Journal of Experimental Biology and Agricultural Sciences, August - 2017; Volume – 5(Spl-1- SAFSAW)

Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

THE ROLE OF SCIENCE AND TECHNOLOGY IN ENHANCING FOOD SECURITY IN ARAB COUNTRIES

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Received – May 13, 2017; Revision – June 06, 2017; Accepted – August 10,2017
Available Online – August 31, 2017

DOI: http://dx.doi.org/10.18006/2017.5(Spl-1-SAFSAW).S1.S14

KEYWORDS

Food insecurity

Factors

Arab Countries

Science and Technology

ABSTRACT

The Arab world is the largest food deficit region in the world due to the major challenges facing increasing food production despite the high potential to increase agriculture production in most Arab countries. In 2013 the Arab world imported 85.6 million tons of cereals compared to 65.3 million tons for Asia, the second largest food importer. Several factors are behind the food deficit in the Arab world including water scarcity and very low water use efficiency; serious climate change implications including more frequent droughts and high temperature; desertification or land degradation due to excessive grazing, loss biodiversity and salinity due to faulty irrigation and sea water intrusion. Political instability is another important factor that contributed to widening the gap between domestic food production and consumption. However, these challenges can be overcome through innovations in science and technology can help in growth in sustainable food production and improve food security without depleting natural resources. This paper describes some of these innovations, developed jointly by national research institutions in collaboration with the International Center for Agricultural Research Dry Areas (ICARDA) and other partners. These include improved, adapted crop varieties with high yield potential and resistance/tolerance to abiotic and biotic stresses; appropriate water management and more efficient water use; diversification and sustainable intensification of production systems which increase the returns to water and land used and reduce the risk associated with variable climatic

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI]
(http://www.horizonpublisherindia.in/).

environments. The paper provides on the ground examples in several Arab countries on bridging the yield gap between farmers yield levels of wheat and the levels of improved wheat production levels following improved varieties and agronomic practices. In an average of six seasons (2010/2011-2015/2016) involving whole provinces in nine Arab countries, wheat productivity yield gap was increased up to 124% under irrigated conditions in Sudan, up to 96% under supplemental irrigation in Yemen and up to 84% under rainfed conditions in Syria. Increasing wheat productivity and production contributes to enhancing food security in Arab countries.

1 The Status of Food Security in Arab Countries

Arab countries, i.e. the Middle East and North Africa (the MENA region), represent the largest contiguous stretch of dry regions. They share common challenges for sustainable development: rapid population growth, acute water scarcity (exacerbated by unsustainable groundwater extraction rates), frequent droughts, widespread land degradation, and salinization of irrigated lands. The region is the world's largest importer of staple cereal food grains.

The MENA region is the only region in the world that is currently experiencing an increase in hunger (FAO, 2015). The number of hungry people in the region has doubled from 16.5 million people in 1990–1992 to 33 million people in 2014–2016. The proportion of undernourished people has also increased from 6.6 to 7.5 percent during this same period; and the number of stunted children is high in countries like Egypt, Iran, Sudan and Yemen. In the region as a whole, anemia affects one third of the population, particularly children, pregnant women and women of child bearing age. This disturbing trend is attributed to the insufficient investment in agricultural research and development as well as the rise of conflicts and instability and the consequent breakdown of public and private services in agriculture, industries and other major sectors.

The sudden global increase in food prices in 2008 has put considerable economic pressure on Arab countries since the region of the Arab world is the largest food deficit region globally and the gap between domestic food production and consumption is widening (Figure 1). This situation has serious negative implications on trade balances and national budgets. During the food crisis of 2008, several food exporting countries put a ban on the exports of staple food crops such as rice and wheat. Consequently, countries that had the financial resources to purchase important staple food for food security from the global market were not able to do so. This has raised serious additional concerns in many countries of the region.

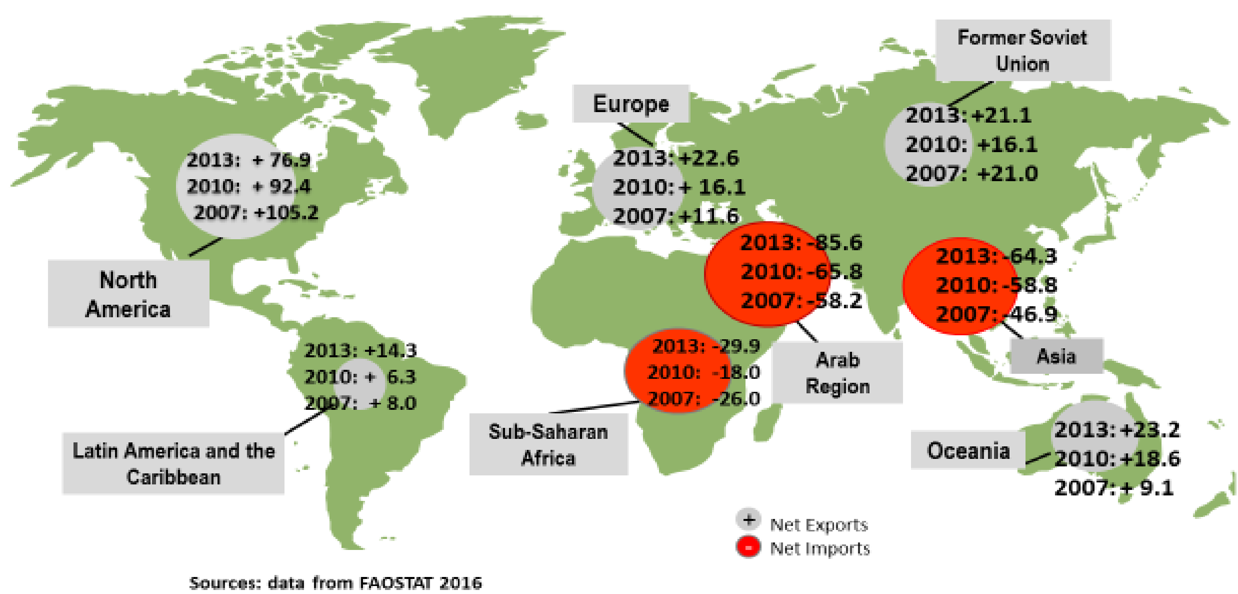

Figure 1 Global Cereal Trade: Cereal imports and exports (in million MT) in different parts of the world in 2007, 2010 and 2013 (El Solh et al., 2017)

