Impact of Climate Change on Food Security[1]

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Recent studies, model projections and observations have indicated that climate change will be one of the main drivers for reducing food security levels in the Arab world in the next few decades. The main impacts on food security will result from an expected lower agricultural productivity, increased temperatures, reduced precipitation, increased risk of extreme weather events and heat waves.

IPCC's Fifth Assessment Report (2014) concluded that arid and semi-arid regions are highly vulnerable to climate change. By the end of the twenty-first century, the Arab region will face an increase of 0.9 to 4.1°C in surface temperature. This increase will be coupled with sharp decreases in precipitation and increases in evaporation, which are likely to reduce available water by half by 2100. These projected changes will lead to shorter winters and drier, hotter summers, more frequent heat wave occurrences, and more variability and extreme weather events occurrences.

The majority of Global Circulation Models (GCMs) project a grim outlook for the Arab region in terms of major reduction in precipitation, increase in evaporation, and subsequent reduction in both runoff and soil moisture. Precipitation is projected to decrease by up to 25 percent, which in combination with a 25 percent projected increase in evaporation would translate to a drastic 50 percent drop in runoff by the end of the century. The net effect will be a major reduction in available water resources, exacerbating current water scarcity conditions.

The dominant agricultural system in Arab countries is rainfed agriculture, with the total irrigated area in the Arab world being less than 28 percent (FAO, 2008b). Therefore, annual agricultural productivity and food security are highly correlated to the annual variability of precipitation, which has exhibited major changes in recent decades.

Average surface temperatures in North Africa have increased 1-2°C between 1970 and 2004 (IPCC, 2007). The region is particularly exposed to water shortages. In North Africa, with a 3°C rise in temperature, an additional 155 to 600 million people may suffer increased water stress, while maize yields could fall by between 15 and 25 percent.

Projections also suggest that climate change will cause world food prices to rise, with negative effects on food security. Egypt expects to lose 15 percent of its wheat crops if temperatures rise by 2°C, and 36 percent if the increase is 4°C. Morocco expects crops to remain stable until about 2030, but then to drop quickly afterwards. Most North African countries traditionally import wheat and are therefore highly vulnerable to price shocks and droughts elsewhere. The crop modeling results indicate that climate change will have a negative effect on crop yields in the Middle East and North Africa in 2050. The region will face yield declines of up to 30 percent for rice, about 47 percent for maize and 20 percent for wheat (IFPRI, 2009).

The Arab World can develop a variety of responses to the threat of climate change on food security in the region. Some of these measures are:

- Enhancing knowledge of climate change exposure, sensitivity and vulnerability on food security
- Enhancing knowledge on main climate change determinants on food security
- Mainstreaming climate change vulnerability and adaptation in agricultural sectoral strategies
- Integrating adaptation measures in agriculture/food security with adaptation measures in the water sector, with both linked to energy mitigation options through a comprehensive water-energy-food nexus
- Providing incentives and proper management tools to shift from high water consuming crops to those with a low water footprint.

I. INTRODUCTION

Climate change is reducing water availability and therefore increasing the demand for water needed for irrigation, which will significantly limit crop productivity in affected areas. The FAO predicted that as a result of global warming, the hydrological cycle will accelerate as rising temperatures increase the rate of evaporation from land and sea. Rainfall is thus predicted to rise in the tropics and higher latitudes, but to decrease in the already dry semi-arid to arid mid-latitudes and in the interior of large continents. Water-scarce areas of the world will generally become drier and hotter. Relatively small reductions in rainfall will translate into much larger reductions in runoff – for example, a 5 percent fall precipitation in Morocco is predicted to result in a 25 percent reduction in runoff (FAO, 2011).

Food security in the Arab world has experienced a long history of environmental and socio-economic pressures. The dominant arid conditions, limited water resources, erratic cropping patterns, low knowledge and technology levels, and reliance on imported food commodities are the main factors affecting food production and distribution systems in the Arab region.

Most recent assessments have concluded that arid and semi-arid regions are highly vulnerable to climate change (IPCC, 2014). On the other hand, at a high level conference of the Food and Agriculture Organization (FAO) held in Rome in June 2008, the delegates asserted that agriculture is not only a fundamental human activity at risk due to climate change, it is also a major driver of environmental and climate change itself. The projected climatic changes will be among the most important challenges for agriculture in the twenty-first century, especially for developing countries and arid regions (IPCC, 2014).

By the end of the twenty-first century, the Arab region will face an increase of 0.9 to 4.1°C in the surface temperature. This increase will be coupled with sharp decreases in precipitation and increases in evaporation, which are likely to reduce water available by half by 2100. These projected changes will lead to shorter winters and drier, hotter summers, more frequent heat wave occurrence, and more variability and extreme weather events occurrence (IPCC, 2013).

II. KEY IMPACTS AND VULNERABILITIES OF THE AGRICULTURE SECTOR IN THE ARAB WORLD

The risks associated with agriculture and climate change arise out of strong and complicated relationships between agriculture and the climate system, in addition to the high reliance of agriculture on finite natural resources (Abou-Hadid, 2009). The inter-annual, monthly, and daily distribution of climate variables (e.g., temperature, radiation, precipitation, water vapour pressure in the air, and wind speed) affects a number of physical, chemical, and biological processes that drive the productivity of agricultural, forestry, and fisheries systems (IPCC, 2014). In the cases of forestry and fisheries systems, vulnerability depends on exposure and sensitivity to climate conditions, and on the capacity to cope with changing conditions.

In the same vein, Marcus Marktanner et al. (2011) indicated that the nexus of climate change and food security is complex. A 2008 FAO report identifies more than 100 links between climate change and food insecurity. Specifically, the FAO examines the climate change impacts of CO_2 fertilization, increase in global mean temperature, precipitation changes, and more extreme weather events on food system assets, food system activities, food security outcomes, and well-being (FAO 2008, p. 14-19). The following is a selection of links between climate change and food security:

SUMMARY OF EXPECTED IMPACTS OF CLIMATE CHANGE ON GLOBAL FOOD SECURITY AS IDENTIFIED IN IPCC 5TH ASSESSMENT REPORT IN 2014

1. Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts.

2. Climate change has negatively affected wheat and maize yields both regionally and globally.

3. Since the IPCC Fourth Assessment Report, several periods of rapid food and cereal price increases following climate extremes in key producing regions indicate a sensitivity of current markets to climate extremes, among other factors.

4. Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings. Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions.

5. Projected impacts vary across crops and regions and adaptation scenarios, with about 10 percent of projections for the period 2030-2049 showing yield gains of more than 10 percent, and about 10 percent of projections showing yield losses of more than 25 percent, compared to the late twentieth century. After 2050 the risk of more severe yield impacts increases and depends on the level of warming.

6. All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability.

7. In Africa reduced crop productivity associated with heat and drought stress is expected with strong adverse effects on regional, national and household livelihoods and food security. Another expected impact is increased damage from pests and diseases, and flood impacts on food system infrastructure.

8. Without adaptation, any local temperature increase in excess of about 1°C above pre-industrial is projected to have negative effects on yields for the major crops (wheat, rice, and maize) in both tropical and temperate regions.

9. These impacts will occur in the context of rising crop demand, which is projected to increase by about 14 percent per decade until 2050. Crop production to be consistently and negatively affected by climate change in the future in low latitude countries, while climate change may have positive or negative effects in northern latitudes.

10. Changes in temperature and precipitation, without considering effects of CO_2 will contribute to increased global food prices by 2050, with estimated increases ranging from 3-84 percent.

11. Under scenarios of high levels of warming, leading to local mean temperature increases of 3-4°C or higher, models based on current agricultural systems suggest large negative impacts on agricultural productivity and substantial risks to global food production and security.

12. Projected benefits of adaptation are greater for crops in temperate, rather than tropical or arid regions. Wheat-based systems are more adaptable than other crops.

13. Fluctuations and trends in food production are also widely believed to have played a role in recent price changes, with recent price spikes often following climate extremes in major producers. Moreover, some of these extreme events have become more likely as a result of climate trends (IPCC, 2014).

WITH REGARD TO AVAILABILITY OF FOOD, CLIMATE CHANGE:

- Adversely affects rural livelihood bases through a decline in water availability, soil erosion, desertification and salination (particularly for coastal agricultural lands), droughts, floods, and wildfires.
- Increases pest and disease problems (locusts, yellow rust and the like).
- Likely reduces agricultural output.
- Likely exacerbates the existing inequalities between rich and marginalized populations.
- Affects livestock health and productivity.
- Negatively affects fish supply.
- Decreases drinking water availability and quality (especially in countries like Yemen, Jordan and Libya).

