Climate change adaptation solutions for the green sectors of selected zones in the MENA region

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Abstract

In this paper, we propose climate adaptation solutions for the green sectors in three different zones of MENA: Egypt's Delta (irrigated), Karak, in the highlands of Jordan (rainfed), and Lebanon's Orontes basin (mixed: rainfed-irrigated). We analysed land use and crop intensification, and calculated the economic productivity of water – a critical scarce resource in MENA. By integrating the results with evidence from literature on the potential impacts of climate change and socio-economic factors, we could identify vulnerability levels of the three regions and propose adaptation measures relying of the concept of the "food-water-energy nexus." While the vulnerability levels are found to be high in the Delta (Egypt) and Karak (Jordan), mainly due to water scarcity and poor adaptive capacity, the vulnerability level is moderate in the Orontes zone (Lebanon) due to a diversified agricultural sector and good market development, coupled with moderate water scarcity. Proposed adaptation solutions range from measures to improve technical efficiency, to measures that encourage economically efficient allocation by use of market forces. For both cases, the development of market opportunities is emphasized to make the proposed measures attractive to farmers.

Introduction

The Middle East and North Africa (MENA) region already suffers from water scarcity, which is projected to become severely affected by climate change, resulting in lower precipitation, higher temperatures, and increased frequency of droughts. Other pressures such as population growth, urbanization and economic development have been the driving forces in policy formulation that has led to the current structure of agricultural systems and pattern of water use (Hoff, 2012). Climate change will act on top of these other drivers, interact with them and complicate their influences. Agriculture, the main user of water, will probably undergo major changes in order to avoid maladaptation. Recently, it has been widely acknowledged that climate change adaptation should span several sectors in an integrated manner, particularly for agriculture, water and energy. Recent studies emphasize the concept of the "food-water-energy nexus" and confirm the need to mainstream climate adaptation in agriculture, while also addressing actual and potential challenges related to the water and energy sectors (Talozi et al., 2015).

In this paper, we propose climate adaptation measures for the green sectors in three different zones of MENA: the Delta zone of Egypt (with intensively irrigated farming systems), the Karak region of Jordan (dominantly rainfed systems), and the Orontes basin zone of Lebanon (mixed irrigated-rainfed systems). The base analysis relies on assessing the efficiency of land use and allocation to different crops using the economic productivity of the scarcest resource: water. The analysis is integrated with evidence from literature on potential impacts of climate change on the green sectors in light of the already ongoing changes caused by socio-economic factors. The

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concept of the "food-water-energy nexus" is used as a reference for the proposed solutions of adaptation.

Summary of climate change impact on MENA region

According to the Intergovernmental Panel on Climate Change's (IPCC) latest assessment report (AR5), in most regions, the frequency of warm days and nights will increase in the next decades. The frequency and intensity of drought have already increased in the Mediterranean and West Africa since 1950. Reduced rainfall over the MENA region is very likely by the end of the 21st century. The annual or seasonal drying/warming signal has become a consistent feature in climate change projections for the 21st century. Hydrological models show a decline in runoff between 0 and 10% in most of the MENA region, and predict further decreases if projected through the end of the century. Groundwater, which supplies over 50% of water demands in the Arab region, will also come under greater pressure due to very low recharge, coupled with excessive extraction. In coastal areas, seawater intrusion and deteriorating water quality compound the problem of climate change (IPCC, 2014). In Egypt, most studies indicate that projected climate change will not significantly affect water resources in the Nile river, as higher evaporation from drier weather will be compensated by a wetter climate in East Africa; however, crop water requirements will increase (Sowers et al., 2011; Fahim et al., 2013; El-Ramady et al., 2013). In Jordan, the runoff will decline, while groundwater recharge will fall by about 5% under moderate scenarios. Under the most extreme scenario, runoff will decrease by about 23% (Abdulla et al., 2009). Similar projections are reported for Lebanon, where increases in temperatures by 1-2°C will be combined with a 10-20% rainfall decrease by 2040, with periods of extreme temperatures and drought becoming more likely (LSNC, 2011).

These dwindling water resources due to climatic factors will be coupled by mounting water demand from population and economic growth, resulting in rapidly decreasing water availability that, by 2025, could be 30 to 70% less per person in the MENA region (Sowers et al., 2011).

Methods and data

Data sources

The analytical framework used in this paper relies on several technical and economic indicators related to water, crops, trade and other socio-economic data. Macroeconomic data, including GDP, employment, and share of sectors in the GDP were taken for various years from the World Development Indicators of the World Bank (2015). Agricultural and food data for several years including crop, livestock, and fishery production and yields were taken from FAOSTAT (2015) and complemented with national sources such as EMALR (2011, 2013), CAPMAS (2012, 2015), and GAFRD (2014) for Egypt, DOS (2015) for Jordan, and LMA (2012) for Lebanon. Water resource data were taken mostly from national sources such as CAPMAS (2012) for Egypt, JMWI (2012) for Jordan, and LMEW (2010) and LNSC (2012) for Lebanon. These data were integrated from Aquastat (2016) in the case of Egypt.

The analysis indicators

The analysis also used a number of technical and economic indicators, some of which were taken from other sources and some of which were the authors own calculations. The principal indicators are defined below:

- *Crop intensification ratio*

  Crop intensification ratio (CIR) is a measure of agricultural intensification and is defined as the ratio of total cropped area (area that receives crops in a given year, including multiple crops per year) to total cultivable land (arable land plus permanent crops, as defined by FAOSTAT (2015), whether actually cropped or temporarily fallow). The CIR was calculated for the three regions based on various data sources cited case by case.
- *Yield trend*

  Yield trend for a selection of crops considered the most important by country and region is captured by a graphical representation of the evolution of yields over the last two decades. Data sources are FAOSTAT (2015) for Egypt and Lebanon (national trends), and DOS (2015) for Jordan, where data are available also at the regional level.
- *Yield gap*

  Yield gap is a technical indicator developed on the basis of the FAO agro-ecological zones methodology to indicate the level of technical efficiency for major crops at the sub-national level. It is the ratio of actual to potential yield (RAPY) calculated for the base year 2000. Actual yield is the observed yield of a crop at a given time. Potential yield refers to the highest yield that can be obtained if technically optimal practices were applied at the same point in time. It reflects the highest possible limit for the yields of individual crops under the given agro-climatic, soil and terrain conditions combined with a specific level of agricultural inputs and management conditions. Mapping is used to represent the RAPYs at the sub-national level for the studied crops (IIASA/FAO, 2012).
- *Crop water consumption*

  Water footprint (WFP) refers to the volume of freshwater used to produce a product, and it is composed of three elements: blue (irrigation water), green

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(rainwater) and grey water (polluted water, which composes such a small share of agricultural water use that we excluded it from our analysis for simplicity). The WFP data source is the Water Footprint Network (Hoekstra et al., 2009). The green and blue WFP refers to consumption as a loss at the water catchment level, which happens when water evaporates, returns to another catchment area or to the sea, or is incorporated into a product (Hoekstra et al., 2009). WFPs are available for all important crops at national and regional levels and expressed in terms of cubic meters of water consumption to produce one ton of a crop. Therefore, to calculate the water consumption of the relevant crops, we multiplied crop output at the relevant level by the crop WFP.

- *Economic water productivity of crops*

The economic water productivity (EWP) of a crop is a measure of efficiency of the water resource use. In our study, it is expressed as the produce value per unit of water consumed. Therefore, we calculated it by dividing the producer price (US dollar/kg) of the relevant crop by the crop WFP (quantity of water consumed to produce one kg of the relevant crop). Data used in the calculations are taken from various sources identified case by case in the proper contexts.

Analytical framework implementation

The analytical framework used in this paper combines a biophysical characterization and socio-economic analysis using the aforementioned technical and economic indicators. The analysis starts with a characterization of the agricultural and water sectors in the studied zones and assesses agricultural intensification with CIRs. Agricultural productivity is then evaluated by examining yield trends and yield gaps for major crops. Water use efficiency for major crops is examined through a combination of two indicators: EWP and water consumption. The analysis results are integrated with simulated forecasts of the potential impacts of climate and hydrological changes on the green sectors as well as the socio-economic drivers of economic change, including population growth, urbanization, and other drivers. The analysis offers an empirical test case for the "food-water-energy nexus" concept.