The implications of the food crisis, and the fact that several factors and major global developments have contributed to the increase in food prices made almost every country in the region put agriculture and food security among their top national priorities since they did not expect the prices to decrease to pre 2008 levels. In reality, food prices in 2011 went even higher than those of 2008. Since 2008 almost all Arab countries have put agriculture investment as a priority to increase domestic enhance sustainable agricultural production and reduce the gap between domestic food production and food consumption to enhance food security to reduce food imports. Even countries with limited potential in agriculture such as the Gulf countries (except for Saudi Arabia and Oman) have been allocating major financial resources to enhance their own food security through foreign investment for food and feed production in several countries including Sudan and other Sub-Saharan African countries. However, it is essential that the Arab countries exploit the great agriculture potential that already exists in the Arab world as will be described late

2 Factors behind the Current Food Insecurity in Arab Countries

2.1 Dry land Agro-ecology

Dry land Agro-ecology prevails in the Arab world being in non-tropical dry areas as well as the degradation of natural resources. The following are major challenges facing enhancing food security:

- **Fragile dryland ecosystems with highly unpredictable variable climatic conditions**
- **High Rates of Population growth**
- **Rapid natural resource degradation with severe water scarcity, land degradation and desertification and loss of biodiversity**
- **Serious climate change implications.**

2.2 Population Growth

The total population of the Arab world was estimated to be 391 million in 2014, with a significant population variation between the Arab countries. In 2005, the population was estimated to be 316.8 million (El Solh et al., 2017). The population increase during this period was 23.4%, about 2.3% annually. The annual population rate in the Arab world is higher than the world average; 0.8% in developed countries and 1.9% in the developing countries. This high population growth is the result of sustained high fertility rates and the lack of family planning as well as the efforts to improve public health and lower mortality rates and combined with young communities. However, this increase has produced problems such as food insecurity, unemployment, migration, and decline the level of education.

2.3 Natural Resource Degradation:

The major constraints in enhancing the food security in the Arab world is degradation of already limited natural resources mainly water, land and biodiversity.

2.3.1 Water scarcity

Water scarcity in the Middle East and North Africa is one of the most severe in the world (Figure 2). The Arab countries account for more than 5 per cent of the world's population, but less than 1 per cent of global water resources. Arab countries face serious challenges in water scarcity and managing their variable water resources. Several countries now draw heavily on non-renewable fossil aquifers to offset the negative water balance. Most Arab countries have already exhausted their water supply development potential (El Solh, 2014). The per capita availability of renewable water resources is less than 500 m^3 per year, which is way below the water poverty level of 1000 m3 and the world average of 7000 m3 (El Solh et al., 2017). Arab countries cover 10 per cent of the world's area but receive only 2.1 per cent of the world average annual precipitation (El Solh et al., 2017). The region's annual renewable water resources that originated in the Arab countries amount to only 6 per cent of its average annual precipitation, against a world average of 38 per cent (El Solh et al., 2017). Most of the Arab region is classified as arid or semi-arid (hyper–arid and desert agro-ecosystem), receiving less than 250 millimeters of rainfall annually. Higher rainfalls are received only in southern Sudan, the southwestern Arabian Peninsula mostly Yemen and the Atlantic and Mediterranean coastlines in Maghreb and Mashreq countries receive high rainfall (El Solh et al., 2017).

Water scarcity threatens development in the Arab region and is exacerbated with serious climate change implications. The Gulf countries have adapted their hyper-arid environment by relying on desalination. Egypt, Iraq and Syria have been relying on renewable, mostly transnational, water resources. Countries with limited renewable water resources and weak financial capability, such as Jordan, have put strict regulation on the use of water resources and pursued water reuse (grey water), water harvesting and demand management initiatives (El Solh et al., 2017).

2.3.2 Land Degradation

Large part of the Arab countries is covered with dry lands, either dry sub-humid, semi-arid, arid or hyper-arid desert ecosystem (El Solh et al., 2017). These harsh environments have limited water resources and fragile ecosystems; and such conditions make the region prone to desertification, salinization, and dust storms,

