor, the renewable energy sources are used for majority of these operations.

The farmers practicing commercial dairy farming are now adopting improved breeds of cows in place of traditional buffalos in general and in rainfed systems in particular. A model milk production farm with 100 cows requires 14.766×10^6 MJ energy per annum. Of this energy use, about 88- 92% is towards the preparing concentrate feed and roughage. If a biogas plant with 85 m^3 digester capacity (50 m^3 gas productions per day) is installed using the dung produced at the farm it would be able to power 15 KVA prime rating biogas gen-set for 4.5 hour, which can run 20 HP electric motor providing electricity to prepare feed, pump water, and operate pressurized floor and animal washers. Since, dung availability would not be a limiting factor in 100 animal's farm, three such biogas plants would be able to meet almost all energy needs in the plant. It is advisable to go for medium size biogas plants, in multiple numbers, in dairy farms in rural areas for easy operation and maintenance.

Domestic applications of biogas: Commonly, energy source for domestic applications in rural areas is firewood, harvested residues, and kerosene and very few household are having liquid petroleum gas (LPG) based stoves. The fuel efficiency of traditional energy sources is very low and they also contribute to green house gas emission. Biogas can be a good alternative in these rural areas. CRIDA has assisted in establishing biogas plants in various villages under National Innovation in Climate Resilient Agriculture Project (NICRA) for feasibility study. In Yagantipally cluster of villages of Kurnool districts 23 biogas plants were installed with a capacity 30 ft^3 each and operated successfully. The establishment of biogas units helped in reducing expenditure of Rs 12,950/- per annum per household on fuel cost like kerosene, LPG etc, besides saving time in fire wood collection. On an average, the cost of energy sources required for each household (05 members family) is about Rs 20,000/ per annum towards cooking of food, water heating, lighting etc.

The study showed that energy produced from 30 ft^3 biogas unit of was able to reduce 35% fuel cost annually for a family of five members. Further, it saved 32 litters of kerosene and 4 tonnes of fire wood annually which amounted approximately to a reduction of 1.29 tonnes in CO_2 emission. In addition, the slurry generated from biogas plant was recycled to agricultural production system as manure. With similar concept, 54 biogas units of one cubic meter capacity each were established in Allepy in Keraala state) (Figure 22). The raw materials like cow dung, domestic waste, organic residues, and cow urine were used for gas production. Each biogas unit could produce gas sufficient for 2-3 hrs continuous operation for cooking, water heating etc. With this kind of plant, one could save Rs 1064/- in LPG, and Rs. 8200/- in fuel.

Figure 22. A model biogas unit for energy production and its domestic use

Success of biogas unit is dependent on availability of raw material. Mostly, farmers prefer cattle dung as raw material for biogas unit but the number of cattle is dwindling in drylands because of the lack of fodder. Therefore, adoption of biogas plants is low. Experience of CRIDA shows that biogas based energy production could be made possible in dryland systems by adopting appropriate farming system module. CRIDA has developed farming system modules suited to different agro-ecological zones that can deliver food and fodder for sustainable dryland systems.

Renewable energy devices and climate change mitigation

Renewable energy devices as discussed above have a role in reducing CO_2 emission by replacing either the use of coal based electricity or fossil fuel burring for different agricultural and domestic activities. Reduction in CO_2 emission for each renewable energy devices can be calculated by considering the respective emission factor (EF) of fossil fuels, which are otherwise used. For example, direct use of electricity from thermal grids leads to an emission of 0.82 kg CO_2e per kWh (CEA, 2014). Similarly, if the solar PV devices replace fossil burning fuel wood, e.g. cooking, water heating etc., it can reduce the CO_2 emission by a factor 1.644 kg CO_2e per kg of fuel wood [EF for fuel wood = net calorific value of fuel wood (0.015 MJ/kg) × CO_2 emission factor of fuel wood (109.6 kg/MJ)]. The EF for diesel is 2.667 kg CO2e per litre of diesel used. Therefore, the renewable energy devices discussed in this paper have a great role in mitigating climate change. Corresponding CO_2 emission reduction potential have been highlighted under each solar PV device. Here, the calculation of CO_2 emission reduction potential is shown for 3 HP solar PV pumping system, which may replace either grid generated electricity operated pumps or diesel operated pumps. In first case, solar pump will save about 2685 kWh energy after considering its use of 200 days in a year for irrigation and 6 hours per day. Thus a single 3 HP solar pump will reduce 2201 kg CO_2e in a year. In the second case, 3 HP solar pumps will replace 790 litre of diesel .per year for similar use as mentioned above and will reduce emission by 2106 kg CO_2e per year

Conclusion

Renewable energy could be an effective option in India to reduce green house gas emission especially in agriculture sector where electric/diesel fuel based equipments are widely used. There is great scope for use of innovative technologies, based on renewable energy, in different parts of drylands in India as there is abundant availability of renewable energy sources in the region.

