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Impacts of Climate Change and Water Resources Management in the Southern Mediterranean Countries

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Abstract

This study seeks to assess the effects of climate change on the agriculture sector across a number of Southern Mediterranean countries and evaluate relevant policy measures addressing these challenges for the region. Agriculture is dependent on land and water use, and key activity for rural populations over large areas in Southern Mediterranean Countries. Water resources are essential to a stable agricultural production, but also to the supply of growing cities. In this region, it is likely that the stress imposed by climate change to agriculture has contributed to the reduction water availability. Adaptation is a key factor that will shape the future severity of climate change impacts on food production. Food and nutrition security presents a significant challenge for these Southern Mediterranean countries. Agriculture, which accounts for 70 percent of all water uses, is increasingly required to 'make its case' for its share of water to enable food production and ensure food security. At the same time, the sustainability of agricultural water use is under increasing scrutiny. In recent decades, attempts to solve the growing water issues have focused on management issues without considering the governance dimension, and mostly on a sectoral basis. While successful in many ways, this approach seems to have reached its limits. This paper describes the first comprehensive assessments of climate change and its impacts in Eastern and Western Mediterranean Countries, covering different sectors, ranging from physical climate drivers as temperature and precipitation, to agriculture, forests, and from water resources to social impacts and policy evaluation. The evidence provided suggests the need for more effective adaptation measures for the agriculture sector across Eastern (Egypt, Israel, Jordan, Lebanon and Palestine) and Western (Algeria, Morocco and Tunisia) of south Mediterranean countries. Southern Mediterranean Countries are affected by climate change. This is associated with increases in the frequency and intensity of droughts and hot weather conditions. Since the region is diverse and extreme climate conditions are already common, the impacts are disproportional. The impacts of climate change on Southern Mediterranean Countries water resources are significant. Climate induced changes in precipitation and air temperature lead to earlier timing of peak flows, greater frequency of flooding, and more extreme drought conditions. Rainfall in these countries is even expected to increase in winter, while decreasing in spring and summer, with a substantial increase of the number of days without rainfall. Anticipated regional impacts of climate change include heat stress, associated with poor air quality in the urban environment, combined with increasing scarcity of fresh water and decreasing water productivity in arid regions.

Keywords: Climate Change; Water Resources Management; Water Productivity.

INTRODUCTION

This study assesses the extent to which the effects of Climate Change are impacting the Agriculture sector across Southern Mediterranean Countries and the relevant policy measures addressing these challenges across the region.

The study consider how policies and measures are addressing the following climate change impacts that affect agriculture destinations, their competitiveness and sustainability, namely. In this context, the effect foreseen for climate change in the region affect agriculture

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destinations, their competitiveness and sustainability, through a range of direct and indirect impacts:

- *Direct impacts*, including geographic and seasonal redistribution of climate resources for agriculture, and changes in operating costs (the resulting impacts on outcomes including prices, production, and consumption)
- *Indirect impacts* due to climate-induced changes in irrigation water availability (precipitations changes, climate change induced higher temperatures increase the water requirements of crops and livestock yields), services (water shortages, water stress on irrigated crop yields) and the economic consequences of these potential yield changes
- *Broader impacts due to mitigation policies* on agriculture competitiveness such as increase of fossil fuel prices and chemical fertilizers and mitigation measures for enteric fermentation

In the Southern Mediterranean countries (Algeria, Egypt, Israel, Jordan, Lebanon, Morocco Palestine and Tunisia), surface water resources are limited, and ground water is the major source for agricultural, industrial and domestic water supplies (Figure 1).

The impact of climate change is difficult to forecast. We aim to provide an integrated analysis about climate change, water resources and agriculture – all in one text. Such an ambitious goal has the purpose of providing readers with current and inter-multidisciplinary information regarding climate change and water resources in agriculture, as well as to give a comprehensive perspective about the core points, which have a bearing on this subject matter. Eastern and Western Mediterranean countries have unique vulnerabilities from the climate and societal point of view that can go critical under climate change. And yet, the region has been rather under-investigated in recent years and comprehensive analyses and assessments of the region are rare (Martínez-Asensio et al., 2014).