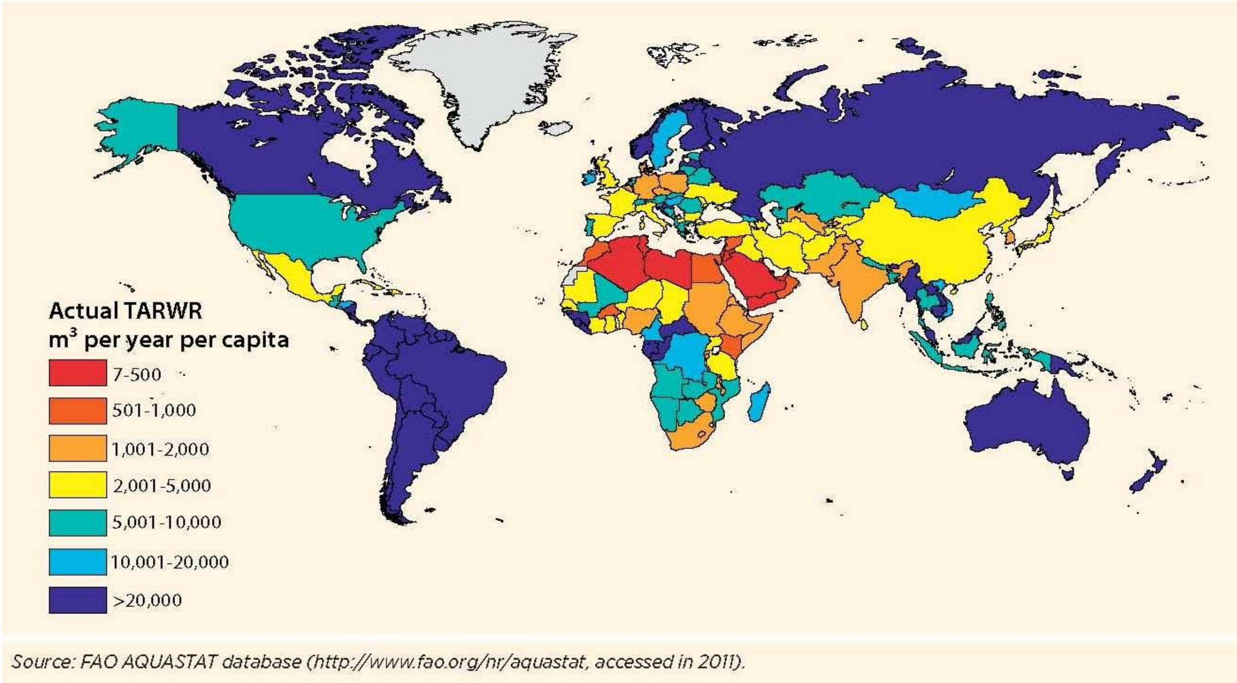

Figure 2 Water scarcity measured by actual total annual renewal water resources (TARWR) per capita.

which are closely related. According to the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD, 2012) land degradation affects some 70 percent of dryland in the Arab region. Around 48.6% of the land area in the Mashreq countries, 28.6% in the Nile Valley and the Horn of Africa, 16.5% in North Africa and 9% in the Arabian Peninsula are highly vulnerable to land degradation and desertification. Among the Arab countries, Bahrain, Kuwait, Qatar, Libya, Egypt, Jordan and the UAE are the most affected countries by land degradation (El Solh et al., 2017).

Desertification or land degradation is caused by drivers due to variations in climate and natural disasters and/or human activities. Variation in climate and natural disasters include drought, soil erosion (wind & water), dust storms, disease and insect pest epidemics while human activities include overgrazing in rangelands; deforestation; non-sustainable intensification of agricultural production; salinization due to faulty irrigation, over pumping of ground water and sea water intrusion; urbanization; pollution and conflict(World Bank, 2014; World Bank, 2016).

Salinization is serious cause of land degradation particularly in Iraq where about 50% of the irrigated land is affected by salinization as a result of faulty irrigation using poor quality drainage water coming through the Euphrates and Tigris after the water is used several times in Turkey and Syria. Salinization is a serious problem in the Delta of Egypt as a result of salt water intrusion. It is also a serious problem in Sues Valey in Morocco as a result of over pumping of water from shallow water aquifers. The soil salinity has been a very serious problem in Gulf countries because of the use of brackish water in irrigation without consideration to the leaching requirements for accumulated salts. Oman lost large areas of date palm plantation as a result of salinity.

2.3.3 Loss of Biodiversity

The loss of biodiversity in the Middle East and North Africa (MENA) region is a major national, regional and international concern. This is of particular concern because the region has two Vavilovian Centers of diversity namely the Fertile Crescent and North Africa (Figure 3, El Solh et al., 2017) where major crops and fruit trees have originated. These are the Centers of origin and domestication of crop species of global significance such as wheat, barley, lentil, and many forage legumes and fruit tree species. Although loss of biodiversity has taken place in many parts of the Arab world or MENA region, landraces and the wild species of these crops are available particularly in the drylands are mountain ecosystems of dry areas. These are important sources of biodiversity to provide important sources of desirable traits for the genetic improvement of these crops to help farmers increase their productivity and adapt to the serious implications of climate change.

The highest density of biodiversity in MENA region is in the Fertile Crescent extending from Palestine, Lebanon, Northern Syria, Southern Turkey and Northern Iraq and in Northern parts of Morocco, Algeria and Tunisia (Figure 3). Biodiversity losses in MENA region are caused by the following factors:

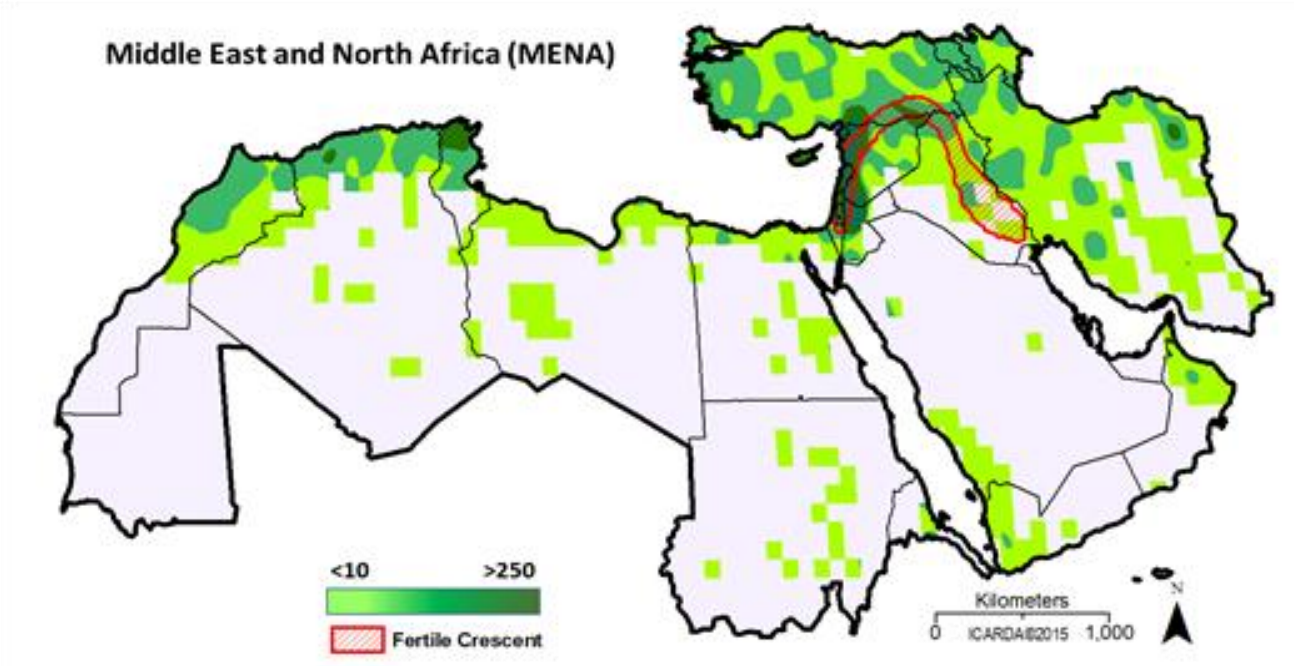

Figure 3 The two Vavilovian Centers of diversity namely the Fertile Crescent and North Africa in the MENA region

- **Urbanization, roads, dams, airports, agricultural expansion, etc…;**
- **Climate variation and change: drought, floods, high temperature and salinity;**
- **Excessive grazing and over-exploitation of rangelands**
- **Uprooting of plant species and deforestation;**
- **Disease and insect pests epidemics;**
- **Replacement of landraces by improved varieties and the non-sustainable intensification of agricultural production systems including use of herbicides, changes, crop burning, etc...**
- **Soil erosion, soil and water pollution and contamination including salinization due to faulty irrigation;**
- **Wars and civil strife.**

2.4 Climate Change Implications

Climate change is a global development that will continue to have serious implications on agriculture and food production in MENA region since the region is characterized by fragile agro-ecology of non-tropical dry areas which are most affected by climate change globally. According to various global climate change scenarios, rainfall is expected to decrease between 15 to 50% up to 2090in the MENA region (Figure 4, El Solh, 2014). Clearly, the Arab countries will be seriously affected by climate change implications with to reduced precipitation and high temperature, with a large part of the region experiencing at least 20% decrease in rainfall.

Temperatures are also expected to increase between 2 to 3.5 degrees centigrade by that year. The increase in temperature will increase droughts, which is already becoming a common phenomenon. New plant diseases and insect pests are already emerging as a result of higher temperature and other climatic changes. All of these developments require additional investment in agricultural research, education and capacity building for development to adapt and cope with the serious implications of climate change.

The likely climate change implications on temperature, precipitation and crop productivity have been widely discussed, and are increasingly being included into policy considerations. In summary, climate change in the region is expected to lead to:

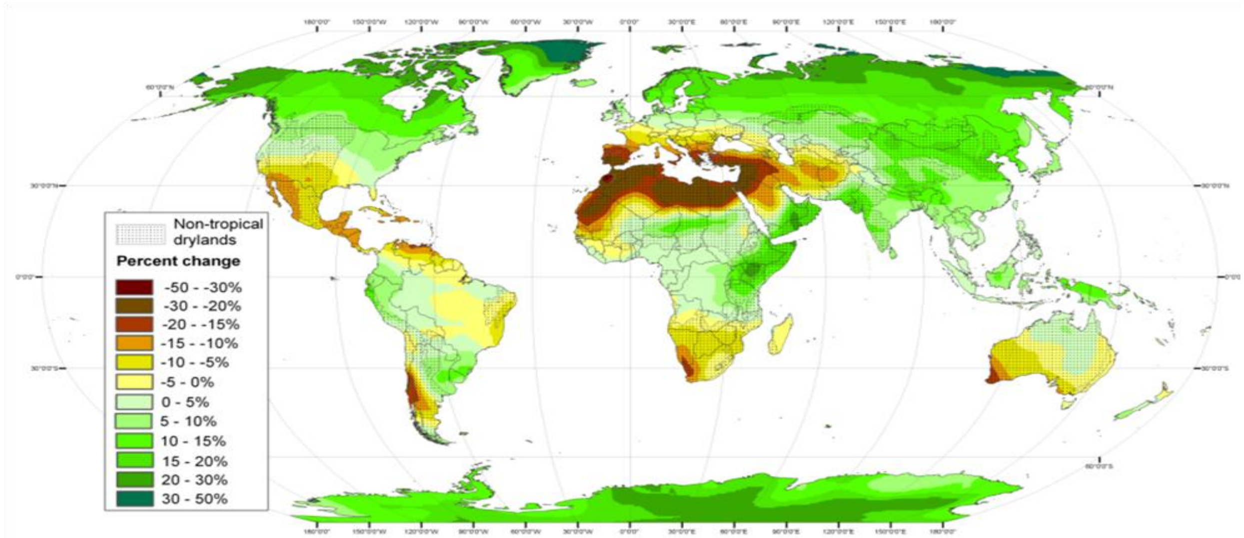

Figure 4 Relative change in mean annual precipitation 1980/1999 to 2080/2099 (Source: GIS Unit ICARDA, based on partial maps from IPCC).