Acknowledgement

The information generated by the National Institute of Plant Health Management, Hyderabad and ICAR-Central Institute for Post Harvest Engineering & Technology, Ludhiana reviewed here is gratefully acknowledged.

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9. Feasibility study on photovoltaic water pumping system for crop cultivation with drip irrigation in the coastal dunes area of Tottori

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Abstract

The goal of this study is to develop a sustainable food production system that is environmentally friendly and economically feasible in dry lands. In this study, a photovoltaic water pumping system has been developed at the coastal dunes of Tottori for crop cultivation using drip irrigation. The field experiment of developed system was conducted to investigate the technical feasibility of the whole system in open and a greenhouse located in the Arid Land Research Center (ALRC), Tottori University in Tottori, Japan. In the field experiment, the saline groundwater was pumped up by supplying the electricity from photovoltaic power. And then, the saline groundwater was supplied for the experiment of salt-tolerant crop cultivation using drip irrigation in the greenhouse. The electricity generation from photovoltaic power, the electric consumption needed to operate the whole system, the amount of pumped groundwater, the amount of irrigation water for crop cultivation, and the meteorological conditions were measured and analyzed to assess the technical and economic feasibility of small-scale system.

Introduction

There is abundant renewable energy resources such as solar and wind in dry lands. The supply of electricity generated from renewable sources for agricultural production makes it possible to decrease the emission of greenhouse gases from fossil fuels. It also contributes to economic food production. On the other hand, procuring irrigation water for conventional agriculture in drylands has been from the groundwater, but its depletion caused by large scale irrigation and the salt accumulation of farmland due to over-irrigation have been serious problems. A stable supply and effective use of water resources, combined with the soil management of farmland, is absolutely essential for sustainable food production in dry lands and for environmental protection (Palm, 2014). Therefore, development of agricultural production techniques that have low impact on environment and sustainable economic efficiency, and are adapted to local infrastructure and social condition is needed (Olsson *et al.,* 2015; Xie *et al.,* 2014).

Several studies have been conducted on water pumping and irrigation system driven by the supply of electricity from the photovoltaic and wind power generation in developing countries of dry lands (Sontake and Kalamkar, 2016; Chandel et al., 2015). These reports pointed the technical and economic issues related to high investment and maintenance costs of power generation, the operation and management of water resources for crop cultivation, and the shortage of human resources for maintenances of the system. This has prevented wider adoption of the technology.

The purpose of this study was to develop a sustainable food production system which is environmentally friendly and economically feasible in dry lands. It combined electric power supply by photovoltaic power generation and supply of irrigation water with low salt concentration for cultivation of vegetable and salt tolerance plants. The field experiment was conducted to investigate the technical feasibility of the whole system in open and in a greenhouse located in the Arid Land Research Center (ALRC), Tottori University in Tottori, Japan. In the field experiment, the saline groundwater is pumped for irrigation by supplying the electricity from photovoltaic power and then it is supplied for the experiments on salt-tolerant crop cultivation using drip irrigation in the greenhouse.

Experimental setup

Figure 1 shows the schematic diagram of experimental site and the layout of experimental system. The photovoltaic water pumping system has been developed at the coastal dunes located in the ALRC. The topographic configuration of experimental site is a gentle slope from the sea coast to the top of sand dune. The altitude of the top is about 30m and the distance along the slope between the sea coast and the top is about 400m. A well for intake of saline groundwater is located at the distance of 30m from seashore. The greenhouse for crop cultivation using drip irrigation in the ALRC is located at a distance of 340m from the top of sand dune.