WITH REGARD TO ACCESS TO FOOD, CLIMATE CHANGE:

- Could reduce access to food of people whose livelihoods depend on agriculture, livestock, forestry, and fisheries (especially smallholder, subsistence, rain-fed farmers, and pastoralists).
- Could lead to livelihood losses in urban populations (extreme weather conditions, coastal erosion, and flooding) and, as a result, could reduce food access of vulnerable urban populations.
- Could reduce access to drinking water.
- Leads to an upward trend of food prices and increases their volatility.
- Creates poverty in rural communities.
- Could spur internal and external conflict that disrupts access to markets.

WITH REGARD TO UTILIZATION OF FOOD, CLIMATE CHANGE:

- Undermines the availability and efficient utilization of food through factors like heat stress, disease, malnutrition, and the deterioration of sanitary conditions.
- Increases competition for scarce public health services.
- Increases likelihood of diseases due to epidemics from food and waterborne diseases such as cholera, malaria, dysentery, etc.

WITH REGARD TO STABILITY/CONTINUITY OF FOOD SUPPLY, CLIMATE CHANGE:

- Disrupts continuous availability through trade restrictions in response to climate change-induced catastrophes.
- Leads to the collapse of social safety nets if the creation of fiscal space does not keep up with rising social assistance needs.

FAO (2011) indicated that climate change manifests itself in the Arab region through a) higher temperatures, b) lower precipitation, c) sea level rise, and d) increase in frequency and intensity of extreme weather events such as drought and floods. Average surface temperatures in North Africa have increased 1-2°C between 1970 and 2004 (IPCC, 2007). The region is particularly exposed to water shortages. In North Africa, with a 3°C rise in temperature, an additional 155 to 600 million people may suffer increasedwater stress, while maize yields could fall by between 15 and 25 percent (FAO, March 2008). Climate change impacts at two levels: (i)the emergencies created by increased events of drought and floods, and (ii)the slow but gradual onset of change in mean temperatures and precipitation resulting in lower annual yields which further stresses the already stretched coping mechanisms of subsistence farmers and pastoralists. In addition to encroachment onto fertile lands, rising sea levels will reduce agricultural productivity in delta areas due to increase in water salinity. The Nile delta, an area responsible for 60 percent of agricultural production in Egypt, is highly vulnerable to future sea level rise (IPCC, 2007). Further intensification and expansion efforts by Egypt will be challenged by other factors identified by FAO as limiting the prospects for increasing agricultural productivity (WFP, 2008). Data from the World Meteorological Organization indicate that 80 percent of disasters in the MENA are climate related (IASC, 2009).The change in average temperature and agricultural output in some Arab countries could be summarized in Table 1.

The current total cultivated area in the Arab region makes up about 5 percent of the total global cultivated area, and it represents about 5 percent of the total area of Arab world (FAO, 2008b). Most of the Arab region's lands are classified as hyper-arid, semi-arid, and arid land zones (WRI, 2002). The relationship between the cultivated area and the population is one of the major challenges facing food production in the region. The land share per capita is decreasing annually as a result of rapid population growth rates and urbanization (AOAD, 2008). By 2007, the average agricultural land share in the Arab region was about 0.23 ha per capita, which is slightly lower than the world average of 0.24 ha per capita.

The dominant agricultural system in Arab countries is rain-fed agriculture, with the total irrigated area in the Arab world being less than 28 percent (FAO, 2008b). Therefore, annual

TABLE 1 **CHANGE IN AVERAGE TEMPERATURE AND AGRICULTURAL OUTPUT**

	Change in Average Temperature			Change in Output 2080	
	Present	Future	Change		
Country	1961-90	2070-99		Without carbon fertilization	With carbon fertilization
Algeria	22.67	27.81	5.14	–36.0	–26.4
Iran	17.26	22.63	5.37	–28.9	–18.2
Iraq	20.86	26.16	5.30	–41.1	–32.2
Saudi Arabia	24.57	29.3	4.73	–21.9	–10.2
Syria	17.48	22.19	4.71	–27.0	–16.0
Yemen	23.77	27.72	3.95	–28.2	–17.0
Morocco	17.43	21.91	4.48	–39.0	–29.9

Source: Cline (2007).

FOOD SECURITY AND CLIMATE CHANGE: THE UAE EXPERIENCE

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Introduction

The Arab world faces critical challenges in ensuring its food security. Our region is already the world's largest net importer of essentials such as cereals and sugar, low water supplies in the region mean that expanding agricultural production is difficult, and population growth means that more people must be fed each year. In many ways, the United Arab Emirates (UAE) presents an exemplary case of this challenge. The country has low potential for agricultural production, and can rely on rainfall for less than one percent of its water needs. That means that its food security depends on international markets. For the UAE, food security is fundamentally a foreign policy issue.

The UAE has placed a wide range of policies and measures in recent years to ensure stable, affordable, and long-term food supplies, ranging from increasing domestic agricultural production to acquisition of foreign agricultural land. At the same time, climate change is affecting global food production, and it is projected to worsen in the coming decades. The UAE therefore needs to address these challenges through a balanced, strategic approach and active participation in relevant international negotiations.

Limits of Domestic Production

Currently, the UAE imports around 90 percent of its food products. This is mainly due to the fact that the UAE is located in a highly arid environment that does not favor agricultural production. The lack of surface freshwater resources (the average annual rainfall is less than 100 millimeters), high temperatures in the summer months and the limited availability of land suitable for agriculture limits domestic agricultural production to less than 1 percent of its gross domestic product. Furthermore, ground water, which is the main source of water used for agriculture, is projected to be depleted in the mid-21st century with the current abstraction rate. Significantly increasing other sources of water in agriculture such as desalinated water is not an economically and environmentally viable option. The UAE has taken many important steps to improve domestic agricultural production through better crop selection (e.g., phasing out of water-intensive Rhodes grass for animal feed), increasing water efficiency (e.g., promoting drip irrigation) and introducing new technologies (e.g., introduction of hydroponics). Entities such as Masdar are exploring new options such as renewable energy for desalination to improve economic and environmental footprints associated with the desalination processes. While such efforts are helpful, domestic agricultural production cannot increase to the level of self-sufficiency. The UAE will continue to be heavily reliant on food imports in the foreseeable future, and it needs to take strategic measures to mitigate associated risks.

Global Food Supply and the Impacts of Climate Change

The UAE has a broad and fairly balanced supplier base across all geographic regions. The top five supplying countries account for approximately less than half of the total food import. India, for instance, is one of the major food suppliers for the UAE, and its share is roughly between 15 to 20 per cent of the total, varying from year to year. Land has been acquired or leased, including in countries such as Sudan, Morocco and Pakistan, to provide an assured supply to the UAE. Regardless of where food products are sourced, however, all of the regions will be affected by impacts of climate change, including decreased yields due to drought and flood increases as well as crop damage due to insect outbreaks. For example, a report of the Intergovernmental Panel on Climate Change projects that agricultural production in many of the African countries will be "severely compromised" and yields from rain-fed agriculture in some countries may be halved by 2020 (IPCC, 2007). Similarly, crop yields in Central and South Asia are projected to decrease by up to 30 percent by 2050 (IPCC, 2007). Some regions have already been affected, as seen by the repeated flooding in India and Pakistan in recent years. Some estimates indicate that climate change may account for as much as half of projected food price increases by 2050 for staples such as maize, rice and wheat (Nelson et al., 2010). Coupled with increasing food demand both domestically and internationally due to population growth, as well as increasing global demand for more resource-intensive food products (such as meat), the challenges of food security for the UAE will grow.

Key Factors for Addressing Food Security and Climate Change

There are a number of key factors in ensuring food security against challenges of climate change. First, all countries must make efforts to limit greenhouse gas emissions and

adapt to the impacts of climate change, especially in areas where agricultural production is projected to be affected. An international climate agreement, scheduled for negotiation by 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), must be effective and ambitious. Second, the UAE must invest strategically to build diversified and resilient food supplies, taking into consideration potential impacts of climate change and other factors. Third, the UAE will continue supporting an open, rules-based multilateral trading system, and support agricultural exporting developing countries in having equal access to markets and obtaining necessary technical assistance. Fourth, global goal setting is important in creating a common ground. Once agreed, the set of universal "Sustainable Development Goals" being developed by the United Nations should help countries to collectively address important issues such as food security and climate change in the coming decades.