Climate change implications affect not only food production, but all four dimensions of food security (FAO, 2008):

- ***Availability:*** **loss in food production due to, natural resource degradation, and increasing biotic and abiotic stresses**
- ***Access:*** **Loss of income, employment opportunities and increased livelihood risks**
- ***Stability:*** **Increased environmental variability leading to larger fluctuations in food supply in the world market, and fluctuation of food prices, higher dependency on food imports and/or food aid.**
- ***Utilization:*** **Healthy and nutritional aspects of the food and human health issues due to pesticides residues and other factors.**

2.5 Political Instability

Regional political instability and the unfortunate developments of civil unrest and lack of political stability led to serious economic instability in a number of Arab countries. Consequently, this situation contributed greatly to the deterioration of the agricultural sector and food security in several countries including Iraq and Syria which were almost food self-sufficient before the civil unrest in these countries. Political and economic stability is a perquisite to sustainable development and food security. Sustainable development is the long term solution to the civil rest in most of the Arab countries. There is an urgent need to rebuild agriculture in conflict and post-conflict countries the region through capacity development among other needs.

Rural to urban migration and overseas migration are serious problems, not only because of the violence and insecurity

situation in some areas of conflict-affected countries but also due to the lack sustainable rural development for which both development of infra-structure and agriculture are the major pillars. The deterioration of the agricultural sector contributed greatly to the lack of opportunities for better livelihoods as a result of unemployment, poverty, food and nutritional insecurity. Sustainable agriculture development, which creates employment opportunities among other important benefits, is certainly a major part of the medium to long term solution for migration.

3 Food security: challenges and opportunities

The key challenges to food security in Arab region are summarized as follows:

- **Physical water scarcity;**
- **Abiotic stresses,particularly drought, heat and salinity;**
- **Biotic stresses including diseases, insect pests and parasitic weeds;**
- **Loss of biodiversity, affecting not only current ecosystem balance;**
- **Lack of improved technology including better crop and livestock management and improvement;**
- **Inadequate policy support to agriculture as a high priority in national polices;**
- **Lack of investment in sustainable agricultural development;**
- **Insufficient investment in agricultural research for development.**

Science and technology, if properly utilized, can help overcome these challenges. It is important to develop improved crop varieties and technologies through research institutions which must play the key role with a range of different partners (national research and extension agencies, NGOs, donor agencies). Crucially, all stakeholders must work with policy makers to adopt an enabling policy environment to support technology development and dissemination, and enable small-scale farmers across the region to grow their way out of poverty.

Opportunities for horizontal agricultural expansion through more arable land are limited. Increase in agricultural production through the cultivation of more area is likely to contribute at most 7% to higher food production at the global level according to FAO. Except for Sudan, all Arab countries have limited uncultivated arable land for horizontal expansion of agriculture food production. Furthermore there are other limitations due to physical water scarcity and serious climate change implications besides the potential to "decertify" millions of hectares of arable land. Increases in food production can therefore come only through vertical increase in agricultural productivity through the sustainable intensification of cropping systems h by increasing productivity per unit of land and water. This will be done by adopting improved technologies, improved crop varieties, more input such as fertilizers; either full irrigation and/or supplemental irrigation and double cropping.

It is critical that agricultural intensification is done a sustainable manner otherwise it could affect negatively the environment and contribute to the degradation of natural resources (water, land, soil and biodiversity). There are examples in the region where intensification led to large increases in output and profitability – but only in the short term, with severe drawing down of water resources. Thus, the emphasis must be on sustainable intensification.

Despite various challenges facing enhancing food security in the Arab world, innovations in science and technology can help create sustainable growth in food production and improve food security without depleting natural resources. This paper describes some of these innovations, developed jointly by national research centers, ICARDA and other partners. These include:

(i) **improved, adapted crop varieties that are more water use efficient, higher yielding and are resistant to drought and other constraints;**

(ii) **water management options for increasing water productivity, the amount of crop produced per unit of water used;**

(iii) **better crop management practices, that improve water use efficiency;**

(iv) **options for diversifying and intensifying production systems, that increase the returns to water and land used and reduce the risk associated with variable climatic environments;**

4. Creating an enabling policy environment

While technologies may be available, they can neither be promoted nor adopted by farmers without an enabling policy environment and supportive institutions. Two challenges must be addressed:

- **Inadequate agricultural policies for sustainable agricultural development**
- **Insufficient investment in agricultural research and development**

Not only biophysical research, but policy-oriented research to inform policy development is also needed to develop new technologies. Research that successfully influences policy can generate large impacts. For example, ICARDA's research on barley fertilization in rainfed areas in Syria led to a fundamental change in government policy on fertilizer allocation. Although some other policy distortions remained, the returns to research on barley fertilization were still substantial and consistent with an estimated rate of return to investments in research and dissemination of 70%, and a benefit-cost ratio of 35-41% (Ahmed et al., 2010; Shideed et al., 2008)

The Syria case highlights important lessons. Policy makers may only partially adopt research results or recommendations. It is vital that national partner institutions are involved in any policy-oriented research. Building mechanisms for leveraging policy influence in project design and implementation also helps address policy makers' concerns, and increase the chances of success. Thus, understanding the impact pathway and identifying key partners along the pathway is a prerequisite for successful research-for-development.

Most of the growth in food supplies in recent decades has been achieved through productivity increase. Science and technological innovation are critical for agricultural development –which in turn is key to economic development in most developing-country dryland areas. Despite this, agricultural research-for-development has experienced significant under-investment.

One of the causes of the slowdown in productivity growth has been the decrease in the growth of public research investments in agriculture. Meeting the global challenge to increase food production by 70% by 2050 depends largely on increasing investments in RD&E, promoting risk management systems, improving farmers' skill and human capital, and developing policies that encourage efficiency gains.

5. Harnessing science and technology: some examples

5.1. Conservation and utilization of crop genetic resources

The GeneBanks of ICARDA in Syria (duplicated outside Syria), Lebanon and Morocco holds 133,065 accessions (Table 1). Most of these accessions are safely duplicated in other GeneBanks around the world. For example, almost 116,000 accessions are being stored in Svalbard Global Seed Vault in Norway, under an agreement involving multiple international centers.