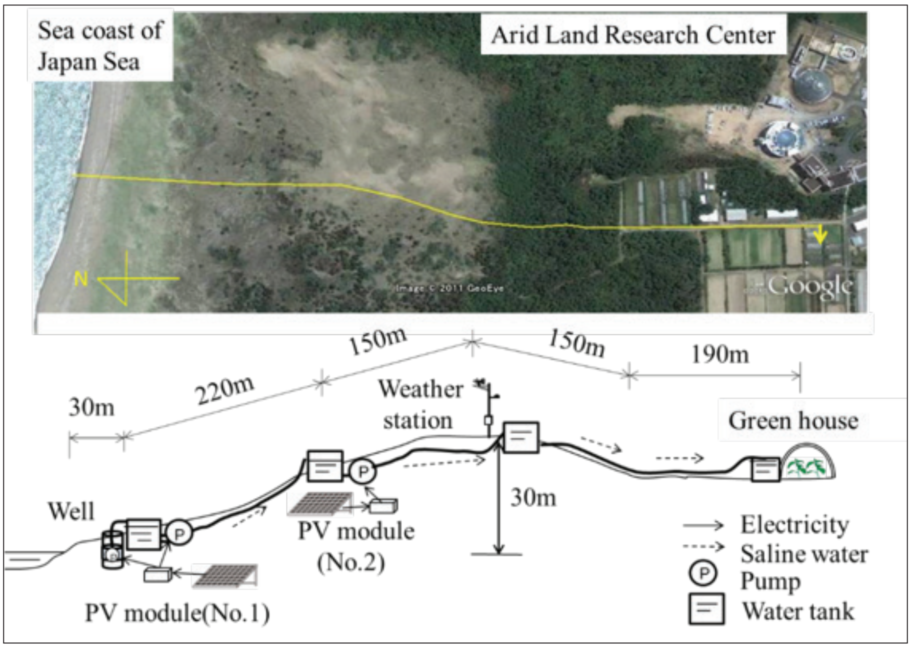

Figure 1. Schematic diagram of experimental site and system configuration.

Two PV systems (No.1 and No.2) were installed at the coast and the hillside in sand dune area. Each photovoltaic (PV) system was composed of photovoltaic module, battery, controller for charging and discharging and instrument for measuring electrical generation. The specification of PV modules is shown in Table 1. The maximum output of PV module in PV system No. 1 was 50W and three modules were connected in parallel. The PV system No. 2 consisted of a PV module with the maximum output of 140W.

Figure 2 illustrates the layout of water intake part around the well. The specification of water pumps used in the experimental system is shown in Table 2. The diameter and depth of the well were 0.5m and 2.5m, respectively

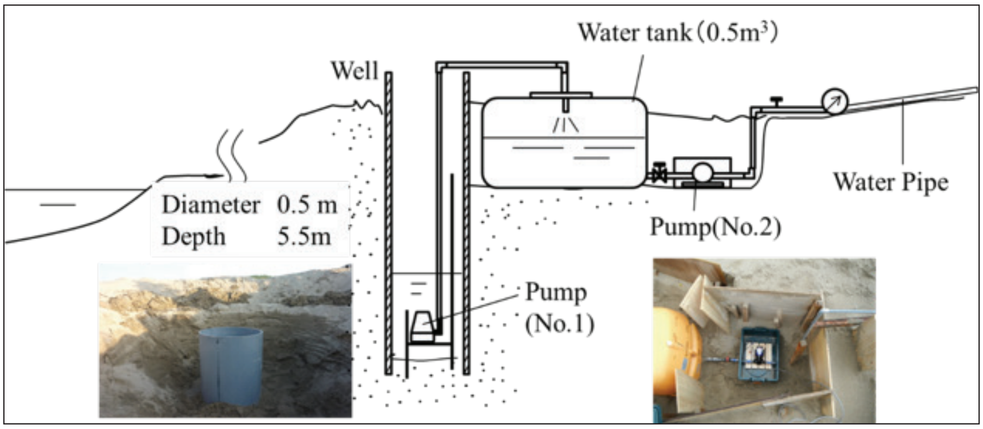

Figure 2. Schematic diagram of water intake part of experimental system at the coast.

Table 1. Specification of PV modules used in the experimental system

	PV module (No.1)	PV module (No.2)
Cell Type	Monocrystalline silicon cell	Monocrystalline silicon cell
Maximum Power Output (P_{max})	50 W	140 W
Maximum Power Voltage	16.4 V	17.6 V
Maximum Power Current	3.05A	7.95A
Open Circuit Voltage (V_{OC})	20.5 V	22.3 V
Short Circuit Current (I_{SC})	3.35A	8.47A
Dimension	1,218mm × 335mm × 35mm	1,496mm × 657mm × 47.5mm
Model and Manufacturer	GT133S, K･I･S Co., Ltd	ASEC-140G6S, K･I･S Co., Ltd

In the experiment on water pumping, the saline groundwater in the well was pumped up to water tank of 0.5 m^3 by a submerged pump No.1. Then, the stored saline groundwater was pumped up to the water tank installed at the hillside of sand dune by the pump No. 2. The electricity of two pumps was supplied by the PV system No.1. Moreover, the saline groundwater stored in the tank at the hillside was conducted to the water tank of 0.5m^3 on the hilltop by using the pump No.3. The range of electric conductivity of saline groundwater was from 0.68 to 0.98 dS/m for the experimental period and its value was one-fiftieth of seawater.