Case study: Egypt's Delta (irrigated)

Outlook

a. Green sectors in Egypt and the Delta region

Agriculture plays a central role in the Egyptian economy, contributing about 15% of the GDP and employing about 30% of the national workforce (WDI of the WB, 2015). It is based on highly intensive, irrigated cropping systems with multiple harvests per year, especially in the Delta, where the CIR was 1.92:1 in 2013 (EMALR, 2014). Surface water from the Nile River provides irrigation water for 83% of the total irrigated area, with the remaining area relying on groundwater and mixed sources (Aquastat, 2016). Half of the cropped area is dedicated to production of cereals, including primarily wheat, maize, and rice. Cotton is the most important fibre crop. Rice, cotton and various fruits and vegetables make up the bulk of Egypt's agricultural exports (FAOSTAT, 2015; EMALR, 2014). Egypt also produces large amounts of forage, with berseem clover (Trifolium alexandrinum) being the major crop cultivated in the Delta. In addition, the fruit production area has expanded over the last three decades to approach 8% of the total cropped area and 14% of the total cultivable area, from which citrus makes up 40%. The former share is higher because multiple fruit production cycles take place on the same cultivable land in one year. Smallholders represent the majority of Egypt's farming sector, as average farm size was 0.8 ha in 2000 (Lowder et al., 2014).

Livestock and fisheries are important in Egypt, making up 37% and 7% of agricultural value, respectively, in 2010. The Delta region is relatively more important for raising cattle and buffalo (45-55% of the national share) compared to sheep and goats (30% of national share) (EMALR, 2011). Livestock is mostly raised either by landless rural households or by small farms that integrate livestock with berseem clover production (El-Nahrawy, 2011). Egyptian fish production expanded significantly over the last two decades, with the share of aquaculture in total fish output jumping from 17% in the 1980s to about 75% in 2011-2013. Most fish production is located in the Delta, which accounted for more than 98% of national aquaculture output in 2008. Fish farming takes place in dedicated fishery farms and ponds as well as in rice fields, with the latter contributing to only 3% of the total aquaculture output in 2012 and activity limited to the rice season (GAFRD, 2014; CAPMAS, 2015).

b. Water and irrigation

Water is the most critical resource, and its increasing scarcity is likely to constrain Egypt's capacity to expand agro-food production. The annual per capita water share (663 m^3) is significantly less than the international benchmark (1000 m^3) and is projected to descend further to 582 m^3 by 2025 due to rapid population growth. Egypt depends on the Nile for 90% of total national water supply, but also extracts large amounts of water from 6 aquifer systems throughout Egypt. Total water use exceeds renewable water availability by 3.5% of total annual renewable water (CAPMAS, 2012). Irrigation water is distributed through an immense irrigation system. Surface

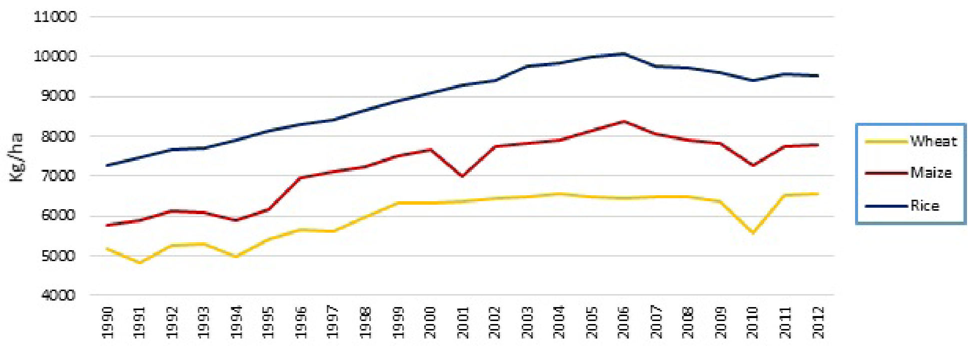

Figure 1 : Trends in cereal crops yields in Egypt (Kg/Ha)
Source: author's elaboration from FAOSTAT (2015)

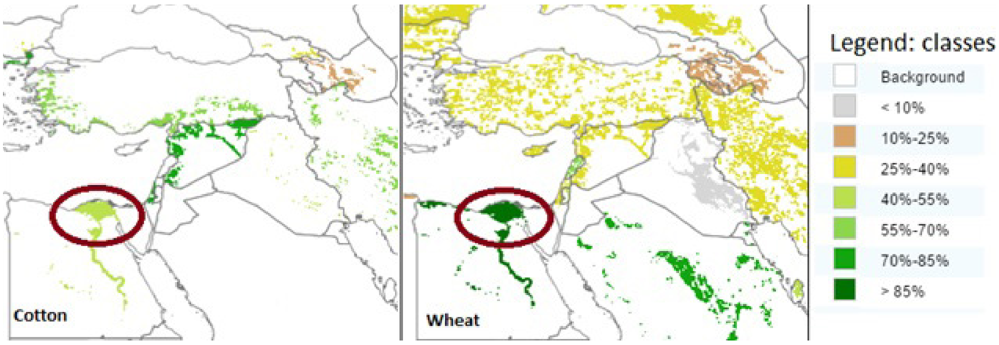

Figure 2 : Ratio of actual to potential yields for irrigated cotton and wheat in Egypt and the neighboring countries
Source: IIASA/FAO (2012)

irrigation is banned by law in the New Lands (newly reclaimed sandy soils), where farmers must use sprinkler or drip irrigation systems. However, overuse of water at the farm level is still a major problem especially in the Old Lands (long-established agricultural areas), where 67% of the area is still using surface irrigation, which causes waterlogging, salinization, and decreased soil fertility (Aquastat, 2016; Antipolis, 2011).

Climate change impacts: indicators of vulnerability and resilience

a. Crop yields and productivity
Egypt's agricultural area in the Old Lands has been declining mainly due to urbanization (Alfiky et al., 2012). On the other hand, New Lands have been brought under cultivation by reclaiming the desert, despite the major problem of poor soil fertility. Over one million ha of the Old Lands are exposed to continuous soil fertility degradation due to salinization caused by extensive irrigation and poor drainage (ICARDA, 2011; EMALR, 2011). Despite that, Egypt generally has high yields by regional and international standards, especially for cereals, which already reached a plateau in yields as shown in **Figure 1**. IIASA/FAO (2012) has found that Egypt is very close to the highest attainable yields for many crops. As shown in **Figure 2**, the RAPY for wheat is 80%, and it is equally high for most other crops. Where RAPY is relatively low, it suggests that potential improvements are possible, as is the case for cotton (**Figure 2**) as well as maize and some vegetables. However, late planting caused by cropping intensity seems to limit any possibility for improvements in the short-run.

Data from FAOSTAT (2015) and CAPMAS (2015) indicate that production and yields of livestock and fish have increased substantially over the last three decades, with variations by production system. For livestock, extensive and semi-intensive systems are still dominant and make about 97% of the total cattle and buffalo (El-Nahrawy, 2011; EMALR, 2011), while semi-intensive systems dominant for fish farming, with yields of 4.5-20 ton/ha. Rice-fish integration produces only about 3% of total fish output and it is considered extensive due to its seasonality, with much lower but variant yields ranging from 20-50 kg/ha (Sadek, 2013) to 300-500 kg/ha (El-Sayed, 2007).

b. Water footprints and economic water productivity of major crops in Egypt and the Delta region
WFPs were calculated for the most important crops in Egypt, except berseem clover due to lack of necessary data. The calculations reveal that cotton is the most

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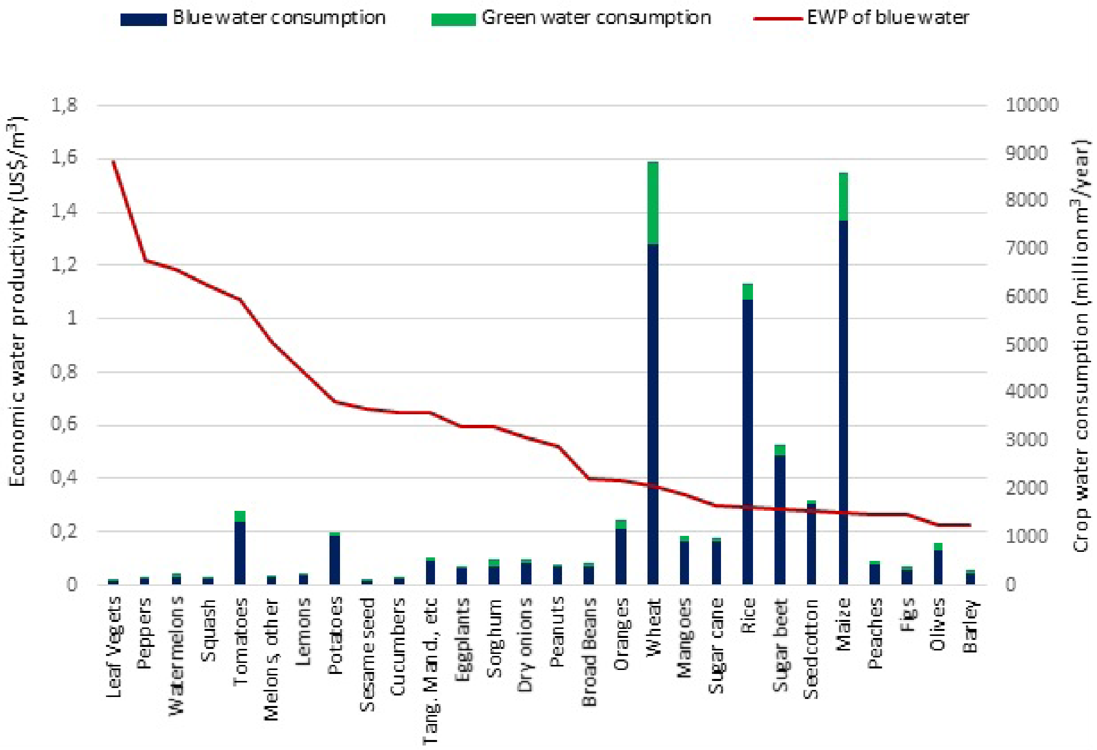