About two-thirds of ICARDA's GeneBank's holdings comprise unique sets of landraces and wild relatives, collected mostly from dryland areas in the CWANA region. This region includes four major centers of biodiversity, and the origin of many of the world's most important crops – and therefore wide diversity in cultivated landraces and their wild relatives. Efforts to conserve and freely share these genetic resources will continue. Previous collection efforts focused on landraces and wild relatives – from diverse eco-geographic origins. Future collections will be based on gap analysis and targeting of valuable traits. An innovative tool known as FIGS (Focused Identification of Germplasm Strategy)

Table 1 Number of accessions held in ICARDA GeneBanks in Syria, Lebanon and Morocco

Taxon/Crop	Accessions held			Total unique accessions in 2016
	Syria	Morocco	Lebanon	
Bread Wheat	14,100	3,487	5,037	14,639
Durum wheat	19,635	4,312	3,655	20,496
Primitive wheat	912	459	124	954
Aegilops	4,057	120	3,953	4,774
Wild *Triticum*	1584	116	2,250	2,079
Barley	28,465	6,007	5,136	29,981
Wild *Hordeum*	1.989	228	354	2,324
Chickpea	14,214	3,326	2,893	15,195
Wild*Cicer*	270		277	547
Lentil	10,496	4,618	335	13,907
Wild *Lens*	587		426	602
Faba bean	9,542		3,397	10,034
Lathyrus	3,996		1,735	4,277
Pisum	6,106		149	8,893
Medicago	8,398		1,321	5,677
Trifolium	4,536		5,088	6366
Vicia	6,144		637	6,115
Range and pasture	5,802		2,130	7,166
Others	219		211	225
Total	141,052	22,673	39,108	154,251

has been developed by ICARDA with partners at the Australian Winter Cereals Collection and the Vavilov Research Institute (VIR) in Russia. FIGS is helping to accelerate the process of searching large germplasm collections to identify sources of specific traits as well as novel resistance genes to diseases and insect pests.

A large number of improved crop varieties have been developed, either directly through collaborative projects or by national programs using ICARDA germplasm. A total of 227 crop varieties are released by national programs in collaboration with ICARDA in the last 10 years (Table 2). The new varieties have generated major net benefits worth an estimated US $850 million per year. These varieties offer a wide range of valuable traits that are particularly important in dryland environments: higher and more stable yields, adaptation to harsh conditions, climate change adaptation traits, specific agronomic traits such as earliness and improved canopy architecture, and resistance or tolerance to biotic and abiotic stresses.

Several high-yielding wheat cultivars with resistance to heat stress have been developed in Sudan, enabling feasible and profitable wheat cultivation in large areas where heat stress once prevented its cultivation. Another program is developing synthetic wheat lines with high drought tolerance. Under severe dry conditions, the synthetic lines give yields up to 147% higher than the recurrent parent.

More than 20 improved varieties developed by the national program in the Agricultural Research Center (ARC) of Egypt in collaboration with ICARDA. As an example, Sakha 4, was released as an early-maturing variety developed specifically for post-rice cultivation in the Nile Delta. Crop improvement research combines traditional methods (conventional plant breeding) with modern biotechnology tools. ICARDA has also pioneered the use of participatory breeding methods – which are being institutionalized by national programs in several Central and West Asia and North Africa (CWANA) countries.

5.2 Integrated pest management

To manage insect pests cost-effectively and with minimal use of chemicals, ICARDA and its partners have developed integrated pest management (IPM) methods that combine resistant varieties with improved crop management practices, as well as biocontrol methods. One example is with the Sunn pest complex, which is an insect pest that affects more than 15 million ha of wheat in West Asia, Central Asia and East Europe.

The Sunn pest IPM research focuses on four components (Parker et al., 2004)

- Hand collection of Sunn pest in overwintering sites
- Use of insect-killing fungi in overwintering sites
- Enhancement and conservation of egg parasitoids
- Genetic resistance at the vegetative stage.

Table 2 Improved crop varieties release by national programs in collaboration with ICARDA in the last 10 years, from 2006 to 2016 (November)

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	**7**		**4**		**2**	**1**	-
Total	**227**	**59**	**56**	**19**	**40**	**45**	**6**

The IPM package includes a major biocontrol component. The use of natural enemies (parasitoids which attack Sunn pest eggs) reduces pest populations without the need for excessive doses of pesticide – thus reducing farmers' costs as well as protecting the environment. This research has helped change national policies in West Asia: government-supported aerial sprays have been replaced with targeted ground applications on over 3 million hectares. In addition, revised 'economic thresholds' for pesticide use have been implemented that are significantly reducing pesticide use.

5.3. Enhancing water productivity

Given the critical scarcity of water resources in all Arab countries, it is crucial to improve water productivity and to develop and promote more efficient ways to use water resources. ICARDA's research focuses on increasing water productivity: the return or the benefits derived from each cubic meter of water consumed. This return may be biophysical (grain, meat, milk, fish etc), socio-economic (employment, income), environmental (carbon sequestration, ecosystem services) or nutritional (protein, calories etc.), at the field, the farm, the ecosystem and the basin levels.

Research on water productivity has shown that it is within reach to, at least, double the current productivity of water used in agriculture. This is equivalent to doubling the amount of water available. Water productivity can be improved by implementing modern technologies, adopting more efficient water management methods such as supplemental irrigation and water harvesting, improved planting cropping patterns such broad-bed planting using improved germplasm. Since irrigated agriculture has reached its potential, rainfed agriculture has the highest potential for increases in water productivity and food production and thus investment in this agroecosystem may be the most feasible (Figure 5).