Table 2. Specification of water pumps used in experimental system

	Water Pump (No.1)	Water Pump (No. 2 and No.3)
Maximum discharge rate	63 *l*/min	14 *l*/min
Total head	4 m	28 m
Voltage	12V DC	12V DC
Maximum Current	7.8 A	6.0 A
Diameter of discharging port	25 mm	18 mm
Model and Manufacturer	BL-2512N, KOSIN, Ltd	Blaster 3901-2214,SHURFLO

Figure 3 shows the schematic diagram of crop cultivation with drip irrigation in the greenhouse located in the ALRC. Eight ridges with length of 10m and width of 0.3m were formed and an irrigation tube was set on the each ridge for drip irrigation. Four irrigation tubes for irrigating the saline groundwater were connected to the water tube from the water tank of hilltop with the valve. The other tubes were connected to the water tank set in the greenhouse for irrigating liquid fertilizer. The saline groundwater was supplied to greenhouse from the hilltop by a driving force of the altitude difference. The tomatoes were cultivated in the experiments. Firstly, 16 tomato seedlings were planted on the each ridge and the liquid fertilizer was supplied for three weeks until the seedlings grew up. After that, the saline groundwater was supplied to the seedlings of four ridges and the liquid fertilizer was supplied to the rests. The irrigation time was 25 minutes from 5 AM. every day. The tomato fruits were harvested when they matured and the number and mass of harvested tomato fruits, the mass of a fruit, and the sugar content of a fruit were measured after harvesting of the fruits.

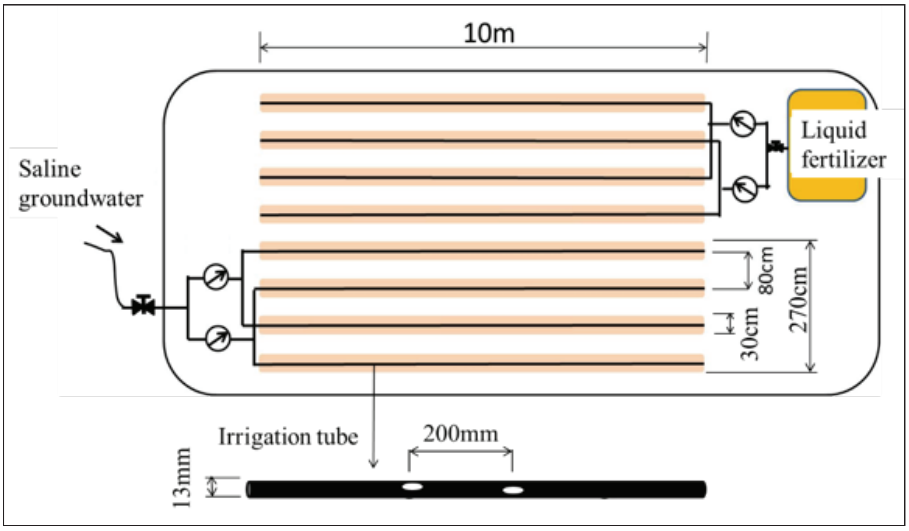

Figure 3. Schematic diagram of crop cultivation with drip irrigation.

Field experiment was conducted to investigate the technical feasibility of the whole system from 16 July to 31 August 2012. Through the experiment of water pumping and crop cultivation, the operation schedule for pumping water was decided in terms of the quantity and time schedule of irrigation in the greenhouse. The voltage and current of photovoltaic module, the voltage and current of pump motor, the amount of pumped groundwater, and the climatic data were measured in the experiment.

Results and discussion

Figure 4 shows the typical results of variation of current and voltage with time for PV module No.1 and pump No.2 located at the coast. The current and voltage of PV module No.1 are generated when the pump is operated around the noon on 1 August. The current and voltage of PV module No.1 decreased in the evening the day. In this case, the electricity for the pump is supplied by the battery. Next day, the current and voltage of PV module generated in the morning recharged the battery when the pump was not operated.

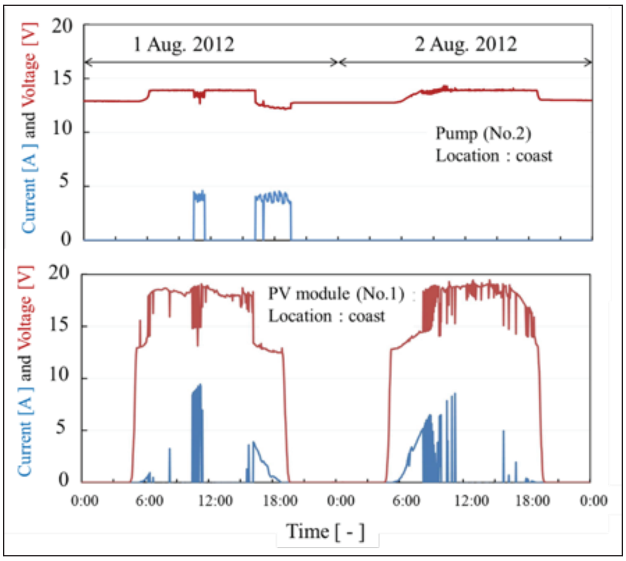

Figure 4. Variation of current and voltage for PV module No.1 and pump No.2 located at coast with time.