Recommendations

The UAE has already done a lot in relation to the above mentioned points. The UAE is active in promoting a climate agreement and sustainable development goals under the United Nations. It plays a major role in clean technology development and deployment through leading actors such as MASDAR. It has taken a wide range of approaches on foreign agricultural investments and supported bilateral and multilateral trade discussions. However, more needs to be done in order for the UAE to safeguard its food security. A strategic national food security policy based on international agreements and investments is essential. The Ministry of Foreign Affairs, in close cooperation with both domestic and international partners, is ready to play a growing role in enhancing the country's food security in the years ahead.

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agricultural productivity and food security are highly correlated to the annual variability of precipitation, which has exhibited major changes in recent decades (Abou-Hadid, 2006). Irrigated agriculture is widely represented in the Arabian Peninsula countries and Egypt, where fully irrigated agriculture makes up 100 percent and 95 percent of the total cultivated area, respectively.

The agricultural productivity of most crops exhibited noticeable increases during recent years. The per capita food production index (PCFPI) shows the food output, excluding animal feed, of a country's agriculture sector relative to the base period 1999-2001 (FAO, 2008b). The PCFPI value of the Arab region increased from 99.8 in 2003 to 112.3 by 2005, an increase of 13 percent, whereas the world values of the PCFPI increased during the same years by 20 percent (AOAD, 2008). The productivities of crops under irrigated agriculture in the Arab region improved due to switching to new cultivars, applying modern technologies, and improving management programs. Some Arab countries such as Egypt now yield some of the highest productivities in the world. Nevertheless, the majority of Arab countries have serious problems in agricultural production as a result of limited economic resources, low levels of technology, limited crop patterns, and environmental limitations and pressures (Agoumi, 2001).

The FAO (2005) expected growth rates in world agricultural production to decline from 2.2 percent/yr during the past 30 years to 1.6 percent/yr between 2000 and 2015, 1.3 percent/yr between 2015 and 2030, and 0.8 percent/yr between 2030 and 2050. This still implies a 55 percent increase in global crop production by 2030 and an 80 percent increase to 2050 (compared with 1999 to 2001). Globally, to facilitate this growth in output, 185 million ha of rain-fed crop land (+19 percent) and 60 million ha of irrigated land (+30 percent) will have to be brought into production. Expanded land use and improved technology are the primary reasons contributing to the expected rise in yields. Cereal yields in developing countries are projected to increase from 2.7 tonnes/ha currently to 3.8 tonnes/ha in 2050 (FAO, 2005). Notwithstanding these overall improvements, important food-security problems remain to be addressed at the local and national levels. Areas with high rates of population growth and natural resource degradation are likely to continue to have high rates of poverty and food insecurity (Alexandratos, 2005). Cassman et al. (2003) emphasize that climate change will add to the dual challenge of meeting food demand while at the same time efforts are in progress for protecting natural resources and improving environmental quality in these regions.

The production and dissemination of seasonal climate forecasts have improved the ability of many resource managers to anticipate and plan for climate variability (Harrison, 2005). However, problems related to infectious diseases, conflicts, and other societal factors may decrease the capacity to respond to climate variability and change at the local level, thereby increasing current vulnerability. Policies and responses made at national and international levels also influence local adaptations (Salinger et al., 2005). National agricultural policies are often developed on the basis of local risks, needs, and capacities, as well as international markets, tariffs, subsidies, and trade agreements (Burton and Lim, 2005).

Water balance and weather extremes are key to many agricultural and forestry impacts. Most Arab countries are characterized by limited water resources and high water demands. The total annual renewable water resources in the Arab world are about 460 km^3, or about 0.9 percent of the global annual renewable water resources. Based on annual water resources per capita, all Arab countries are facing a vulnerable water situation, except Mauritania, Iraq, Comoros and Somalia, which have renewable water resources of more than 1,500 m^3/capita/year. Sudan and Lebanon are currently facing water stress (1,000 to 1,500 m^3/capita/year), while the rest of the Arab countries are facing water scarcity (less than 1,000 m^3/capita/year) (AFED, 2010 and Table 6 of Chapter 1 of AFED 2014 report). The agriculture sector uses about 80 percent of the total water resources of the Arab world. However, the water use efficiency of the agriculture sector in most of the Arab countries is low (Montazar et al., 2007).

The climatic wind system that brings precipitation to North Africa and the Eastern Mediterranean is expected to drift northward, thereby removing

a large portion of already meager precipitation levels. This grim perspective makes it necessary for Arab countries to take active and long-term measures to bridge the widening gap between rising water demands and exhausted and deteriorating water resources. (AFED, 2010)

IPCC projections for this century are for further warming in all seasons, while precipitation shows some distinct sub-regional and seasonally dependent changes, characterized by model scatter. In both winter (October to March) and summer (April to September), precipitation in general is projected to decrease. However, the Mediterranean side still appears likely to become drier, the likely precipitation changes for the interior land masses are less clear and the intensified and northward shifting may imply an increase in precipitation in the most southern part of the Arabian Peninsula. Overall, the projections by the end of the century (2081–2100) indicate little overall change, although with a tendency for reduced precipitation, particularly in the high end scenarios (IPCC, 2013).

The majority of Global Circulation Models (GCMs) project a grim outlook for the Arab region in terms of major reduction in precipitation, increase in evaporation, and subsequent reduction in both runoff and soil moisture. Precipitation is projected to decrease by up to 25 percent which in combination with a 25 percent projected increase in evaporation would translate to a drastic 50 percent drop in runoff by the end of the century. The net effect will be a major reduction in available water resources exacerbating current water scarcity conditions (AFED, 2010).

Many negative impacts of climate change on freshwater systems are observed in recent studies. These impacts are mainly due to the observed and projected increases in temperature, evaporation, sea level, and precipitation variability (IPCC, 2007 and IPCC, 2014).

Changes in annual mean runoff are indicative of the mean water availability for vegetation. Projected changes between now and 2100 show

REVIEW OF THE LIKELY IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN SELECTED ARAB COUNTRIES

Fidele Byiringiro

Climate change is expected to impact agriculture in the region in one way or another. Below is a short review of the anticipated impact of climate change on agricultural in selected Arab countries.

In Egypt, climate change is expected to lead to decreased crop yields for most crops. Wheat yields are projected to be lower by up to 9 percent by 2030 and by close to 20 percent by 2060. Despite this drop in yield levels, overall farm income is projected to be higher as a result of the anticipated higher global commodity prices, which will benefit market-oriented farmers while worsening the situation of subsistence farmers, urban poor and Egypt's overall food security situation (Smith et al., 2013).

In Jordan, higher levels of water consumption are anticipated by 2030 as a result of population growth. However, the county is one of the most water-scarce in the world and as such expansion in irrigation is severely limited unless new sources of water (e.g., water treatment and/or water desalination) are developed. Though crop yields may slightly be bumped up by the positive effects of increased CO_2 concentration due to climate change, severe water restrictions will be the major determinant of agriculture and food production especially that Jordan is already reaching the limit of its technological capacity given that modern pressurized systems are already installed across a large share of its irrigated area (Varela-Ortega et al., 2013; Verner et al., 2013).

In Lebanon, higher temperatures, lower precipitations and reduction in snow cover are anticipated, which might increase the occurrence of drought, heat and fires. These will negatively affect crop yields with some estimates putting, for example, some yield decreases to up to 80 percent notably for the most vulnerable crops such as sugar beets, cherries, grapes but also wheat. Higher temperatures may also lead to the discontinuance in the production of temperate crops, which would be displaced by those with a more tropical nature (Verner et al., 2013).

In Morocco, assessments show that climate change will substantially alter regional production patterns and induce yield shocks (mostly negatively) while driving up commodity prices. Agricultural production is projected to decrease by up to 5 percent in the worst case scenario (Ouraich & Tyner, 2012). The Oum Er Rbia River basin, which houses half of the irrigation potential of Morocco and where 60 percent of sugar beets, 40 percent of olives and 40 percent of milk are produced, is already plagued by lower-than-expected rainfall for a decade or more, which has reduced water for irrigation by half. As a result, groundwater pumping is at all time high, which has dropped the water table by more than 5 meters (World Bank, 2014).

some consistent runoff patterns: increases in high latitudes and the wet tropics, and decreases in mid-latitudes and some parts of the dry tropics. Declines in water availability are therefore projected to affect some of the areas currently suitable for rain-fed crops, for instance in the Mediterranean basin and sub-tropical regions (Christensen et al., 2007).