A regional project, involving ten Arab countries in West Asia and North Africa (WANA) has completed three phases with the support of the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Agricultural Development (IFAD).The WANA Water Benchmark Sites Project aims to promote community participation to stimulate adoption of technologies that increase water productivity in three major agro-ecosystems: marginal rangelands, rainfed systems, and irrigated systems. Results from farmers' fields in different agro-ecologies have developed the following innovative technologies to enhance water use efficiency (WUE) and water productivity (WP):

- **Deficit Irrigation**
- **Supplemental irrigation**
- **Rain 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 Greywater reuse**
- **Hydroponics/Soilless Culture for high-value crops**

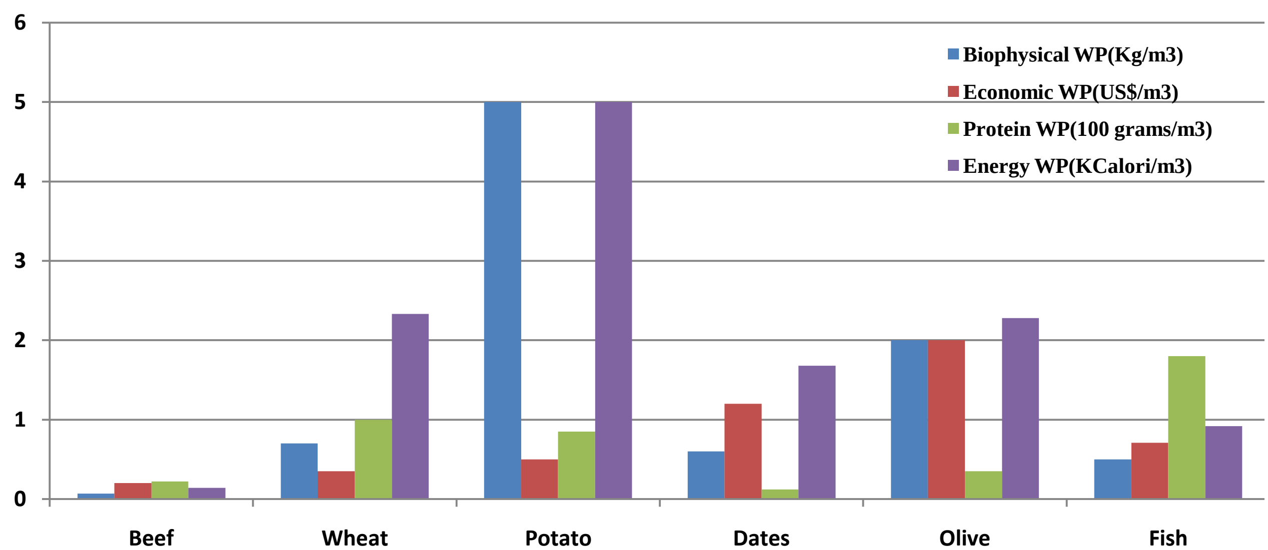

Figure 5 Average water productivity (biophysical, economical, nutritional and energy) values of selected food products. Calculated by averaging high and low values (adopted from Molden et al., 2007)

The results clearly demonstrate that water productivity is significantly higher under supplemental irrigation compared to full irrigation and rainfed agriculture (Figure 6).Supplemental irrigation is the application of small amounts of water, during long periods of drought to alleviate soil moisture stress of rain fed crops or to early sowing winter crops for better growth and to avoid frost and heat stresses (Oweis 1997, Oweis & Hachum, 2004).

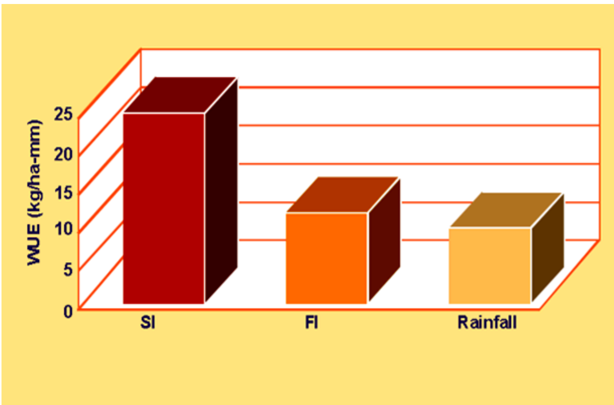

Figure 6 Water use efficiency (WUE) under supplemental irrigation (SI) system, full irrigation (FI) and Rainfall in wheat

In water-scarce areas, water is becoming the most limiting resource to agricultural development. Accordingly, the current strategy to maximize agricultural production per unit of land (land productivity) may no longer be valid. In dry areas new irrigation management strategies, based on maximizing the production per unit of water, are more relevant since water is the most limiting factor to increase agricultural production in dry areas. Such practices for increasing water productivity also improve land productivity, but within limits (Figure 7). A tradeoff needs to be made to optimize the use of both water and land resources. This will require substantial changes in the way we think and conduct agricultural development. These changes can be achieved though adopting new irrigation guidelines using deficit irrigation, supplemental irrigation in rainfed agriculture, changing cropping patterns, reforming water policies to valuate water, increase support to research, encourage people participation and promote regional cooperation (Oweis & Hachum, 2009, El Solh et al., 2017).

In irrigated agriculture, broad-bed planting (BBP) in the Sharkia province in the Delta of Egypt increased wheat productivity by 25% and reduced applied water by 30%. This is a good example to produce more with less water resources which is critical in Egypt and other Arab countries. The national campaign to expand BBP resulted in the adopted of this technology on 700,000 acres across Egypt in 6 years. The Egyptian Government National Campaign is targeting 1.8 million acres (600, 000 ha) by 2018 (Figure 8).