Figure 5 shows the results of global solar irradiance, power generation of PV module No.1 and power consumption of pump for same two days shown in previous Figure 4. The water pump was operated from 10:20 A.M. to 11:20 A.M. in the daytime and from 16:10 to 19:00 in the evening. In the case of operation in daytime, power generation of PV module starts at the same time as the operation of the pump. The power output of PV module becomes larger as the global solar irradiance becomes higher. In the case of operation in the evening, the electric power was supplied by the battery because the power output of PV module is less than the power consumption of pump. The flow rate of pumped water of a pump was 3.0 – 5.0 *l*/min and the power consumption of the pump was about 100W.

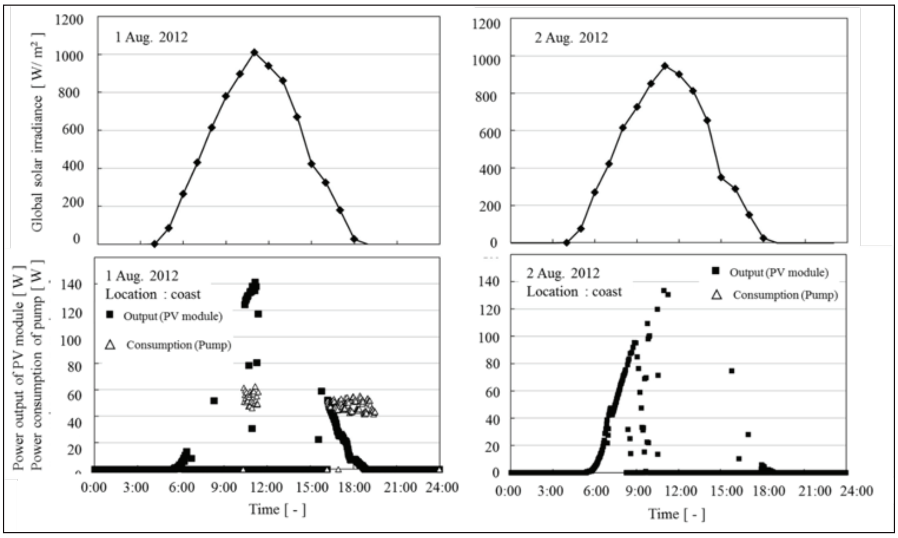

Figure 5. Variation of power output and consumption for PV module No.1 and pump No.1 located at coast with time.

Figure 6 shows the daily electric power generation of PV module No.1 installed at the coast, the daily electric power consumption of pumps No.1 and No.2 and the daily amount of pumped water August 2012. The operation of water pumping was carried out for a few hours per day because the demand of irrigation water for crop cultivation in greenhouse was 0.08 m^3/day to 0.1m^3/day. The ratio of power consumption of pump to daily power generation of PV modules is about 20% for the experimental period. These results are very important to make the operation schedule with the consideration of balance between the amount of stored water in the water tank at the hilltop and the demand of irrigation.

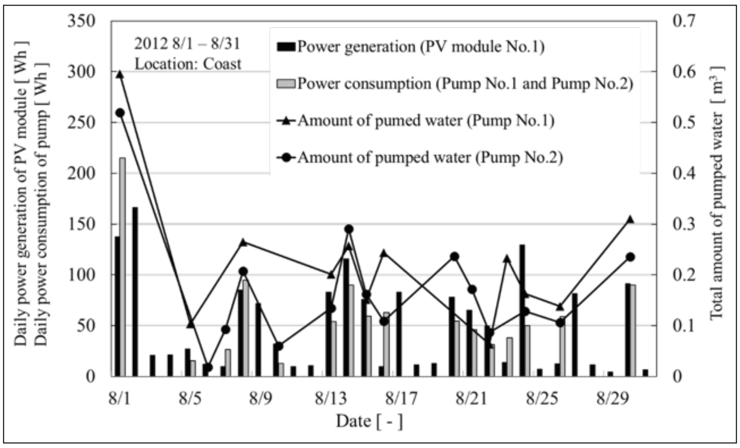

Figure 6. Experimental results of power generation and water pumping.