The AFED report on water (AFED, 2010) used a vulnerability approach analysis on climate change impacts on water resources in Arab countries. Arab countries are situated in climate change hotspots where major reductions in precipitation accompanied with increases in evapotranspiration are projected to result in an even more precarious water balance. Faced

In Saudi Arabia, climate change is expected to have a major impact on agriculture and food production largely as a result of reduced water availability. Climate change impact is expected to manifest through higher temperatures, up to 3°C higher by 2040, greater rainfall variability and sea level rise. These are expected to dramatically impact agriculture and food production, which are already highly affected by the lowering of groundwater tables. When there are low precipitations, wells often dry up causing substantial crop yield variability (Darfaoui & Al Assiri, 2010).

In Sudan, projections point to greater variability in wheat production and yields under various climate change scenarios together with a decrease in harvested area due to the impact of higher temperatures and rising water scarcity. However, the same projections show potential increases in sorghum and millet production. Thus, the impact on overall food security for Sudan will be mixed at best (Taha, Thomas & Waithaka, 2012).

In Syria, it is projected that food prices might increase as a result of climate change, which would benefit the agricultural sector even though these high prices would hamper overall economic growth. In the long run, however, agricultural growth rate should exhibit a declining trend largely because of the combined effect of lower precipitations and higher temperatures, which will negatively affect crop yields even while discounting the impact of the on-going conflict (Al-Riffai et al, 2013).

In Yemen, climate change is a real concern. A decrease in the levels of precipitation will put rainfed agriculture in peril and worsen the already precarious food security situation. Yields are projected to vary because of climate change. Sorghum and millet yields are expected to increase while those of maize and wheat would decrease. However, the overall impact of climate change on agricultural GDP would be positive because of the anticipated higher global prices even though most farmers would likely not benefit from these higher prices as they are not market-oriented (Breisinger et al., 2011).

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with the reality of physical water scarcity, sharp increases in pumping costs driven by high energy prices, and declining water levels in strategic aquifers, many Arab countries have started to reorient their food policies by relying on imports and restricting irrigation to high value crops.

Climate change will increase consumptive water use in key sectors in the future, especially in countries that have limited water resources, high population growth, and high development rates. Magano et al. (2007) point out that irrigation demands will increase and the period of supplementary irrigation will become longer under projected climate changes. For example, the total annual reference irrigation demands

of Egypt are projected to increase by 6 to 16 percent by the 2100s, due to the increase in reference evapotranspiration values, which will lead to a general increase in the crop-water demands.

Smallholder agriculture is used here to describe rural producers, who farm using mainly family labour and for whom the farm provides the principal source of income (Cornish, 1998). Pastoralists and people dependent on artisanal fisheries and household aquaculture enterprises (Allison and Ellis, 2001) are also included in this category. Smallholders in most Arab countries are poor and suffer in varying degrees from problems associated both with subsistence production (isolated and marginal location, small farm size, informal land tenure, and low levels of technology) and with uneven and unpredictable exposure to world markets, which have been characterized as 'complex, diverse and risk-prone' (Chambers et al., 1989). Risks are also diverse (drought and flood, crop and animal diseases, and market shocks) and may be felt by individual households or entire communities (Scoones et al., 1996). Subsistence and smallholder livelihood systems currently experience a number of interlocking stressors other than climate change and climate variability (Iglesias, 2002). It is likely that smallholder and subsistence households will decline in numbers, as they are pulled or pushed into other livelihoods, with those that remain suffering increased vulnerability and increased poverty (Lipton, 2004).

The impacts of climate change on subsistence and smallholder agriculture, pastoralism, and artisanal fisheries will include, (i) the direct impacts of changes in temperature, CO_2 and precipitation on yields of specific food and cash crops, productivity of livestock and fisheries systems, and animal health; (ii) other physical impacts of climate change important to smallholders such as decreased water supply for irrigation systems, effects of sea level rise on coastal areas, increased frequency of tropical storms (Adger, 1999), and other forms of environmental impact still being identified, such as increased forest-fire risk (Agrawala et al., 2003) and remobilization of dunes (Thomas et al., 2005); and (iii) impacts on human health, like malaria risk.

III. IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION

Plant response to elevated CO_2 alone, without climate change, is positive and was reviewed extensively in a vast number of studies, which confirmed that the effects of elevated CO_2 on plant growth and yield will depend on photosynthetic pathways, species, growth stage, and management regimes, such as water and nitrogen (N) applications (e.g. Ainsworth and Long, 2005). On average, across several species and under unstressed conditions, recent data analyses find that, compared to current atmospheric CO_2 concentrations, crop yields increase at 550 parts per million (ppm) CO_2 in the range of 10-20 percent for C3[2] crops and 0-10 percent for C4[3] crops (Ainsworth et al., 2004; Long et al., 2004).

Some studies use re-analyses of recent FACE (Free Air Carbon Enrichment) to argue that crop response to elevated CO_2 may be lower than previously thought, with consequences for crop modelling and projections of food supply (Long et al., 2006). Studies found that temperature and precipitation changes in future decades will modify, and often limit, direct CO_2 effects on plants. For instance, high temperatures during flowering may lower CO_2 effects by reducing grain number, size, and quality (Caldwell et al., 2005). Increased temperatures may also reduce CO^2 effects indirectly, by increasing water demand (Xiao et al., 2005).

Future CO_2 levels may favour C3 plants over C4 (Ziska, 2003), yet the opposite is expected under associated temperature increases; the net effects remain uncertain. In particular, since more than 80 percent of total agricultural land and close to 100 percent of pasture land is rain-fed, general circulation model (GCM) dependent changes in precipitation will often shape both the direction and magnitude of the overall impacts (Reilly et al., 2003).

The IPCC (2007a) reported that agricultural production in many African countries is projected to be severely compromised by climate variability and change. Yields from rain-fed agriculture in Africa could be reduced by up to 50 percent by 2020, and the projected sea-level rise will affect low-lying coastal areas with large populations,

which will require a total cost of adaptation that could amount to at least 5-10 percent of GDP.

The IPCC (2014a) moreover indicated that reduced crop productivity is associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihoods and food security in Africa. Also expected are increased occurrences of pests and diseases and flood impacts on food system infrastructure. The same report indicates increased risk of drought-related water and food shortage causing malnutrition in Asia.

For the Arab world, the overall conclusion of most studies indicates a general trend of reduction for most major field crops. El-Shaer et al. (1997) concluded that climate change could do severe damage to agricultural productivity if no adaptation measures were taken.

Figures 1 and 2 show the change in percentage of crop productivity and crop water needs for some main crops in Egypt under climate change conditions compared to current conditions (El-Marsafawy, 2011). The results indicate that climate change could decrease the national production of the main crops in Egypt (except cotton) and increase water needs by up to 16 percent.

There are additional negative impacts of increased climate variability on plant production due to climate change. Understanding links between increased frequency of extreme climate events and ecosystem disturbance (fires, pest outbreaks, etc.) is particularly important to quantify the impacts (Hogg and Bernier, 2005).

Furthermore, CO_2-temperature interactions are recognized as key factors in determining plant damage from pests in future decades, though few quantitative analyses exist to date. CO_2-precipitation interactions will likewise be important (Zvereva and Kozlov, 2006).