Figure 3 : Economic water productivity (US$/m3) and green and blue crop water consumption (million m3/year) of main crops in Egypt, using average values for the years 2007-2011
Source: authors' calculations based on data from FAOSTAT (2015) and Mekonnen and Hoekstra (2010)

water-consuming crop per unit of raw output. Among cereals, barley has the highest WFP mainly due to lower yields, while rice has the lowest WFP since much of the applied water returns to the system for use elsewhere downstream in the Nile valley. Vegetable and sugar beet WFPs are the lowest, mainly due to high yield per unit area.

In order to gain insight into efficiency of water allocation, we calculated the EWP for the most important crops. These EWPs are then contrasted with total water consumption by crop. The results are summarised in **Figure 3**, showing that, at the national level, crops consuming the most water exhibited the lowest EWPs, including maize, cotton, sugar beet and rice. On the other hand, vegetables, including leaf vegetables, peppers, watermelons, squash, tomatoes, melons and potatoes, had the highest EWPs.

c. Vulnerability of Egypt and the Delta's green sectors to climate change

Vulnerability to climate change is the result of the interaction between the Delta's green sector and other drivers, such as population pressure, economic development, urbanization trends, and market opportunities. This interaction poses complex management problems for land and water resources, making climate change vulnerability better assessed in light of overall risks to the country.

Climate change may affect Egypt's agricultural production in different ways. Higher temperatures will directly affect yields of various crops, causing a decrease by 10-30% for crops like wheat, rice, maize, barley, sunflowers, and soybeans. However, impacts on potato and cotton yields are generally positive, especially if grown in the main seasons, with expected increases ranging from 15-40% (Abou-Hadid, 2006; Medany, 2006; El-Ramady et al., 2013). In addition, higher temperatures will likely affect crops indirectly by increasing demand for water. The ESNC (2010) cited several studies that projected 5 to 13% increases in irrigation needs for Egyptian crops. Moreover, projected climate change would cause shifts in agro-climatic zones in Egypt, with implications for crop suitability and pests and diseases. These impacts are still under consideration, but Fahim and Abou-Hadid (2011) report that the incidence of late blight, the most damaging disease causing yield losses for tomatoes, has increased in the last three decades, probably due to climate change.

Information on the impact of climate change on livestock and fisheries in Egypt is limited, but the ESNC (2010) notes that bluetongue and Rift Valley fever have recently emerged in Egypt, and this may be related to climate factors (Taqi, 2012). Decreased fodder production (e.g. berseem clover) would be another challenge for livestock (ESNC, 2010). Climate change may also have heavy impacts on coastal resources through sea level rise (SLR), already occurring in the Nile delta mainly due to factors such as coastal subduction and reduced sediment loads (Smith et al., 2013). This may lead to the loss of most productive agricultural lands along the Mediterranean coast, with negative consequences on fish production since one third of Egypt's fish catches take place in the Mediterranean lagoons (El-Ramady et al., 2013; Sušnik et al., 2014).

Therefore, given that other drivers (e.g. high population growth and slow economic growth) are limiting Egypt's adaptive capacity, the overall vulnerability of Egypt's agriculture to climate change is high. Population density poses great challenges to achieving self-sufficiency in staple crops, despite distinctly high crop productivity. This has resulted in heavy dependence on imports for staple foodstuffs, which makes Egypt vulnerable to external shocks. Government plans to increase self-sufficiency in food staples, aiming for about 90% compared to the current level of around 60% (ESAD, 2009), do not seem feasible, as they rely on a combination of increased productivity and expanding cultivated lands, both of which are threatened by climate change and limited water availability. In addition, serious land fragmentation would further reduce the adaptive capacity of the green sectors, as average farm size is further decreasing due to population growth and low urbanization. Egypt's rural population makes up 57% of the total, with high and equal annual population growth (1.7%) for both rural and urban areas (WDI of the WB, 2015).

Adaptation measures for Egypt's Delta

a. Technical and farm level adaptations for Egypt's Green sectors

As cereal yields in Egypt have reached a plateau, yield enhancing investments through research into new cropping schedules, adapted varieties and improved irrigation techniques could slow the negative yield trends aggravated by climate change, but are unlikely to reverse them. For many crops, the potential to increase yields depends on the type of crop rotation. Given the intensive cropping in Egypt's Delta, yield per ha is not a sufficient measure of economic performance. Consequently, yield-enhancing practices advocated by agricultural research (including planting dates) must be tailored to the recommended type of rotation. Climate adaptation also requires researching and testing alternative crops for agro-climatic suitability under future climate scenarios, for which sub-tropical crops currently grown in small-scale production could be first examples. Adaptation options for livestock entail improving the current low productivity of cattle in general and buffalo in particular, in addition to improving the suitability of feeding programs to warmer conditions. Integrated rice-fish farming should be further encouraged among rice farmers, and intensification of fish production should be considered. For coastal areas, adaptation measures may include creation of wetlands in low-lying lands, supportive protection structures (including dams), and natural sand defense systems. However, an integrated coastal management approach is necessary due to the cross-sectoral characteristics of the SLR impacts.

b. Adaptation measures for water

Options for improving the water supply in Egypt include recycling wastewater and desalination. There is great potential for wastewater reuse, which requires public attention to proper investments and could involve the private sector. Desalination in the short-run can be utilized for brackish groundwater, since it is much cheaper than desalinating seawater and in many cases can be economically viable for salt-tolerant cropping. Seawater desalination might remain a long-run option when cost-effective technologies become attainable. Therefore, harnessing renewable energy is very much needed to ensure both energy security and affordable options for water treatment and desalinization plants.

Egypt's adoption of integrated water resource management (IWRM) since 2005 is an important pillar to direct institutional adaptation for the water sector, but there is still a significant opportunity to improve irrigation efficiency since only a third of irrigated areas apply modern irrigation techniques (drip and sprinkler schemes). The EWP should be a key determining factor guiding the promotion of water saving techniques and the reallocation of water to higher value crops through public efforts to foster market opportunities. A key measure to regulate demand is through water pricing, which should be regarded as a complementary measure within IWRM, as it can only work alongside strong complementary measures including collaboration with stakeholders (e.g. water user associations) to ensure farmers' participation. A complementary measure to water pricing could be the application of quotas, with minimum quantities allocated to farmers free of charge.

c. Adaptation measures through trade

Trade already plays an important role in Egypt's food security strategy due to heavy reliance on imports for staple foods, while exporting mainly fruits and vegetables. Considering that climate change may affect Egypt's comparative advantages through changing crop suitability, a reconsideration of the role of trade would be essential in the adaptation strategy. We have seen that the bulk of water is consumed by crops with the lowest EWPs, giving a rationale for reallocating water to higher value crops, but also raising the concept of the virtual

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water trade (VWT), since water is the most scarce resource of the country (Mekonnen & Hoekstra, 2011). The risks associated with VWT should be evaluated and minimized, including political risks due to overdependence on a few export countries, macro-instability caused by burdening foreign reserves, and adverse effects on local production and farm incomes. Moreover, water shortages are often due to poor management or inefficient allocation, so that relying on VWT should be preceded and accompanied by the other economic and technical measures, while emphasizing the complementary role of VWT within a broader water management strategy.

Case study: Jordan's Highland (Karak, rainfed)

Outlook

a. The green sectors in Jordan and Karak

Jordan's agricultural sector is small relative to the national economy, contributing only 3% of the GDP and employing only 2% of the national workforce (WDI of the WB, 2015). Agriculture is concentrated in two of the three agro-ecological zones of the Country: the Jordan Valley and the Highlands, while the Eastern Desert is relatively lacking in agriculture. The Jordan Valley is specialised in fruit and vegetable production, while the Highlands grow mostly cereals and olives, and to a lesser extent vegetables (mostly tomatoes). The cropping mixes in Jordan are not diversified, reflecting the sector's small size and the country's prevalent dry agro-climatic conditions (Al-Jaloudy, 2006).