Figure 7 shows the total amount of pumped water and irrigated water from 17th July to 31th August 2012. The total amount of pumped water from the well is about 1.2 times as large as that of irrigated water. Therefore, 60% of total amount of pumped water by the pump No.1 is used for irrigation to cultivate tomato and the rest of pumped water is stored in the water tanks to arrange the irrigation schedule. The outline of experimental result on PV generation and water pumping is briefly shown in Table 3.

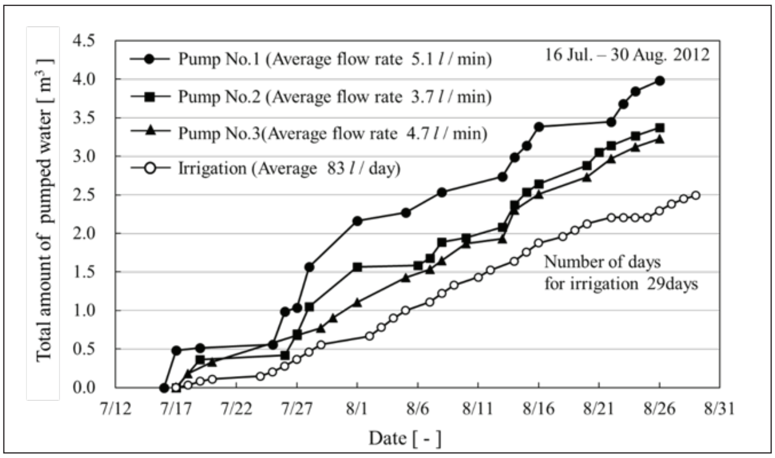

Figure 7. Total amount of pumping water and irrigation.

Table 3. Experimental results on PV generation and water pumping

Parameters	PV module		Pump		
	No.1	No. 2	No.1	No. 2	No. 3
Electricity generated (Wh)	1,794	1,405			
Electricity consumed (Wh)			1,280*	518	
Operating days	54	54	19	16	
Operating time (min)			788	902	525
Pumped water (m^3)			4.0	3.4	2.5
Flow rate of pumped water			5.1	3.7	4.7

* mean total amount of electricity consumption of pump no.1 and 2

The weight and number of the harvested tomatoes are shown in Table 4. There has not been any difference in the appearance, the weight and number of the harvested tomatoes. The sugar content of harvested tomatoes supplied with the saline groundwater is higher than that of liquid fertilizer. From the experimental results, the total amount of pumped saline groundwater by the developed system is enough to cultivate tomatoes for the irrigation of an area of $20m^2$ having 64 tomato seedlings using drip irrigation. Assuming that 80% of daily power generation of PV module is consumed for pumping the saline groundwater, the daily amount of pumped water is estimated to be 0.8 m^3 to 1.0 m^3, which is 10 times as large as the amount used in the field experiment. The developed system is expected to supply the irrigation water for crop cultivation with land area of $20m^2$. The cost of water pumping for this case is calculated as about $8\ \$/(\mathrm{m}^3\square\mathrm{day})$.

Table 4. Experimental results of tomato cultivation

Irrigation with water and fertilizer (EC = 0.14 dS/m)			
Week	Total weight (g)	Number of fruits	Weight per a fruit (g/fruit)
7/17-7/23	742.8	87	85.3
7/24-7/30	11024.6	156	70.7
7/31-8/6	761.3	14	54.4
8/7-8/13	6043.4	87	69.5
8/14-8/20	4076.1	74	55.1
8/21-8/27	4725.5	81	58.3
Irrigation with saline water (EC = 0.68 - 0.98 dS/m)			
Week	Total weight (g)	Number of fruits	Weight per a fruit (g/fruit)
7/17-7/23	7485.1	78	96.0
7/24-7/30	9771.9	155	63.0
7/31-8/6	1789.9	30	59.7
8/7-8/13	7004.5	87	80.5
8/14-8/20	4086.6	72	56.8
8/21-8/27	1942.7	29	67.0

Conclusion

The study combing the crop cultivation using drip irrigation with photovoltaic pumping system has been performed to find the technical feasibility of energy-water saving crop cultivation system. The electric generation from photovoltaic power, the electric consumption needed to operate the whole system, the supply of irrigation water by the pump, and the meteorological conditions were analyzed through the field experiment.

The total amount of pumped saline groundwater by the developed system is enough to cultivate tomatoes for an area of $20m^2$ and 64 tomato seedlings, irrigated using drip irrigation. Assuming that 80% of daily power generation of PV module is consumed for pumping the saline groundwater, the daily amount of pumped water is estimated to be 0.8 m^3 - $1.0m^3$, which is 10 times as large as the amount needed for irrigation of the field experiment. It is also expected that the sugar content of harvested tomatoes raised with the saline groundwater would be higher than those raised with liquid fertilizer.