5.4 Bridging the Yield Gap

Enhancing Food Security in Arab countries on realizing the agricultural potential of Arab countries by bridging the yield gap in wheat is another example of enhancing food security in the Arab world. In an average of six seasons (2010/2011-2015/2016) targeting whole provinces in nine Arab countries, wheat productivity yield gap was increased up to 124% under irrigated conditions in Sudan, up to 96% under supplemental irrigation in Yemen and up to 84% under rainfed conditions in Syria (Table 3, El Solh et al., 2017). This project is supported by the Arab Fund for Economic and Social Development (AFED), the Kuwait Fund for Arab Economic Development (KFAED) and the Islamic Development Bank (IsDB) which supported the project only the first three seasons. At the national level, there are clear examples in both Syria and Iraq, the only Arab countries that managed to

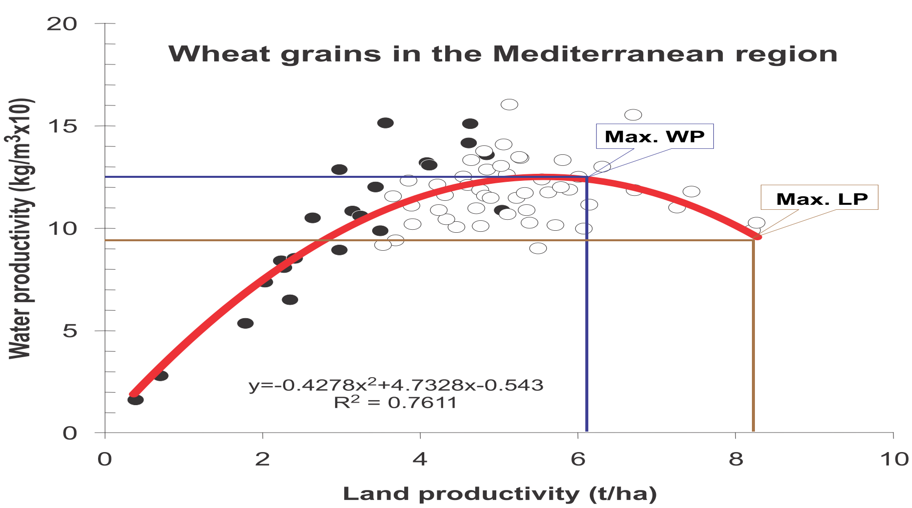

Figure 7 Trade-offs between water productivity and land productivity of wheat in the Mediterranean region (Adapted from Zhang & Oweis, 1999)

Figure 8 Increasing water productivity in wheat for enhancing food security while saving water resources in Egypt (ICARDA/ARC – Egypt)

Table 3 Grain wheat yield (t/ha) as an average of six seasons (2010/2011-2015/2016) seasonsin the farmers' demonstration fields versus farmers' traditional fields (El Solh et al., 2017)

Country	Egypt	Iraq ****	Jordan *	Morocco		Palestine ***	Sudan	Syria		Tunisia		Yemen **	Overall mean
Productionsystem	I	I	R	R	SI	R	I	R	SI	R	SI	SI	
ParticipatingFarmers	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-ParticipatingFarmers	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
Averageincrease (%)	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 maxincrease %	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

Source: Enhancing Food Security in the Arab Countries, ICARDA/National Programs Project (2011 to present) supported byArab Fund for Economic and Social Development (AFESD), the Kuwait Fund for Arab Economic Development (KFAED), Islamic Development Bank, the Bill & Melinda Gates Foundation (BMGF) and the OPEC Fund for International Development and implemented by ICARDA. Unpublished data provided by the courtesy of Dr. Habib Halila, ICARDA Project Manager.

achieve self-sufficiency in staple food crops before the wars and civil strife. Food security deteriorated drastically in these two countries after the war in Iraq in 2005 and after the disturbances in Syria in 2011. So there is no reason why Arab countries could not exploit their agricultural potential to enhance food security.

5.5 Crop-livestock integration

Small ruminants (sheep and goats) are a key source of livelihood and income – and rangelands are the single largest land use category – in marginal or low rainfall areas of drylands. It is important to develop integrated crop-livestock technologies that exploit crop-livestock synergies to increase livestock production using rangelands, fodder crops and crop residues. These technologies were developed through livestock research which covers the following areas:

- Conservation, management and genetic utilization of indigenous livestock breeds, which are well adapted to dryland conditions

- Development of integrated livestock/rangeland/crop production systems that involves the following: Increased fodder production with a combination of improved fodder varieties, more effective use of native fodder species, new fodder sources (Atriplex and spineless cactus),and low-cost 'feed blocks' made from farm residues and agro-industrial products.
  - Flock management including 'strategic feeding' (where feed supplementation is limited to critical periods) and market-oriented management
  - Rangeland management and rehabilitation through community-led grazing calendars with adequate 'rest' periods.
  - Value added products such yogurt, cheese, mohair etc. with research complemented by training for small-scale livestock producers

Several technologies are in the hands of pastoralists and farmers because of this research. Efforts and effective technology transfer. These technologies have increased livestock production contributing to an increase in income and improving livelihoods. The added value dairy products (such as yoghurt, cheese and '*Jameed'*) has helped enhance food security and increase income to improve livelihoods particularly empowering women in marginal or low rainfall areas.

Conclusions and recommendations

This paper has listed some examples of currently available, proven technologies and concepts that could help ensure food and water security for dryland regions in developing countries. Many more technologies are available, and others are still in the pipeline. But food insecurity and unsustainable use of natural resources still persist.

What can make a difference in efforts to enhance both water and food security in dry areas?

- First, an enabling policy environment and strong political commitment are critical. Policies are needed that support sustainable productivity growth.

- Second, the dry areas must give greater priority to and investment in agricultural and rural development, particularly in the vulnerable rainfed areas.

- Third, a shift in strategy is needed to emphasize water productivity for maximum benefits in water scarce areas. This should mainly involve changing water management guidelines and modifying cropping patterns with consideration of virtual water trade options when appropriate.

- Fourth, advances in science and technology are crucial in overcoming or adapting to the challenges facing dry areas. An integrated approach is needed, that addresses both agricultural productivity and the better management of the natural resources on which that productivity depends.

- Above all, greater investments are needed in agricultural research capacity development and institutional support. Far greater investment is needed in developing a new generation of national scientists and technicians that will carry these efforts into the future.

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