The International Food Policy Research Institute (IFPRI) predicted that warming in the MENA region, combined with the high likelihood of overall declines in precipitation, makes the region particularly vulnerable to climate change. Projections also suggest that climate will cause world food prices to rise, with negative effects on food security. Egypt expects to lose 15 percent of its wheat crops if temperatures rise by 2°C,

FIGURE 1 **CHANGE PERCENT IN MAJOR CROPS PRODUCTION (EXCESS OR DEFICIT) IN EGYPT BY THE YEAR 2050 DUE TO CLIMATE CHANGE.**

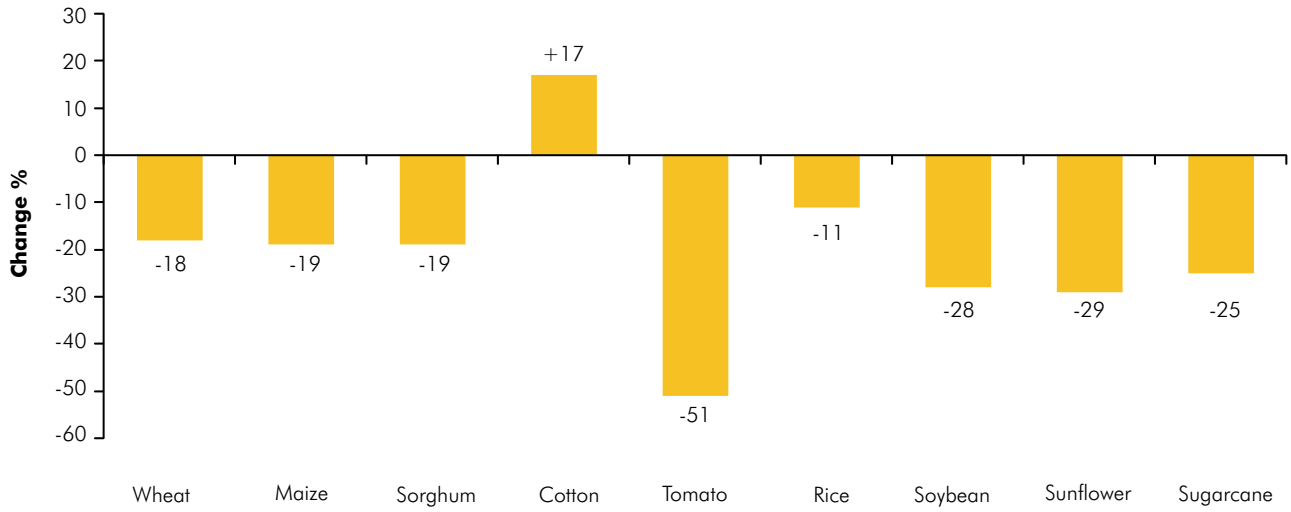
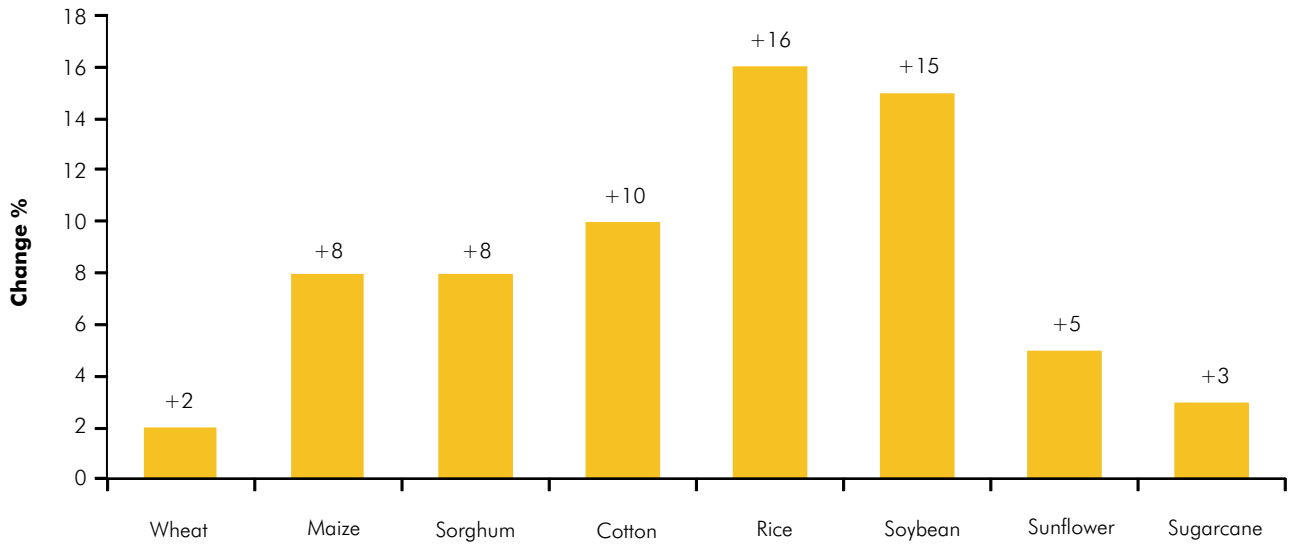


FIGURE 2 **CHANGE PERCENT IN CROP EVAPOTRANSPIRATION FOR MAJOR CROPS IN EGYPT BY THE YEAR 2050 DUE TO CLIMATE CHANGE.**



and 36 percent if the increase is 4°C. Morocco expects crops to remain stable up to about 2030, but then to drop quickly later. Most North African countries traditionally import wheat and are therefore highly vulnerable to price shocks and droughts elsewhere. The crop modeling results indicate that climate change will have a negative effect on crop yields in the Middle East and North Africa in 2050. The region will face yield declines of up to 30 percent for rice, about 47 percent for maize and 20 percent for wheat (IFPRI, 2009).

The impact of climate change on pests and diseases was studied for some important diseases at the national level, such as pear early blight, potato

late blight (Fahim, et al., 2007), and wheat rust diseases (Abo Elmaaty et al., 2007). Importantly, increased climate extremes may promote plant disease and pest outbreaks (Gan, 2004).

IV. IMPACT OF CLIMATE CHANGE ON LIVESTOCK AND GRAZING

Pastures comprise both grassland and rangeland ecosystems. Rangelands are found on every continent, typically in regions where temperature and moisture restrictions limit other vegetation types; they include deserts (cold, hot, and tundra), scrub, chaparral, and savannas. Pastures occupy 33 percent of the total area of the Arab region. However, this area faces risks due to events related to climatic variability (e.g. drought, floods) and desertification (AOAD, 2008).

Pastures and livestock production systems occur in most climates and range from extensive pastoral systems with grazing herbivores to intensive systems based on forage and grain crops, where animals are mostly kept indoors. The combination of increases in CO_2 concentration with changes in rainfall and temperature is likely to have significant impacts on grasslands and rangelands, with production increases in humid temperate grasslands, but decreases in arid and semi-arid regions (IPCC, 2007a).

Animal requirements for crude proteins from pastures range from 7 to 8 percent of ingested dry matter, up to 24 percent for the highest-producing dairy cows. In conditions of very low Nitrogen status in pasture ranges under arid and semi-arid conditions, possible reductions in crude proteins under elevated CO_2 may put a system into a sub-maintenance level for animal performance (Milchunas et al., 2005). The decline under elevated CO_2 levels (Polley et al., 2003) of C4 grasses, which are a less nutritious food resource than C3 (Ehleringer et al., 2002), may also compensate for the reduced protein content under elevated CO_2. Generally, thermal stress reduces productivity and conception rates, and is potentially life-threatening to livestock. Because ingestion of food and feed is directly related to heat production, any decline in feed intake and/or energy density of the diet will reduce the amount of heat that needs to be dissipated by the animal. Mader and Davis (2004) confirm that the onset of a thermal challenge often results in declines in physical activity with associated declines in eating and grazing (for ruminants and other herbivores) activities. New models of animal energetics and nutrition (Parsons et al., 2001) have shown that high temperatures put a ceiling on dairy milk yield irrespective of feed intake. Increases in air temperature and/or humidity have the potential to affect conception rates of domestic animals not adapted to those conditions. This is particularly the case for cattle, in which the primary breeding season occurs in spring and summer months. Amundson et al. (2005) reported declines in conception rates of cattle for temperatures above 23.4°C and at high thermal heat index.

Moreover, impacts on animal productivity due to increased variability in weather patterns will likely be far greater than effects associated with the average change in climatic conditions. Lack of prior conditioning to weather events most often results in catastrophic losses in confined cattle feedlots (Hahn et al., 2001), with economic losses from reduced cattle performance exceeding those associated with cattle death losses several-fold (Mader, 2003). In dry regions, there are risks that severe vegetation degeneration leads to positive feedbacks between soil degradation and reduced vegetation and rainfall, with corresponding losses of pastoral areas and farmlands (Zheng et al., 2002). A number of studies in Africa (Batima, 2003) show a strong relationship between droughts and animal death. Projected temperature increases, combined with reduced precipitation in North Africa would lead to increased loss of domestic herbivores during extreme events in drought-prone areas. With increased heat stress in the future, water requirements for livestock will increase significantly compared to current conditions, so that overgrazing near watering points is likely to expand (Batima et al., 2005).