In Karak, located in the Highlands, the cropping mixes are very simple, with only four crops (barley, wheat, olives and tomatoes) occupying 85% of the cropped area, while 20-50% of agricultural land is left fallow every year (DOS, 2015). Thus, the CIR is relatively low (certainly lower than the national CIR, which is equal to 0.79:1). In Karak, wheat, barley and olives are mostly rainfed crops, and their yields vary considerably from year to year due to rainfall variation. Vegetables are mostly irrigated from deep wells with the use of drip irrigation networks. Livestock production is important on the national level, but has much less relevance for Karak. Livestock animals are mostly sheep and cows, which are usually raised in specialized farms with little integration with crop production (Al-Jaloudy, 2006).

b. Water and irrigation in Jordan and Karak

Jordan has very limited water resources. Per capita share of annual renewable fresh water resources was less than 125 m^3 in 2013 and is projected to fall to 90 m^3 in 2025 due to population growth alone, without accounting for climate change (Al-Ansari et al., 2014; JMWI 2012). Water in Jordan is supplied from 16 surface and 12 groundwater basins, in addition to treated wastewater, which currently accounts for more than 10% of total water supply. A significant share of the country's water (27%) originates externally, making Jordan adversely affected by unilateral water development projects by neighboring countries (Syria and Israel). Agriculture relies almost exclusively on irrigation in the Jordan Valley, while 99% of the rainfed cropped area is in the Highlands, including Karak. Over-extraction of groundwater by farmers is a common practice, despite high irrigation efficiency since modern irrigation schemes cover 88% of national irrigated area and 100% of irrigated area in Karak.

Jordan applies water tariffs to encourage farmers to adopt water conservation practices. These are prorated on the basis of water consumption. Trade liberalization, especially for imports, is also considered an attempt to push farmers to move into crops offering high returns per unit of water. In the Highlands, private farmers require licensed permits to extract groundwater and water use is monitored via metering.

Indicators of vulnerability and resilience in Karak

a. Crop yields and productivity

The evolution of yields in Karak shows different patterns by crop, but they resemble the national trends for the region's important crops. While those of wheat and barley are declining, those of vegetables and olives still show a climbing trend despite yearly fluctuations (**Figure 4**). Fluctuations from year to year might be attributed to rainfall variations. The IIASA/FAO's estimation of the RAPY for rainfed wheat in Jordan stood at about 50% in 2000, pointing to possible improvements, but actual yields have declined since, suggesting a change in crop suitability due to climate change and possibly the occurrence of maladaptation. This, however, should be well-studied before prescribing adaptation measures for cereals.

Karak's olive yields fluctuate more than national yields, as the latter is usually smoothed by averaging. While the positive trend for tomatoes is explained by the implementation of irrigation, which enables the use of improved varieties, supplemental irrigation is sometimes used by olive farmers in Karak when available from private tube wells, or through rainwater harvesting techniques (Oweis & Hachum, 2009). The RAPY for both rainfed and irrigated olives are shown in **Figure 6**, which also gives useful information on the distribution of irrigated olive orchards in Jordan. While rainfed olive orchards are concentrated in the Highlands, where there is relatively high average rainfall (more than 250 mm per year), irrigated orchards are spread across wider areas to the east and south, where average rainfall does not exceed 100

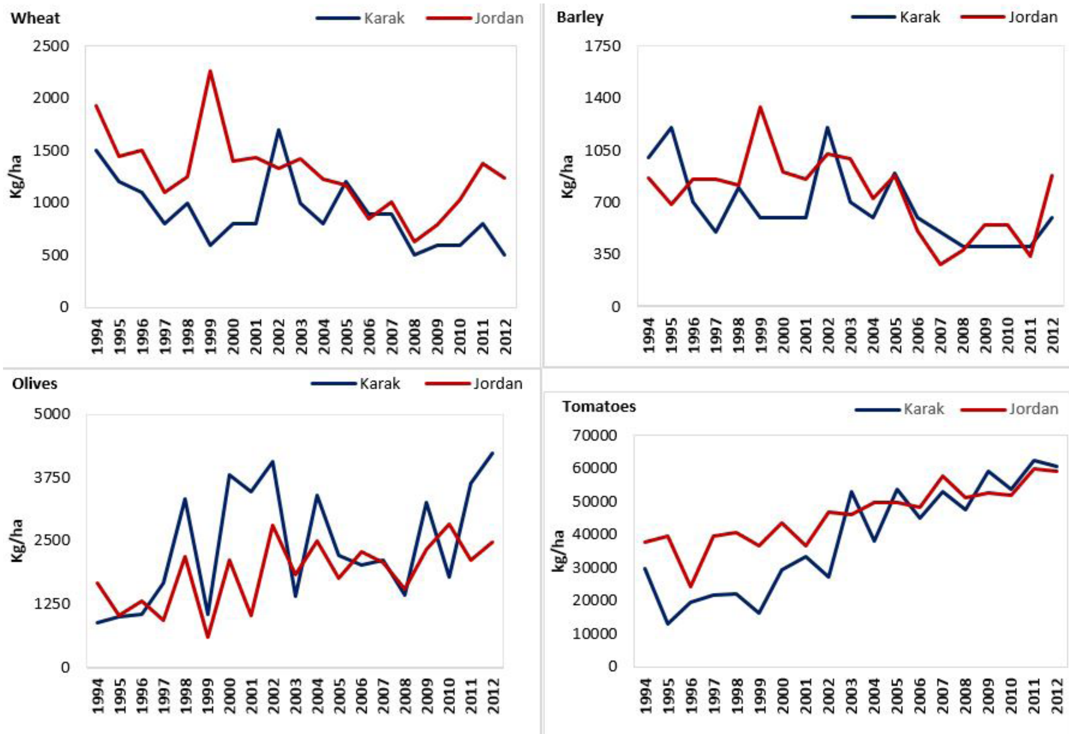

Figure 4 : Trends in yields for most important crops in Karak compared to their national counterparts
Source: authors' elaboration from DOS (2015)

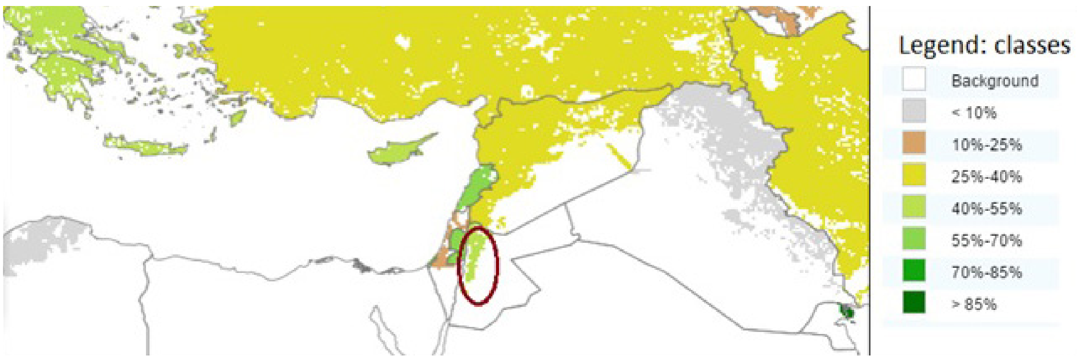

Figure 5 : Ratio of actual to potential yields for rainfed wheat in Jordan and neighboring countries
Source: IIASA/FAO (2012)

mm per year.

Cereal crops in Karak show high WFPs per ton of output due to low yields. Most of the barley WFP is green (heavy reliance on rainfall), while half of the wheat WFP is blue (stronger reliance on supplemental irrigation). Olives rank third, while vegetables have the lowest WFPs for both green and blue water. The four crops (barley, wheat, olives and tomatoes) occupying 85% of cropped area consume 95% of blue water. These same crops have the lowest EWPs for blue water while other vegetables (squash, cucumber, lettuce, melons, and cauliflower) have the highest EWP for blue water (**Figure 7**).

c. Vulnerability to climate change in Karak
Due to the dominance of rainfed agriculture within Karak, climate change will have substantial impacts on crop production, with a higher probability of crop failure. Wheat and barley are prone to further yield reductions as warmer temperatures tend to reduce the necessary time for dry matter assimilation.