Acknowledgements

This study was partly funded by the Joint Research Program of Arid Land Research Center, Tottori University. This study have been also funded by the International Platform for Dryland Research and Education.

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Recommendations

The three recent global agreements, 'Sustainable Development Goals', 'The Paris Agreement regarding Climate Change', and 'Sendai Framework for Disaster Risk Reduction', would greatly impact sustainable development globally. Sustainable development of dry areas is central and crucial for achieving the objectives of these agreements, because the dry areas are home to a large population -- a major proportion of global poor -- and have a fragile natural resource base, extremely vulnerable to climate change**.** An approach of integrated natural resources management, customized to different dryland ecosystems to meet the needs of communities that depend on them, would be crucial for this development. Such an approach would, however, require developing intensive knowledge and understanding of the coping mechanisms to deal with drought risk, managing and restoring ecological functions, sustainably using biodiversity, and diversifying production system and livelihoods. Supporting policies and institutional options would also be needed. This integrated approach only can enable us to realize the various components included in the SDGs. The objectives and approaches internalized by the International Dryland Development Commission (IDDC) are congruent to the SDGs as has become apparent from the deliberations of the 12th International Conference of IDDC.

Several important recommendations have been made by the participants in various presentations made in six plenary sessions, three specialized group sessions, and eleven concurrent sessions on nine themes included in the program of this Conference. The poster presentations and panel and post-presentation discussions have complemented the oral presentation sessions contributing to the main themes covered by the Conference. These recommendations are summarized below:

1. Coping with increasing water scarcity:

- Drylands are already suffering from water scarcity and this will get further accentuated with climate change and rising demand for water by different sectors. Miss-management of water resources results in lower agricultural productivity and progressive land degradation. Improving water productivity is essential for sustaining productivity and ensuring healthy ecosystems and services. There is, therefore, need for increased investments in practices and technologies that enhance water use efficiency/productivity such as modernizing irrigation systems, supplemental irrigation and water harvesting.
- Furthermore, a rethinking of cropping patterns and agro management is needed to ensure that systems are more adaptive and resilient to climate change.
- Examples from *badias* of Syria and Jordan on restoring degraded lands through integrated approach of improved technology of micro water-harvesting, seeding of native vegetation and controlled grazing showed the potential for reversing land degradation based on the use of local rains. Same way, rainwater harvesting and storage of the harvested water in small farm tanks and using it for strategic micro irrigation, enhanced the sustainability of production by small-holder farmers in the dry areas of India. There is a need for promotion of these technologies. 'More from less for more' is the way for achieving sustainability of this natural resource.
- Technologies for effective use of marginal quality water, brackish water, gray water, and black water being developed are promising to make up in part the increasing scarcity of water for agriculture in dry areas.

2. Restoration of degraded ecosystem/preventing degradation:

- Drier ecosystems that are already mostly degraded have ceased providing usual ecosystem services and are negatively impacting other ecosystems through degradation, dust storms, migration etc. The heavily degraded systems are now difficult to restore as the conventional approaches have not made substantial change. Major obstacle is the failure to alter the degradation processes and lack of integrated technical and socioeconomic solutions, and enabling environments. Integrating appropriate rainwater harvesting with soil and plant options in packages, supported by public and private investment, would be necessary to halt the degradation and restore those ecosystems.
- There were, however, several case studies of success achieved in reclaiming degraded and desert lands, and developing oases, particularly from China and Egypt. These were based on integrated approaches, involving participation of local communities, human resource development, availability of proven technologies, and availability of resources and enabling governmental policy and institutional support.
- Technologies such as integrated 'Agri-aquaculture' permitted effective and sustainable utilization of available natural resources in the dry/desert environments, integrating use of marginal quality water for fish production, using water for irrigating forage crops, raising ruminants on the forage and using animal waste for producing biogas to supplement solar energy, using solids for making compost/Vermi-compost, makes the system nearly carbon-neutral. This was an example of producing food in highly cost-effective manner and supporting the livelihoods of dryland communities with nearly zero carbon footprint. The lessons learnt there would permit up and out-scaling of these innovations and it is recommended that the private and public sector support should become available for the expansion of these innovative techniques.