V. IMPACT OF CLIMATE CHANGE ON FISHING AND AQUACULTURE

Aquaculture resembles terrestrial animal husbandry and therefore shares many of the vulnerabilities and adaptations to climate change with that sector. Similarities between aquaculture and terrestrial animal husbandry include ownership, control of inputs, diseases and predators, and use of land and water. Some

GENETICALLY ENGINEERED CLIMATE-RESILIENT SEEDS AS A POSSIBLE RESPONSE TO CLIMATE CHANGE-INDUCED FOOD SHORTAGES

Anne Saab

Climate change is predicted to have dramatic impacts on agricultural production globally. Although food production in some regions of the world may benefit from increasing average temperatures, most of the world will face severe challenges in adapting agricultural systems to the predicted climatic changes. The Arab region will be among the most affected, with precipitation estimated to drop by 25 percent and evaporation to increase by 25 percent before 2100. In addition to higher average temperatures, incidences of drought and higher soil salinity will influence agriculture and food production. Agriculture is highly dependent on climate and therefore changes in climatic conditions impact crop yields for food production.

The latest IPCC assessment report emphasizes the severe impacts climate change is already having, and will continue to have, on food production. Food security is at risk, and methods of food production will have to adapt to the changing climate in order to maintain adequate levels of food supply. As with all other impacts of climate change, food security is most at risk in those areas of the world that are most vulnerable. Part of the reason is that these vulnerable regions, including sub-Saharan Africa, parts of Asia, and the Arab world, already have warmer and drier climates and already suffer from more droughts and floods than other parts of the world. Another important reason for their increased vulnerability is the regions' lack of adaptive capacity. Unless effective adaptation strategies are developed and implemented, this decrease in crop yields and food production could result in millions more people facing food insecurity. The World Food Programme has estimated that the number of people at risk of hunger and food insecurity will increase by 10-20 percent by the year 2050 as a result of climate change.

Agriculture in the Arab world is particularly vulnerable to climate change. As this AFED report illustrates, Arab countries have mostly arid climates with high temperature and low precipitation levels. Moreover, adaptive capacity is currently inadequate to deal with these challenges. Lack of water is a particular problem for agriculture in the Arab world. Adaptation strategies are being devised in the international sphere that may contribute to adapting agriculture to the impacts of climate change and addressing problems of food insecurity. One of these strategies is the development and use of genetically engineered seeds that are made for resilience to certain climatic conditions.

For thousands of years, farmers have adapted to changes in climate through a process of seed selection. Seeds of crops that can grow with little water, for example, are saved and replanted during periods of drought. This process of natural selection and breeding, however, is a slow process and it can take years or even decades for suitable seeds to consistently yield enough crops. Agricultural biotechnology and particularly genetic engineering has in recent years directed attention to the development of climate-resilient seeds and crops. The use

of genetic engineering techniques is intended to speed up this process of natural selection. It allows the transfer of specific genetic traits from one seed to another, with the objective of developing seeds with resistant traits.

The world's largest seed corporations (including Monsanto, Syngenta, Dupont, Bayer, and BASF) are focusing their efforts on the research and development of drought-resistant seeds, as water is one of the main limiting factors in agriculture. Climate-resilient seeds are presented as a possible adaptation strategy to climate change. Seeds that are genetically engineered to require less water to grow crops, for example, could be useful in maintaining adequate food production in periods of drought. For Arab countries that already have dry climates and whose agriculture suffers from the impacts of climate change, such climate-resilient seeds could prove to be a very useful adaptation tool.

Many governments, policymakers, corporations, and even civil society organizations are increasingly promoting the use of biotechnology, and especially genetic engineering, in agriculture. The impacts of climate change are considered unprecedented and sufficiently severe to require new and more effective adaptation measures that go beyond convention breeding techniques. Despite the promise that genetically engineered climate-resilient seeds may hold, there is also a great deal of criticism directed against these seeds as an adaptation strategy to climate change. Critical voices claim that large seed corporations are abusing the climate and food crises for their own commercial gain. The ETC Group, an influential civil society organization, has called the promotion of 'climate-ready' seeds by corporations 'climate profiteering'.

Critiques of climate-resilient seeds take several forms. Some scientists argue that these seeds have not proven to produce more crop yields than non-genetically engineered seeds. For instance, the Union of Concerned Scientists has noted that drought-resistant corn seeds have not proven to produce more corn than other types of corn seeds. Scientists contend that it is very difficult to develop climate-resilient traits in seeds, considering the complexity of these genetic traits. Additionally, they argue that it is almost impossible to develop resistance against climatic conditions such as drought, most fundamentally because such climatic conditions are unpredictable. Every instance of drought is different from the next instance of drought, and developing resistance against one does not guarantee resistance against another.

Another strong criticism is that seed corporations focus their research on commercially viable crops, such as corn. Commercially viable crops are, however, not necessarily the crops that are needed to feed the developing world. In the Arab region, rice is one of the staple crops. However, the production of rice requires a great deal of water. Instead of genetically engineering rice to be able to grow with less water, it might be more beneficial to switch to production of other crops that naturally require less water. An additional criticism is that genetically engineered climate-resilient seeds are often patented by seed corporations. As their research and development requires substantial investments, patent rights are viewed as an appropriate reward and incentive for these corporations. Patent rights, however, also block access to these seeds by the vulnerable populations, as they cannot afford to pay the fees to obtain them.

Perhaps the most fundamental critique of climate-resilient seeds as a strategy to adapt agriculture to climate change and prevent food insecurity is the question of whether increasing food production is enough. If climate-resilient seeds are capable of increasing food production in the face of climate change, will the people who are most food insecure and who require such seeds most urgently be able to benefit from them? Food security depends not only on adequate availability of food, but also and importantly on adequate access to food. If genetically engineered climate-resilient seeds are successfully developed, the people in the Arab world might still not benefit from this adaptation tool if farmers are not able to afford those seeds.

Genetically engineered climate-resilient seeds hold both great promise and great controversy. They could provide a valuable contribution to adapting the world's agriculture to the impacts of climate change and combat food insecurity. At the same time, the critiques voiced must also be taken seriously. This dilemma is common to all climate change adaptation strategies and presents policymakers with difficult challenges. Climate change impacts on society on so many different levels – environmental, social, political, economic, cultural, etc. – and potential solutions must therefore also take all these dimensions into account. The legal framework must also be considered. International law concerning climate change adaptation, patent rights, and human rights in the form of the right to food are all relevant in discussions about climate-ready seeds. In addition to international law, regional and domestic laws also apply. How these laws can best be employed to achieve the most effective adaptation outcomes is not always evident. Identifying and acknowledging the complexities may be a good place to start.

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IMPACT OF CLIMATE CHANGE ON FOOD PRODUCTION IN EGYPT

Egypt, the most populous Arab country, is most vulnerable to the potential impacts and risks of climate change. The climate change effects examined are alterations in Nile water inflows, irrigation water requirements, crop yields, land loss to sea level rise, livestock performance, and increase in municipal and industrial water use. Results of McCarl et al (2013) indicate that:

- Climate change damages the Egyptian agricultural sector and the damages increase over time (2030-2060).
- Prices for agricultural commodities increase and this has a negative effect on producers.
- Egypt may reduce these damages by adapting through lower demand growth, raised agricultural technological progress, sea rise protection and water conservation strategies.
- The Agricultural Sector Model (ASME) was updated to include the most recent Egyptian agricultural data, a water flow model, and municipal and industrial water use.
- Regarding climate change 2030; agricultural production decreases by 6 percent and prices increase by 19 percent with agricultural revenues rising by 15 percent. Farmers benefit from these increased prices. Consumers experience a 1.7 percent welfare loss as there is a reduction in production and increase in price. Imports rise by 23 percent. Agricultural water use increases by 8 percent. Agricultural employment increases by 4 percent. More desert land is reclaimed for agricultural production.
- For climate change 2060; agricultural production decreases by 6 percent, prices increasing by 19 percent plus an increase in imports of 19 percent. Land dedicated to agriculture decreases by 19 percent with agricultural water use is reduced by 17 percent and agricultural employment by 13 percent. There is an increase in groundwater use of 12 percent. Also the agricultural value of production increases by 15 percent while welfare reduces by 6 percent because consumers are spending more on food.

aquaculture, particularly of plants, depends on naturally occurring nutrients, but the rearing of fish usually requires the addition of suitable food. Capture fisheries depend on the productivity of natural ecosystems and are therefore vulnerable to climate change induced changes affecting production in natural aquatic ecosystems.