It is reported that a 1°C increase in temperature and 10% reduction in precipitation will decrease yield by 7% for wheat and 18% for barley. By comparison, a 2°C increase in temperature and 20% reduction in precipitation will decrease yield by 21% for wheat and 35% for barley (Al-Bakri et al., 2010). Olive production is also anticipated to

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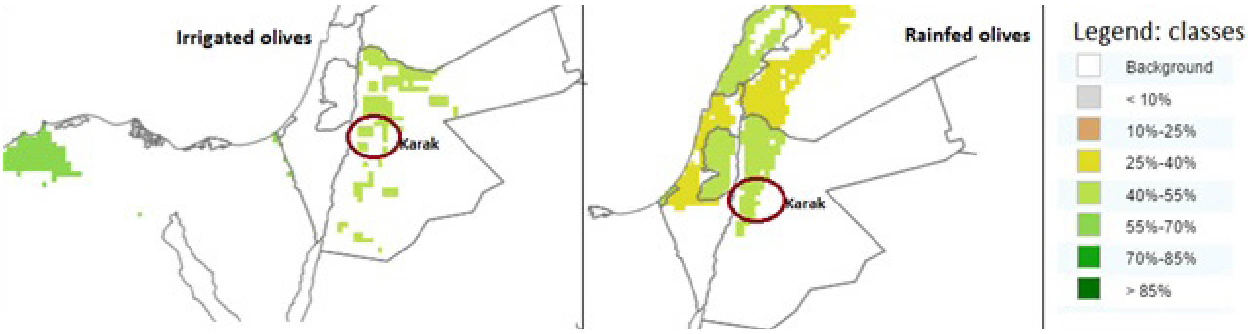

Figure 6 : Ratio of actual to potential yields for rainfed and irrigated olives in Jordan and neighboring countries
Source: IIASA/FAO (2012)

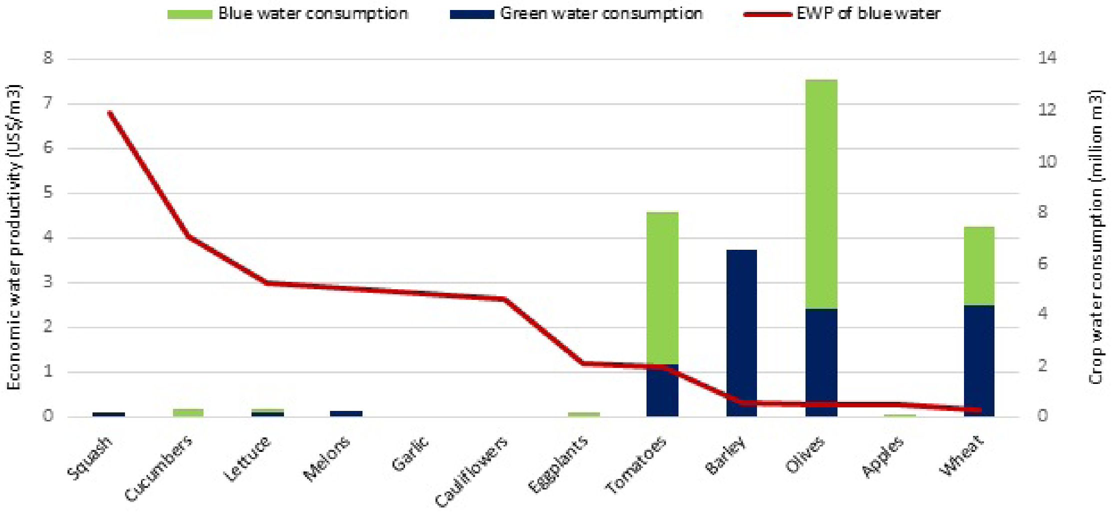

Figure 7 : Economic water productivity (US$/m^3) and green and blue water consumption (Million m^3/year) of main crops in Karak using average values for the years 2007-2011
Source: authors' calculations from DOS (2015) and Mekonnen and Hoekstra (2010)

experience a decline in yields by 5% due to a 10% drop in precipitation, coupled with a 1°C increase in temperature, while the decline in yields will be 10% if the increase in temperature is 2°C (Al-Bakri et al., 2013). The lack of water resources, already exploited at unsustainable rates, will reduce the adaptive capacity of farmers. Irrigated vegetable yields will be less affected, but their extent may decrease due to increased crop water requirements.

Consequently, farmers' incomes will be adversely effected, especially for poor smallholders, whose adaptive capacity will be further reduced due to the ongoing land fragmentation caused by population growth. The reliance of farmers on a limited number of crops will increase their vulnerability in the case of crop failures, which may become more frequent due to climate change. Although no specific studies have been conducted on the impacts of climate change on livestock, the JTNC (2014) reports that rising temperatures, coupled with reduced rainfall, increased frequency of extreme weather events and shorter winter crop length will have a negative impact on livestock productivity and will expose the country to further desertification.

Adaptation measures for the green sectors in Karak, Jordan

Current yields of wheat and olive are far below the maximum attainable yields, and thus improvements should be investigated. In the case of cereals, changing climate suitability and the occurrence of maladaptation should be investigated to explain the declining trends despite low RAPY for wheat. If so, the yield trends may be reversed by using more adapted varieties. Further on-farm crop diversification is still possible in Karak. EWP is one important criterion to guide crop diversification by expanding minor crops with high EWPs. This should be supported by public efforts in market development to ensure successful adoption by farmers, while reconfiguring subsidies (credit, energy use, water pumping) in light of water scarcity. The potential for improving physical irrigation efficiency is limited in Karak due to 100% imple-

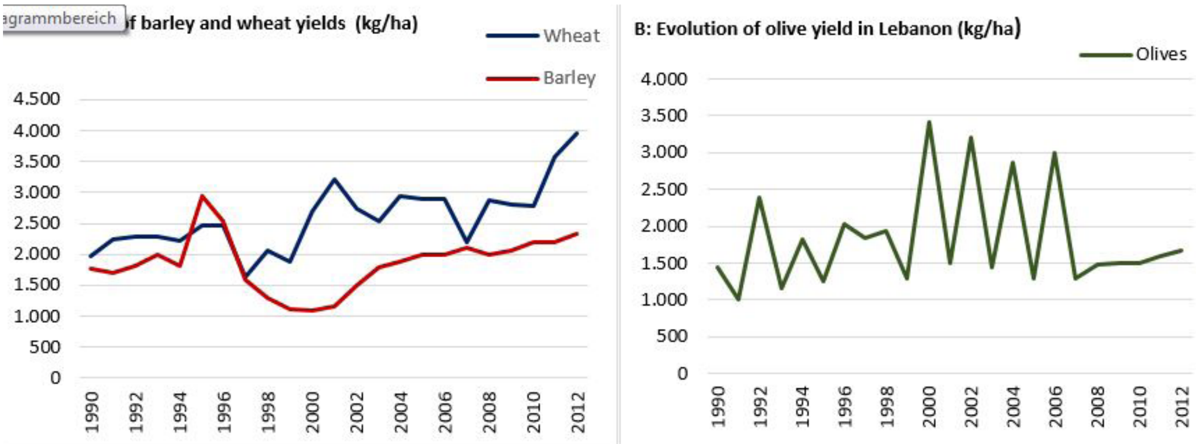

Figure 8 : Trends in yields of barley, wheat (A) and olive (B) yields in Lebanon (Kg/Ha)
Source: authors' elaboration from FAOSTAT (2015)

mentation of drip irrigation, and any further savings cannot erase the current deficit. Rainwater harvesting has a good potential for increasing water supply due to terrain suitability that can help collect the dispersed rain for use as supplemental irrigation at the farm level. Floodwater harvesting at the macro-catchment scale can also collect considerable amounts of water in small dams to be used by surrounding farms.

Water pricing is a necessary instrument to manage groundwater extraction for agriculture in the Highlands, but to be effective it has to overcome the lack of significant technological improvements, which are costly for many farmers. Moreover, due to an already high irrigation efficiency, farmers are less responsive to any imposed block tariff, so water pricing should create a shift towards high value crops that raise EWP in order to be effective. The risk remains that poor farmers may not adapt without public support in removing market obstacles, pointing to the necessity of an integrated value chain approach for water management if tangible water savings are to be reached while enhancing farmers' incomes.

In the long-run, a decrease in water supply is inevitable as all basins of the country already experience water deficits. Wastewater treatment remains an important option and it should be expanded. However, in light of population growth, desalination seems to be the only solution to bridge the gap between growing water demand and dwindling supply. This will depend on Jordan's ability to deploy solar energy at effective costs. In the short run, desalinization can focus on the brackish groundwater which is much cheaper than seawater desalination. Jordan should also make political efforts to increase its share of water from the basins shared with neighboring countries, such as the Disi aquifer shared with Saudi Arabia. Given the small amount of agriculture nationally, the concept of VWT may work better in the Jordanian context since Jordan cannot achieve any tangible level of food self-sufficiency and should rely on trade and other mechanisms (such as storage) for national food security. It may be suitable that water resources should be allocated to economic activities with higher values inside and outside agriculture.