3. Crop diversity and use of genomics for increased stress tolerance:

- Plant genetic resources in dry areas are greatly threatened because of increasing ecosystem degradation. Therefore, there is urgent need to collect, evaluate and conserve this diverse germplasm. Efforts of organizations such as Global Crop Diversity Trust in this regard have to be strongly supported and sustained funding augmented.
- There is a wide range of desert plants that can be used for preventing advance of desert. Their collection, conservation and utilization would deserve priority attention. The key to effective greening of deserts was the use of indigenous and adapted plant species and raising them with techniques including treatments with effective micro-symbionts that enhance establishment and fast growth.
- Techniques for gene mining in diverse germplasm of cultigens and wild relatives of important food crops of dry areas have been developed and are being used to identify novel genes that can impart tolerance to common abiotic (heat, salinity, drought) and biotic (fungal diseases) stresses , which are likely to get accentuated with climate change. Production of transgenic wheat conferring resistance to various stresses offers much hope for sustaining its productivity under such conditions. Wide hybridization with wheat wild relatives and development of multiple synthetic derivative lines have opened opportunities for identifying promising stress

tolerant lines with good quality traits. While there is an urgent need further strengthening of these efforts, similar work should be initiated in other important crops.

4. Mitigation of climate change

- **Enteric fermentation control**: Ruminal enteric fermentation is a major contributor of greenhouse gas emission from agricultural sector. Pasture species differ widely in fermentative traits and a choice of fodder species may offer a way for mitigation of environmental impact of enteric fermentation. *Biserrula* stands out as a promising pasture species. Selection and use of such fodder plant species in different modes deserves immediate attention.
- **Paddy cultivation:** Paddy fields in dry areas have several functions including producing much grain and controlling soil salinity, while their high water use induces some hydrological and environmental problems. Sustainable rice cultivation in dry areas would necessitate adoption of integrated water saving techniques and development of new cultivars adapted to upland cultivation and increased water use efficiency. Upland rice production should also reduce the emission of greenhouse gases associated with paddy rice.
- **Use of renewable energy:** Potential of using renewable energy for the development of rural communities in the dry areas was demonstrated in presentations from Arizona, USA, various parts of Egypt, Cameroun, and India. These were based on use of solar and wind power and biogas-based devices. Innovations in the use of PV devices to meet the needs at various scales, from using them for desalinization of saline water to doing inter-cultivation and lifting water for micro irrigation by small holder farmers need wider scale adaptive utilization in different parts of the vast dry area environments.

5. Community involvement and empowerment:

- Noting that success in up-scaling innovations in dryland development is closely linked to community involvement, it is recommended that local communities are embedded within future research and development initiatives. Role of human resource development and empowerment, particularly of women and youth, is crucial for getting most out of this involvement. In this context the importance of Inquiry based science education (IBSE), specially for STEM subjects, for the young generation is immense and should be harnessed. So also, the approach of 'Farmers Field Schools' needs to be adopted on large scale.
- Use of traditional knowledge, supported by innovative use of newer technologies, is key to sustainable use of natural resources. The example of 'ADOBE' architecture, for developing dwellings for farming communities in the dry and desert areas, was commendable and warrants wide use under similar ecological conditions.

5. Enhancing resilience of dryland farmers to climate change

- Increasing weather aberrations are enhancing the vulnerability of the smallholder farmers. Development of contingency plans based on the weather forecast and making the inputs and strategic management techniques timely available has proved very helpful for improving the resilience of Indian dryland farmers. Use of up-to-date information technologies, which are becoming increasingly accessible, has been helpful. The policy support for this initiative and convergence of actions of all stakeholders is key to the success of this initiative. Similar initiative needs to be taken in other dry areas.

- In the panel discussion on role of private sector, panelists from Egypt, China, India and Jordan recommended the need for legislative changes and development of policies that would empower the farmers and permit development of institutions that will help them improve their performance. Public–private partnership has to be encouraged and linkage to market and help in developing market-oriented agriculture through government support would be desirable for sustainable development of agriculture in the dry areas. Gender dimension has to be kept in focus and empowering the women is essential for achieving equity and ensuring sustainable development

6. Suggestions for IDDC

- IDDC should revisit the question of virtual water. And its implications for world community trade in a water scare world. One ton of imported wheat brings with it 3 tons of virtual water. Many water-poor countries are exporting water-rich products grapes, fruits, etc., thus exporting tons of water.
- IDDC should focus more on socio-economics and less on technical themes. The program should not be top-heavy with technical experts. The rural development specialists, ethno-anthropologists and rural sociologists should be given greater voice.
- IDDC should reconsider the role of presentations in the Conference. Fewer presentations that promote more discussion, rather than reports on experiments and quasi-research reports, would be better. The latter might go to posters with specific time allowed to participants to meet with authors.

Appendix

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INTERNATIONAL DRYLAND DEVELOPMENT COMMISSION

International Dryland Development Commission

August 2017

ISBN 978-977-452-463-3