The IPCC (2007a) reports a number of key negative impacts of climate change on aquaculture and freshwater fisheries, including (i) stress due to increased temperature and oxygen demand and increased acidity (lower pH); (ii) uncertain future water supply; (iii) extreme weather events; (iv) increased frequency of disease and toxic events; (v) sea level rise and conflict of interest with coastal protection needs; and (vi) uncertain future supply of fishmeal and oils from capture fisheries. Positive impacts include increased growth rates and food conversion efficiencies, increased length of growing season, range expansion, and use of new areas due to decreases in ice cover.

Temperature increases may cause seasonal increases in growth, but may also affect fish populations at the upper end of their thermal tolerance zone. Increasing temperature interacts with other changes, including declining pH and increasing nitrogen and ammonia, to increase metabolic costs. The consequences of these interactions are speculative and complex (Morgan et al., 2001).

Changes in primary production and transfer through the food chain due to climate will have a significant impact on fisheries. Such changes may be either positive or negative and the aggregate impact at the global level is yet unknown (IPCC, 2014). However, climate change has been implicated in mass mortalities of many aquatic species, including plants, fish, corals, and mammals, but a lack of standardized epidemiological data and information on pathogens generally makes it difficult to attribute causes (Harvell et al., 1999).

VI. IMPACT OF CLIMATE CHANGE ON FOREST PRODUCTIVITY

Forests cover almost 928 thousand ha constituting 6.6 percent of the Arab world's physical territory. Approximately one third of this area is located in Sudan. Modelling studies predict increased global timber production. Whereas models suggest that global timber productivity will likely increase with climate change, regional production will exhibit large variability, similar to that discussed for crops. Climate change will also substantially impact other services, such as seeds, nuts, hunting, resins, and plants used in

pharmaceutical and botanical medicine and in the cosmetics industry; these impacts will also be highly diverse and regionalized. Recent studies suggest that direct CO_2 effects on tree growth may be revised to lower values than previously assumed in forest growth models. A number of FACE studies showed average net primary productivity (NPP) increases of 23 percent in young tree stands at 550 ppm CO_2 (Norby et al., 2005). However, in a 100-year old tree stand, Korner et al. (2005) found little overall stimulation in stem growth over a period of four years. Additionally, the initial increase in growth increments may be limited by competition, disturbance, air pollutants, nutrient limitations, and other factors (Karnosky, 2003), and the response is site- and species-specific.

A number of long-term studies on supply and demand of forestry products have been conducted in recent years (IPCC, 2007a). These studies project a shift in harvest from natural forests to plantations (Hagler, 1998). Finally, although climate change will impact the availability of forest resources, the anthropogenic impact, particularly land-use change and deforestation, is likely to be extremely important (Zhao et al., 2005).

VII. ADAPTATION OF AGRICULTURE IN THE ARAB WORLD

In 2001, the IPCC defined "Adaptation" as any adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions or activities to climatic change and variability (IPCC, 2001).

The high vulnerability of the agricultural sector in developing countries should place it at the top of priority lists of adaptation plans. Although climate change is projected to have serious impacts on the agricultural sector in the Arab world, only modest efforts and steps are currently being taken in the areas of scientific research, mitigation, and adaptation.

Agriculture has historically shown high levels of adaptability to climate variations. For cropping systems, there are many potential ways to alter management to deal with projected climatic

and atmospheric changes (Challinor et al., 2007). These adaptations include:

a. Altering inputs such as varieties, species, fertilizer, and amounts and timing of irrigation and other water management practices;

b. Wider use of simple technologies;

c. Water management to prevent water logging, erosion and nutrient leaching in areas with rainfall increases;

d. Altering the timing or location of cropping activities;

e. Diversifying income by integrating other farming activities such as livestock raising;

f. Improving the effectiveness of pest, disease, and weed management practices; and

g. Using seasonal climate forecasting to reduce production risk.

In its 2014 report, IPCC suggested the following Adaptation measures for Africa and Asia (IPCC, 2014):

a. Technological adaptation responses (i.e. stress tolerant crop varieties, irrigation, and enhanced observation systems).

b. Enhancing smallholder access to credit and other critical production resources.

c. Strengthening institutions at local, national and regional levels to support agriculture (including early warning systems) and gender-oriented policies.

d. Agronomic adaptation responses (e.g. agro-forestry and conservation agriculture).

e. More efficient use of water (i.e. improved agricultural practices, irrigation management, and resilient agriculture).

Many options for policy-based adaptation to climate change have been identified for agriculture, forests, and fisheries (Easterling et al., 2004). These can either involve adaptation activities such as developing infrastructure, or building the capacity to adapt in the broader user community and institutions, often by changing the decision making environment under which management-level, adaptation activities occur. Designing and applying national adaptation strategies for the agriculture sector faces a number of barriers, including limitations of the existing scientific base, policy perceptions under current conditions and pressures, poor adaptive capacity of rural communities, lack of financial support, and the absence of an appropriate institutional framework.

AFED (2010) indicated that strategic changes in water policies due to Climate Change have created a positive virtual water balance as water became imbedded in imported agricultural produce. This has prompted several GCC countries to seek acquirement of titles to land resources and even fishing rights in developing countries in Africa and Asia to secure food for their rapidly growing populations.

VIII. CONCLUSION AND RECOMMENDATIONS

Food security is a growing international challenge that is felt especially in the Arab world. The factors affecting food security in the region are ever growing population, the limited water resources, the unfavourable weather conditions, and political and economical instability. Climate change has added to this a major new challenge and uncertainty.

Adaptation to climate change is therefore highly needed. Adaptation strategies should build on a mix of local heritage and modern technologies. The target of adaptation in this region is mainly directed towards improving water use efficiency, heat and stress tolerance, and reducing the energy inputs used for crop production.

Capacity building is a major prerequisite for climate change adaptation action to improve the ability of the community to utilise science, technology, and heritage for planning and implementation plans. Awareness and advocacy are also needed to set the community priorities and establish appropriate policies. Community reaction to adaptation measures is a vital issue. Therefore, training and awareness programs should be carefully designed to improve timely implementation of the adaptation schemes.

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NOTES

1. This chapter is based on Dr. Ayman Abou Hadid's chapter on Food Production, published in AFED 2009 Annual Report on Impact of Climate Change on Arab Countries (AFED, 2009). It has been revised by the author to take into account recent developments, especially the latest IPCC reports.

2. C3 carbon fixation is a metabolic pathway for carbon fixation in photosynthesis. This process converts carbon dioxide and ribulosebisphosphate (RuBP, a 5-carbon sugar) into 2,3-phosphoglycerate through the following reaction:

CO_2 + RuBP → 2,3-phosphoglycerate

This reaction occurs in all plants as the first step of the Calvin cycle.

3. C4 carbon fixation is one of three biochemical mechanisms, along with C3 and CAM photosynthesis, functioning in land plants to "fix" carbon dioxide (binding the gaseous molecules to dissolved compounds inside the plant) for sugar production through photosynthesis. Along with CAM photosynthesis, C4 fixation is considered an advancement over the simpler and more ancient C3 carbon fixation mechanism operating in most plants. Both mechanisms overcome the tendency of RuBisCO (the first enzyme in the Calvin cycle) to photorespire, or waste energy by using oxygen to break down carbon compounds to CO_2. However C4 fixation requires more energy input than C3 in the form of ATP. C4 plants separate RuBisCO from atmospheric oxygen, fixing carbon in the mesophyll cells and using oxaloacetate and malate to ferry the fixed carbon to RuBisCO and the rest of the Calvin cycle enzymes isolated in the bundle-sheath cells. The intermediate compounds both contain four carbon atoms, hence the name C4.

OPINION

THIRSTY ENERGY OR HUNGRY WATER?

Najib Saab

The World Bank chose "Thirsty Energy" as title for its report on the energy-water nexus. If we were to produce such a report for the Arab region, the title could better be "Hungry Water"- as production of water eats the bulk of Arab energy.