Case study: Lebanon's Orontes basin (mixed: rain-fed-irrigated)

Outlook

a. Agriculture in Lebanon and the Orontes basin

Lebanon is a highly urbanized country with a small agricultural sector that suffers from under-investment and lack of interest from investors and the young workforce. Agriculture contributed to only 4-7% of GDP over the last decade, and employed 6% of the labor force despite the favorable agro-ecological conditions (WDI of the WB, 2015). Even with the country's small size, cropping patterns are diversified with a tendency for crop specialization across regions due to agro-climatic diversity. The Orontes river basin (ORB) is located in the Bekaa Valley, which includes 43% of the national cropland, while the share of ORB (almost identical to the governorate of Baalbak-Hermel) is 25% of the national cropland.

In the ORB, cropland is distributed among 25.6 thousand landholders, with an average farm size of 2.75 ha, almost double the national average. The ORB zone specializes in cereals, potatoes, grapes, stone fruits, olives and leaf vegetables. Livestock is an important subsector in Lebanon, comprising about 30% of the agricultural production value. It is largely based on cattle, sheep and goats, with the latter two being relatively more important in the ORB compared to cows (LMA, 2012). National domestic fishery resources come from fish capture (90%) and aquaculture production (10%), with the latter con-

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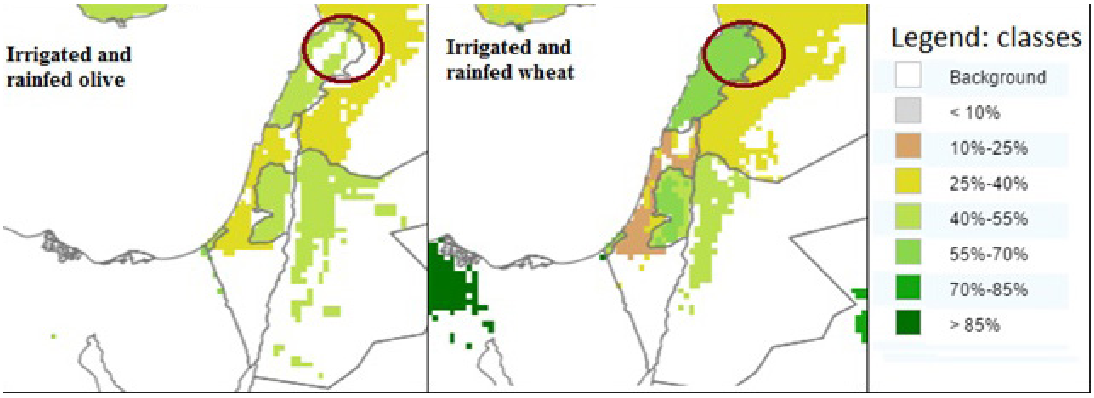

Figure 9 : Ratio of actual to potential yields for olive and wheat in Lebanon and neighboring countries
Source: IIASA/FAO (2012)

centrated mostly in the ORB, where it has become commercially attractive and has grown quickly over the last decade (Bachour et al., 2011).

b. Water and irrigation in Lebanon and the ORB
Lebanon has better water resources compared to other MENA countries, with renewable available water per capita at 926 m3/year in 2009. The country will likely face considerable challenges to meet growing water demand, since unsustainable irrigation practices with shortcomings in water management and governance are still prevalent, creating water deficits in most basins. The national deficit was 96 million m3 in 2010, from which the share of the Bekaa Valley amounted to 84 million m3 (LMEW, 2010). In the ORB, the irrigated area accounts for 45% of total cropland, of which 48% uses intensive irrigation (for summer crops) while the remainder relies only on supplemental irrigation (for winter and perennial crops). Surface irrigation is still dominant and used in 43% of irrigated land in ORB. Sprinkler and drip irrigation schemes are more commonly used when irrigation draws on groundwater due to technical requisites (e.g. pressure and water quality) that are difficult to meet with surface water in Lebanon (LNSC, 2012).

Climate change impacts: indicators of vulnerability and resilience in the Orontes basin

a. Cropping intensity and agricultural productivity in Lebanon and the ORB
In 2010, the total cropped surface slightly exceeded the total cultivated land, resulting in a CIR of almost 1:1, though it is slightly higher in the ORB. This low ratio, compared to the country's potential, can be explained by low investments in agriculture that led in many cases to the abandonment of farming. Crop yield trends are upward for cereals and olives despite annual fluctuations (**Figure 8**), with potential for further improvement since RAPYs stand at only 50% for both wheat and olives (**Figure 9**). Upward trends are also observed for vegetables, especially tomatoes, potatoes and eggplants. In contrast, fruits yields have declined by more than 20% over the last two decades (FAOSTAT, 2015). Despite that, Lebanon still has high yields for most fruits and vegetables compared to other Mediterranean countries. Some sources state that Lebanon's technical effi¬ciency in fruit and vegetable production is the highest among Arab countries and the second highest in the Mediterranean region, after France. This is due to higher reliance on modern technologies, such as modern irrigation and high yielding varieties, as well as trade openness (measured by imports of agricultural equipment) and high human capital levels (Hassine & Kandil, 2009).

Aquaculture productivity is also reported to be high in ORB according to LMA's (2012) survey, which revealed that 40% of farms used intensive production methods in 2013, of which almost half are small farms. Semi-intensive farms account for about 35% of systems, with the remaining 25% classified as extensive with lower productivity. The average yield is reported to be 26 kg/m^2, but actual yield differs by production system and generally ranges from 20-50 kg/m^2.

b. Water footprints and economic water productivity of crops in the ORB
The WFP calculations show that vegetables have the lowest WFPs, while olives have the highest. In terms of total water consumed, fruits and cereals consume more than vegetables. However, it must be noted that barley and wheat consume very small amounts of blue water, reflecting their high reliance on rainfall. The EWPs show an inverse relation with crop water consumption, as in the case of Egypt and Jordan. Therefore, vegetables in the ORB make better use of irrigation water than tree crops, including olives (**Figure 10**).

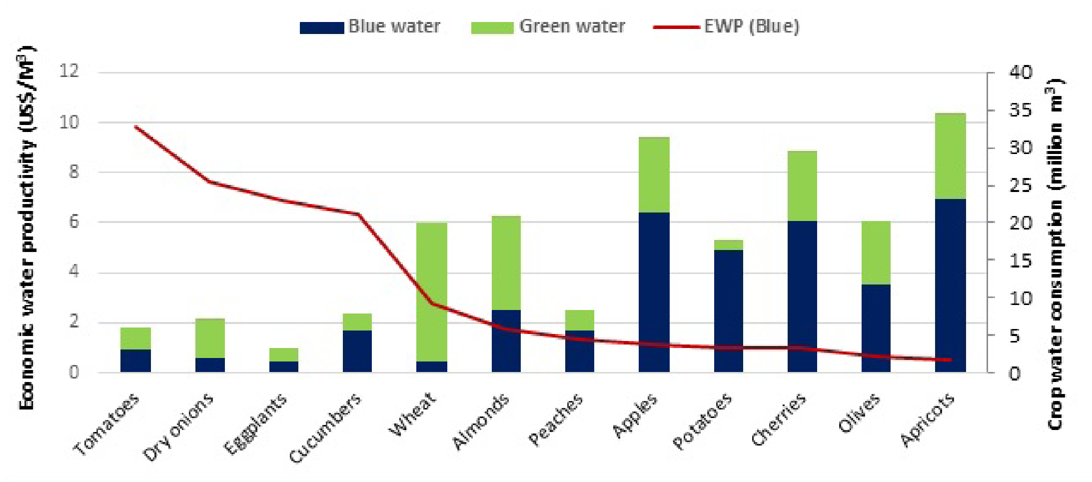

Figure 10 : Economic water productivity (US$/m^3) and green and blue crop water consumption (million m^3 per year) of main crops in the Orontes basin using average values for the years 2007-2011

Source: authors' calculations from FAOSTAT (2015), agricultural census (LMA, 2012) and Mekonnen and Hoekstra (2010)

c. Vulnerability to climate change in Lebanon and the Orontes Basin

Climate change will manifest itself with rising temperatures, leading to increased crop water requirements, while precipitation will decrease. The impacts on yields will differ by crop, with the highest impacts on potatoes, stone fruits, and apples, and lowest effects on olives, while the impacts on wheat, grapes and tomatoes will be moderate (LSNC, 2011). The impacts of climate change on crop and livestock production will be felt more in the Baalbak-Hermel and Bekaa governorates than elsewhere in the country, as reduced rainfall will negatively affect wheat and barley (mostly rainfed), while fruits and summer crops are likely to experience water stress (Verner et al., 2013). Reduced water availability and water stores that are already exploited at unsustainable rates will reduce farmers' adaptive capacity, while a possible increase in irrigation demand of up to 6% is projected in the Bekaa Valley by the 2020s (Bou-Zeid & El-Fadel, 2002).

However, when averaged across Lebanon, climate change impacts on renewable water resources are modest in comparison to the projected impacts of population and economic growth by 2025 (Verner et al., 2013). This partially makes Lebanon's overall vulnerability to climate change moderate, as the country is currently more challenged by resource management problems than absolute water scarcity. Relatively low population growth compared to other MENA countries (0.96% in Lebanon compared to 1.7% and 2.2% in Egypt and Jordan, respectively) implies that the pressure on water is less strenuous at least in the near future, allowing time to respond with proper adaptation measures. The relatively high income level, coupled with a long reliance on market forces, have helped Lebanon to develop more resilient farming systems manifested by high crop diversity and high productivity in some areas, notably fruits and vegetables.

Adaptation measures for Lebanon's ORB's green sectors

Increased resilience to climate change can be achieved through farm income diversification, which is already practiced by utilizing a large variety of crops and cultivars. Most farmers do not rely exclusively on agriculture as their primary source of livelihood, but sustain it through other activities even where agriculture is the major income source. The relatively better-off situation of most Lebanese farmers strengthens their adaptive capacity and puts them in a position to adopt new technologies. A number of technical options that Lebanese farmers, especially in the ORB, can consider and the Government could support are: changing planting dates, adopting drought and heat tolerant crops and varieties, and replacing stone fruits, whose yields are declining, with apples, grapes and olives. These options should be guided by the EWP and can be enhanced by adopting sustainable agricultural practices such as conservation agriculture and organic farming, as Lebanon's long experience with open trade may enable farmers to take full advantage of such quality products. For aquaculture, there is great potential for intensification, and efforts should be made to further develop the fish value chain and strengthen the integration of fish farming with other growth sectors such as tourism (already a leading sector in Lebanon). This can be achieved by supporting fish farmers' organizations to strengthen their managerial, business and marketing skills.

As Lebanon faces moderate water scarcity, it should

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focus on management issues. Options for demand management in agriculture include modern irrigation techniques to cover the remaining 45% of cropland still irrigated by surface methods. Irrigation scheduling and reallocation of irrigation water to higher value crops are also viable options. In addition, Lebanon's rainfall may permit small-scale water mobilization through rainwater-harvesting techniques that can help increase and stabilize yields of rainfed crops such as wheat and barley. The current uniform, area-based tariffs provide no economic incentive for water saving or improved EWP and should be replaced to ensure that farmers' decisions take water scarcity into account, but at the same time ensure that new measures are enforceable. One option is to implement progressive, area-based tariffs differentiated by crops according to irrigation requirements. However, for the long term, volumetric tariffs, as in the case of Jordan, are desirable.

Conclusions

This paper presents a socio-economic vulnerability analysis for green sectors facing water scarcity and climate change in three MENA regions: the Delta zone of Egypt (intensive, irrigated systems), Karak, Jordan (rainfed cropping systems) and the Orontes basin in Lebanon (mixed rainfed and irrigated cropping systems). Major results show that Egypt and Jordan exhibit higher vulnerability than Lebanon due to unfavourable initial endowments of resources, which limit their adaptive capacities. Moreover, Lebanon's vulnerability is also moderated by lower population growth and less reliance on agriculture. Groundwater deficit and per capita water share are reaching alarming levels in Jordan, and becoming serious problems in Egypt too. In the latter case, extreme land fragmentation and encroaching urbanization substantially reduce the country's adaptive capacity, while climate-induced rising sea level aggravates soil salinity due to seawater intrusion, which is already a problem due to unsustainable farm level practices.

Proposed adaptation solutions range from measures to improve technical efficiency to those that encourage economically efficient resource allocation and alternative crop choices, induced by policy incentives as well as market instruments. For all cases, the development of market opportunities is emphasized to make the proposed measures attractive to farmers. Results show low potential for further yield improvement in Egypt (where yields are already high) and high potential in Jordan and Lebanon. The results also show that reallocation of land to new crops, if combined with stimulated demand, has further adaptation potential in Karak, Jordan, where the top four crops that consume 95% of blue (irrigated) water also exhibit the lowest economic values per unit of water. Significant improvement in water supply in Jordan and Egypt requires harnessing affordable renewable energy for seawater desalinization, while Lebanon has the possibility to expand rainwater reservoirs. On the demand side, market-based tools to optimize water use must be combined with regulatory and institutional measures for maximum effectiveness, especially in Egypt and Lebanon, while Jordan, the most water deficient country, has already made substantial advances in water efficiency practices.

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Conflict of Interests

The authors hereby declare that there are no conflicts of interest and the views expressed in this study are the authors' and do not necessarily reflect those of the FAO or the University of Florence.

References

Abou-Hadid A. F. (2006). *Assessment of Impacts, Adaptation, and Vulnerability to Climate Change in North Africa: Food Production and Water Resources*. Washington, DC: The International START Secretariat.

Antipolis, S. (2011). *Water Use Efficiency and Economic Approach*. Plan Bleu, UNEP/MAP Regional Activity Centre. Retrieved from *https://planbleu.org/sites/default/files/publications/efficience_eau_egypte_en.pdf*

Aquastat. (2016). *Food and Agriculture Organization of the United Nations Statistics*. Retrieved on December 3, 2016 from: *http://www.fao.org/nr/water/aquastat/countries_regions/egy/index.stm*

Al-Ansari, N., N. Alibrahiem, M. Alsaman, and & Knutsson, S. (2014). Water Demand Management in Jordan. *Engineering*, 6, 19-26. *doi: http://dx.doi.org/10.4236/eng.2014.61004.*

Al-Bakri, J, Suleiman, A., Abdulla, F. & Ayad, J. (2010). Potential impact of climate change on rainfed agriculture of a semi-arid basin in Jordan. *Physics and Chemistry of the Earth*, 35, 125–134. *doi: 10.1016/j.pce.2010.06.001.*

Al-Bakri, J., M. Salahat, A. Suleiman, M. Suifan, M. R. Hamdan, S. Khresat, and &. Kandakji, T. (2013). Impact of climate and land use changes on water and food security in Jordan: Implications for transcending "the tragedy of the commons." *Sustainability*, 5, 724-748. *doi:10.3390/su5020724.*

Al-Jaloudy, M. A. (2006). *Jordan: Country Pasture/Forage Resource Profiles*. Prepared for the Food and Agriculture Organization of the United Nations. Retrieved from *http://www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Jordan.pdf*

Al-Karadsheh, E., S. Akroush, and & Mazahreh, S. (2012). *Land Degradation in Jordan – Review of knowledge resources. International Center for Agricultural Research in Dry Areas*. Retrieved from *http://www.icarda.org/publication/working-papers*

Bachour, R., Al Arab, M., Nimah, M., & McKee, M. (2011). *Research Priorities for Water and Irrigation System Management on the Orontes Benchmark Site, Lebanon. Middle East Water and Livelihoods Initiative (WLI), International Center for Agricultural Research in Dry Areas.* Retrieved from *http://www.icarda.org/wli/pdfs/ResearchPrioritiesForWaterAndIrrigationSystemManagementOnTheOrontesBenchmarkSiteLebanon.pdf*

Bindoff, N.L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S., Hanawa, K., Quéré, C. Le., Levitus, S., Nojiri, Y., Shum, C.K., Talley L.D., and Unnikrishnan, A. (2007). Observations: Oceanic climate change and sea level. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, H.L. Miller (Eds.), *Climate Change 2007*: *The Physical Science Basis*. Cambridge, UK: Cambridge University Press.

Bou-Zeid, E. & El-Fadel, M. (2002). Climate Change and Water Resources in Lebanon and the Middle East. *Journal of Water Resources Planning and Management*, 128(5), 343. *doi: 10.1061*

CAPMAS. (2012). *Environment and Energy Statistics in Egypt. Cairo, Egypt: Central Agency for Public Mobilization and Statistics*. Retrieved from *http://unstats.un.org/unsd/energy/meetings/2013ees/2013negyp.pdf*

CAPMAS. (2015). *Egypt Agriculture in Figures. Cairo, Egypt: Central Agency for Public Mobilization and Statistics*. Retrieved from *http://www.sis.gov.eg/newvr/Egypt-inFigures2015/EgyptinFigures/pages/arabic%20link.htm*

DOS. (2015). *Jordan Department of Statistics*. Retrieved August 4, 2015 from: *http://web.dos.gov.jo/sectors/economic/?lang=en*

Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, J., and Tubiello, F.N. (2007). Food, fibre and forest products. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge, UK: Cambridge University Press. p. 273-313

ECIDSC. (2011). Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction. Cairo, Egypt: The Egyptian Cabinet Information and Decision Support Center. Retrieved from http://www.climasouth.eu/docs/Adaptation011%20StrategyEgypt.pdf

El-Nahrawy, M. (2011). Country Pasture/Forage Resource Profiles of Egypt. Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Egypt.pdf

El-Ramady, H.R, El-Marsafawy, S.M, & Lewis, L.N. (2013). Sustainable Agriculture and Climate Changes in Egypt. In E. Lichtfouse (Ed.), *Sustainable Agriculture Reviews* 12. *doi: 10.1007/978-94-007-5961-9_2.*

El-Sayed, A-F.M. (2007). Analysis of feeds and fertilizers for sustainable aquaculture development in Egypt. In M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon (Eds.), *Study and analysis of feeds and fertilizers for sustainable aquaculture development*. Rome, Italy: FAO. Retrieved from *https://articles.extension.org/sites/default/files/w/5/54/Studyandanalysis.pdf.* p.401-422

EMALR. (2011). *Bulletins of Livestock, Crop production, Agricultural Incomes, Agricultural Inputs. Ministry of Agriculture and Land Reclamation*. Retrieved March 31, 2015 from: *http://www.agr-egypt.gov.eg/En_StudiesAll.aspx*

EMALR. (2014). *Bulletin of Agricultural Statistics. Egyptian Ministry of Agriculture and Land Reclamation*. Obtained through personal communication.