In no other part of the world is the link between energy and water as critical as it is in the Arab region. While it is one of the driest areas on earth, the Arab region holds the bulk of the world's oil reserves. The energy sector plays a major role in meeting water and food needs in Arab countries, mainly through seawater desalination, in a region which hosts 50 percent of the world's desalination capacity. Water is also heavily needed to generate energy, in all its types; from fossil fuels to solar PV and Concentrated Solar Power (CSP) to nuclear energy.

Climate change will only worsen the water situation, according to a report produced by the Arab Forum for Environment and Development (AFED) on Impact of Climate Change on Arab Countries. By the end of the 21st century, Arab countries are predicted to experience an alarming 25 percent decrease in precipitation and 25 percent increase in evaporation rates.

Desalination, water distribution, and pumping groundwater consume 50 percent of total energy in some Arab countries. Irrigation efficiency is among the world's lowest, while per capita domestic water consumption in some of the most water-scarce Arab countries is among the world's highest. Half of the wastewater produced is discharged without treatment, while only 20 percent of the treated water is reused.

A 2013 AFED report on Sustainable Energy concluded that Arab energy is not managed better than water. Although energy intensity and per capita carbon emissions are among the highest in the world, over 50 million Arab people are without access to modern energy services. Growth in energy consumption, at 8 percent, has been twice the growth in GDP, at 4 percent. Average energy efficiency in the region stands at less than 50 percent. A combination of water and energy efficiency measures can save up to half of the energy currently used, while maintaining the same production levels.

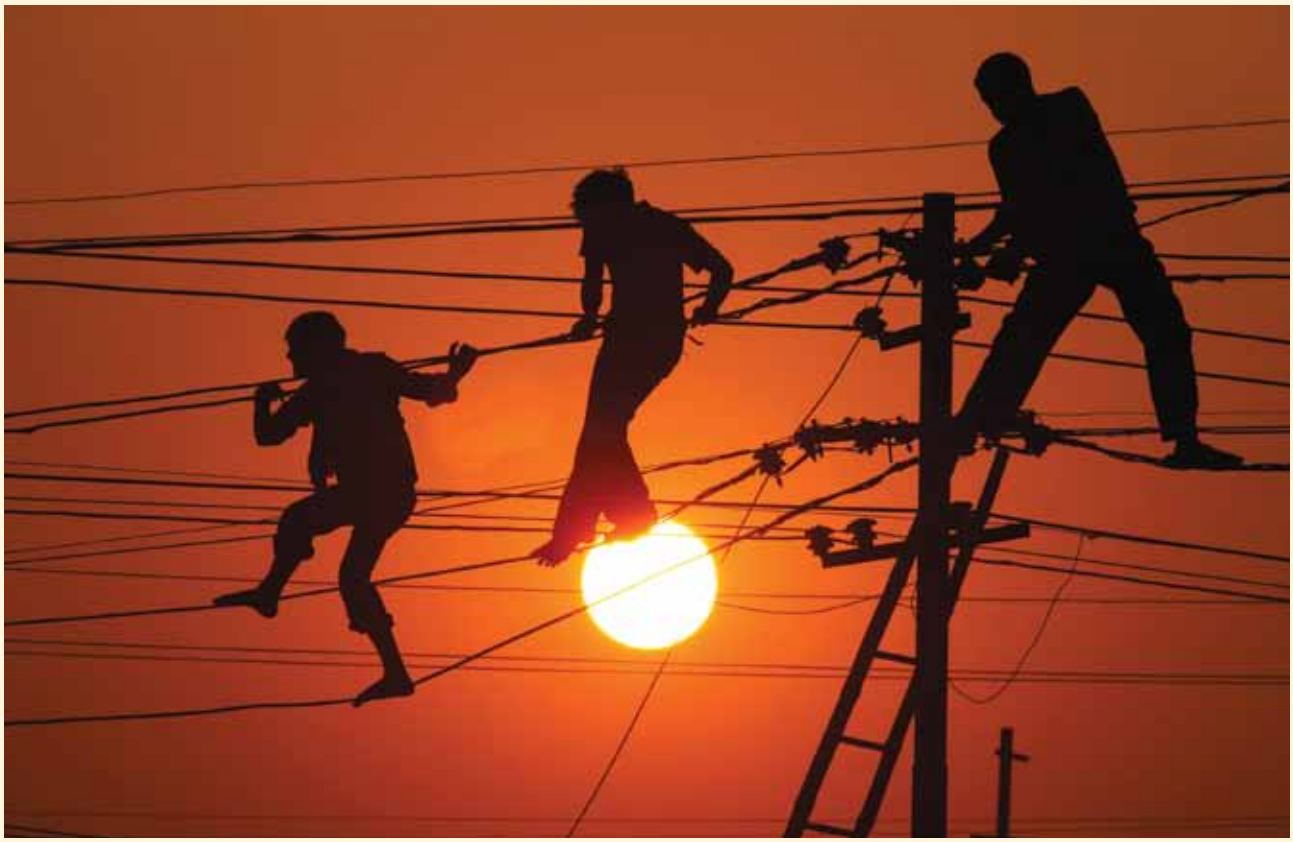
Experience has shown that free water and energy are wasted resources. Artificially low prices and heavy subsidies are at the root of inefficiency, overuse, excessive pollution and environmental degradation in the Arab region. For example, the average price charged for water in the Arab region is about 35 percent of the cost of production, and in the case of desalinated water it is only 10 percent. Unrestrained energy and water subsidies, reaching 95 percent in many cases, are the main obstacle to achieving real results in this regard. This practice only promotes waste, and does not help to ease the burden on the poor, as over 90 percent of the uncontrolled subsidies go to the rich. It is futile to deplete strategic reserves of fossil groundwater, to grow fodder in the desert supporting the production of dairy products for export, while desalinating water to irrigate urban gardens.

Proper management of water and energy supplies requires the introduction of pricing schemes which meet the goals of local acceptability, economic efficiency, cost recovery and equity.

A recent Chatham House report estimated that if consumption levels of water and electricity in the oil exporting GCC countries continue to rise at the same rates, demand would double by 2024. This means more groundwater depletion and growing use of energy for desalination. If no remedial measures are taken, most of the fuel produced will consequently have to be used locally, thus depriving these countries of major export revenues.

Various schemes currently being planned and executed will likely further strain water resources. Some countries (UAE, Jordan) are pursuing nuclear energy, requiring water resources. Other countries, such as Qatar, have ambitious plans to meet food security by cultivating thousands of hectares mainly with desalinated seawater.

This brings us to the root of the problem, which is resource management. A report on Ecological Footprint produced by AFED has found that demand for life supporting goods and services in the Arab countries is twice as much as the potential renewable resources their ecosystems can provide. This imbalance is a threat to future growth opportunities and quality of life.



Pursuing national development strategies is naturally a main priority for Arab countries, but economic growth must take into account ecological limits and the capacity of nature to sustainably support life. Growth targets should respect the regenerative limits of nature. Given the relative low efficiency with which resources are turned into final products, Arab countries must improve their resource productivity by prioritizing energy and water efficiency. Decision makers will need to look beyond GDP as the sole measure of performance, and seek to complement traditional economic analysis with data on resource consumption and availability.

The good news is that serious work has started to stand up to the challenge. Arab ministers of electricity have adopted a comprehensive energy efficiency framework. Abu Dhabi's water strategy was the latest plan to be announced in the region to manage water resources. Saudi Arabia has embarked on an aggressive energy efficiency program. Renewable energy is rapidly expanding: Saudi Arabia plans to meet 33 percent of its local energy needs from renewables by 2032. Abu Dhabi has built Shams-1, a CSP plant with 100 megawatt capacity. Renewable energy projects worth US$11 billion are underway in Morocco, with the aim to build9 gigawatts capacity.

Ultimately, wide-spread reforms in the energy and water sectors require serious institutional and policy measures. Overconsumption cannot be checked, efficiency measures cannot be adequately implemented, and renewable energy cannot spread out if current subsidy regimes are not phased out. Private sector participation in the energy and water sectors requires that policy makers establish the appropriate enablers, including well-defined policies and sound regulatory frameworks.

Arab countries, both oil exporters and importers, are well endowed with renewable sources of energy, primarily solar. For now, these are underutilized. Together with enhanced energy efficiency and cleaner technologies, these renewable sources can help diversify and power a more sustainable future.

Najib Saab, AFED Secretary General and Publisher and Editor-in-Chief of Al-Bia Wal-Tanmia (Environment & Development).