ESAD. (2009). *Sustainable Agricultural Development Strategy Towards 2030*. Cairo, Egypt: Ministry of Agriculture and Land Reclamation. Retrieved from *http://faolex.fao.org/docs/pdf/egy141040E.pdf*

ESNC. (2010). *Egypt Second National Communication under the UNFCCC*. Cairo, Egypt: Environmental Affairs Agency. Retrieved from *http://unfccc.int/resource/docs/*

ISSN-Internet 2197-411x OLCL 862804632

natc/egync2.pdf

Fahim, M.A., Hassanein, M.K., Abou-Hadid, A. F. & Kadah, M.S. (2011). The Impacts of Climate Change on the Widespread and Epidemics of Some Tomato Diseases during the Last Decade in Egypt. *Acta Hort*., 914, 317-320.

Fahim, M. A., Hassanein, M. K., Khalil, A. A. & Abou Hadid. A. F. (2013). Climate Change Adaptation Needs for Food Security in Egypt. *Nature and Science*, 11(12).

FAOSTAT. (2015). *Food and Agriculture Organization of the United Nations Statistics*. Retrieved August 25, 2015 from: *http//faostat.fao.org/site/291/default.aspx*

GAFRD. (2014). *Fish Statistics Yearbook 2012*. General Authority of Fish Resources Development. Retrieved August 15, 2015 from: *http://kenanaonline.com/users/StatisticsAR/downloads/77469?re=78969*

Hassine, N. B. & Kandil, M. (2009). Trade liberalization, agricultural productivity and poverty in the Mediterranean region. *European Review of Agricultural Economics* 36(1), 1–29. *doi: 10.1093/erae/jbp002.*

Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M. & Mekonnen, M. M. (2009). *Water Footprint Manual: State of the Art*. Water Footprint Network.

IIASA/FAO. (2012). *Global Agro-ecological Zones (GAEZ v3.0)*. Laxenburg, Austria: IIASA and Rome, Italy: FAO.

IPCC. (2014). Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In R.K. Pachauri & L.A. Meyer (Eds.), *Climate Change 2014: Synthesis Report* Geneva, Switzerland: IPCC. Retrieved from *http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.* p. 151

JMWI. (2012). *Annual Water Report: 2011.* Amman, Jordan: Jordan Ministry of Water and Irrigation. Retrieved from *http://www.mwi.gov.jo/sites/en-us/Annual%20Reports/Annual%20Report%202011.pdf*

JTNC. (2014). *Jordan Third National Communication to the UNFCCC.* Ammar, Jordan: Jordan Ministry of Environment. Retrieved from *http://unfccc.int/resource/docs/natc/jornc3.pdf*

LMA. (2012). *Resultats Globaux du Module de Base du Recensement de L'agriculture 2010*. Lebanon Ministry of Agriculture. Retrieved from *http://www.agriculture.gov.lb/html/RESULTATS_RECENCEMENT_AGRICULTURE_2010/RAPPORT_RESULTATS_GLOBAUX_DU_RECENCEMENT_2010.pdf*

LMEW. (2010). *National Water Sector Strategy: A right for every citizen, a resource for the whole country*. Lebanon Ministry of Energy and Water. Retrieved from *http://climatechange.moe.gov.lb/viewfile.aspx?id=182*

Lowder, S. K., Skoet, J. & Singh, S. (2014). What do we really know about the number and distribution of farms and family farms in the world? (*ESA Working Paper No. 14-02*). Food and Agriculture Organization of the United Nations. Retrieved from *http://www.fao.org/docrep/019/i3729e/i3729e.pdf*

LSNC. (2011). *Lebanon Second National Communication to UNFCCC*. Lebanon Ministry of Environment. Retrieved from *http://unfccc.int/resource/docs/natc/lebanon_snc.pdf*

Medany, M. (2006). *Assessment of the Impact of Climate Change and Adaptation on Potato production*. Central Laboratory for Agricultural Climate, Agricultural Research Center/Egypt Ministry of Agriculture and Land Reclamation. Retrieved from *http://www.agridema.org/opencms/export/sites/Agridema/Documentos/Egypt_Medany.pdf*

Mehanna, S. F. (2008). Northern Delta Lakes, Egypt: Constraints and Challenges. International Conference on Research for Development in Agriculture and Forestry, Food and Natural Resource Management Competition for Resources in a Changing World: New Drive for Rural Development. Suez, Egypt: National Institute of Oceanography and Fisheries. Retrieved from *http://www.tropentag.de/2008/abstracts/full/95.pdf*

Mekonnen, M.M. & Hoekstra, A.Y. (2010). The green, blue and grey water footprint of crops and derived crop products. *Value of Water Research Report Series* (No. 47). Delft, Netherlands: UNESCO-IHE Institute for Water Education. Retrieved from *http://wfn.project-platforms.com/Reports/Report47-WaterFootprintCrops-Vol1.pdf*

Mekonnen, M.M. & Hoekstra, A.Y. (2011). The green, blue and grey water footprint of production and consumption. Value of Water Research Report Series (No. 50). Delft, Netherlands: UNESCO-IHE Institute for Water Education. Retrieved from *http://waterfootprint.org/media/downloads/Report50-NationalWaterFootprints-Vol1.pdf*

Sadek, S. (2013). Aquaculture site selection and carrying capacity estimates for inland and coastal aquaculture in the Arab Republic of Egypt. In L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez (Eds.), *Site selection and carrying capacities for inland and coastal aqua-*

culture. Rome, Italy: FAO. Retrieved from *http://www.fao.org/3/a-i3322e.pdf.* p. 183–196

Smith, J., Deck, L., McCarl, B., Kirshen, P., Malley, J. & Abdrabo, M. (2013). *Potential Impacts of Climate Change on the Egyptian Economy*. Cairo, Egypt: United Nations Development Programme. Retrieved from *http://www.eeaa.gov.eg/portals/0/eeaaReports/CCRMP/6.%20Potential%20Impact%20of%20Climate%20Change%20on%20the%20Egyptian%20Economy/Potential%20Impact%20of%20CC%20on%20the%20Egyptian%20Economy%20English.pdf*

Sowers, J., Vengosh, A. & Weinthal, E. (2011). Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change*, 104(3), 599-627.

Sušnik, J., L. S. Vamvakeridou-Lyroudiaa, Baumertb, N., Kloosb, J., Renaudb, F. G., La Jeunessec, I., Mabrouk, B., D.A. Savić, Kapelan, Z. Ludwig, R., Fischer, G., Roson, R., and Zografos, C. (2014). Interdisciplinary assessment of sea-level rise and climate change impacts on the lower Nile delta, Egypt. *Science of the Total Environment*. 503–504, 279–288. *doi: 10.1016/j.scitotenv.2014.06.111.*

Talozi, S., Al Sakaji, Y. & Altz-Stamm, A. (2015). Towards a water-energy-food nexus policy: realizing the blue and green virtual water of agriculture in Jordan. *International Journal of Water Resources Development*, 31(3), 461-482.

Taqi, M.O (2012). Milk productivity and physiological parameters of Egyptian buffalo under climatic conditions of Giza and Qena governorates (*Master Thesis*). Department of Animal Production, Faculty of Agriculture, Cairo University, Egypt. Retrieved from *http://www.philadelphia.edu.jo/newlibrary/eng/english-books/671-english-books/141781-engb-141781*

Verner et al. (2013). *Increasing Resilience to Climate Change in the Agricultural Sector of the Middle-East: The Case of Jordan and Lebanon*. Washington, DC: The World Bank. Retrieved from *http://documents.worldbank.org/curated/en/115381468249300050/pdf/763670PUB0EPI0001300PUBDATE03021013.pdf*

WDI of the WB (2015). World Development Indicators of the World Bank Database. Retrieved July 3, 2015 from *http://data.worldbank.org/data-catalog/world-development-indicators*

ISSN-Internet 2197-411x OLCL 862804632

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