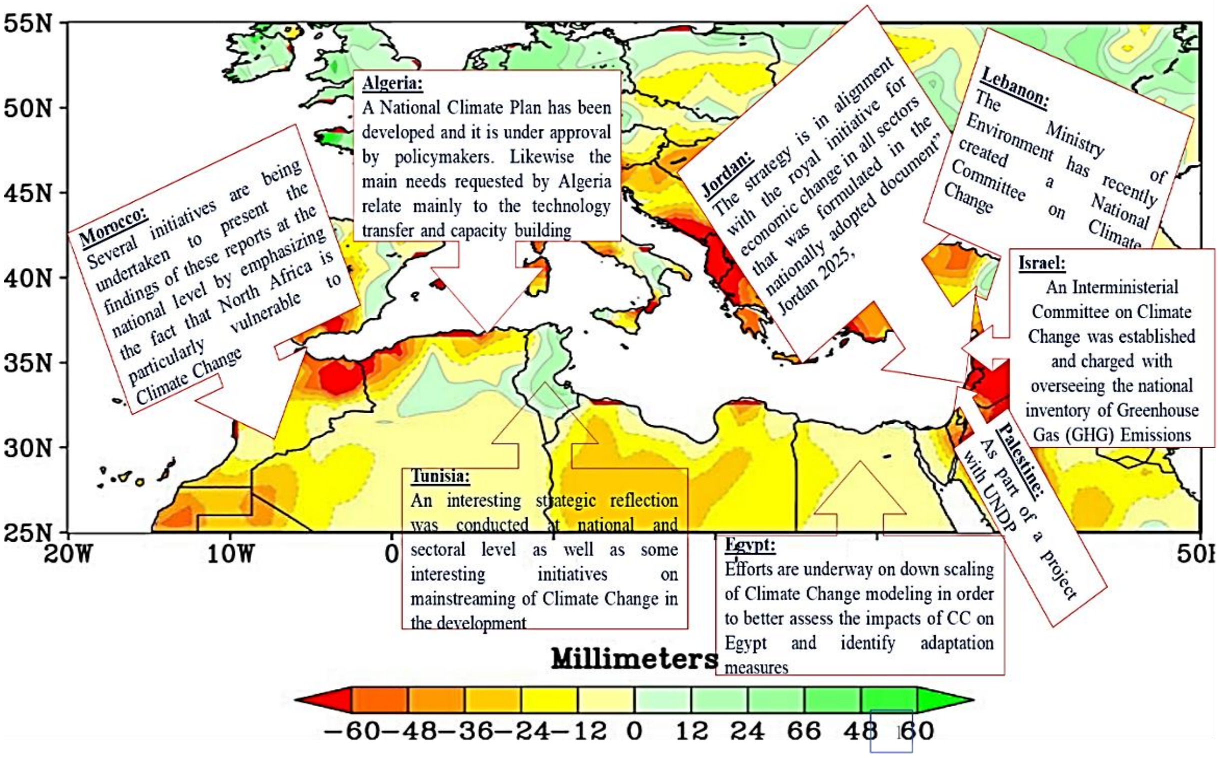

Fig. 1. Situation of the Southern Mediterranean countries and the review of national circumstances regarding data availability and access to Climate Change on Agriculture.

In the Southern Mediterranean Countries' groundwater is often the only natural resource for water supply. The intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater from aspects of quantity and quality. Usually quantity problems are directly related to groundwater extraction by human beings more or less. Over-extraction of groundwater modifies drastically piezometric head fields and groundwater flow patterns, inducing various drawbacks (Margat, 1977; PNUE/PAM/PLAN BLEU, 2004)). Therefore, ground water quality assessments are becoming increasingly important as the long-term protection of water resources is at stake (Gaaloul and Eslamian, 2014).

Salinization due to poor irrigation management is one of the main causes of soil degradation and the groundwater quality and risks of soil salinization. Arid and semi-arid regions face major challenges in the management of scarce freshwater resources under pressures of population, economic development, climate change, pollution and over-abstraction. Increasing access to groundwater plays a key role in alleviating poverty, stabilizing populations and reducing the need for farmers to migrate when drought threatens agricultural livelihoods (Gaaloul, 2019). The traditional development of water resources in arid environments areas has relied heavily on the use of groundwater. Groundwater uses natural storage, is spatially distributed and, in climates where potential evaporation rates can be of the order of meters per year, provides protection from the high evaporation losses experienced by surface-water systems. Traditional methods for the exploitation of groundwater have been varied, including the use of very shallow groundwater in seasonally replenished riverbed aquifers (as in the sand rivers of Botswana), the channeling of unconfined alluvial groundwater in afalaj (or qanats) in Oman and Iran, and the use of hand-dug wells. Historically, abstraction rates were limited by the available technology, and rates of development were low, so that exploitation was generally sustainable (Gaaloul et al., 2018; Gaaloul, 2020).

WATER RESOURCES, AGRICULTURE AND CLIMATE CHANGE IN THE SOUTHERN MEDITERRANEAN COUNTRIESS

Current trends in the Mediterranean agriculture reveal differences between the Northern and Southern Mediterranean countries as related to population growth, land and water use, and food supply and demand. The changes in temperature and precipitation predicted by general circulation models for Eastern and Western Mediterranean Countries will affect water availability and resource management, critically shaping the patterns of future crop production (IPCC, 2013).

Water resource managers face the dilemma of ensuring future sustainability of water resources while maintaining the strategic agricultural, social and environmental targets. The average annual potential water availability per capita considering the total freshwater resources in southern Mediterranean countries is less than 1,000 m^3 per capita and year (Table 1). The Mediterranean Region embodies similar physical features and lifestyle but also, it brings forward significant contrasts between the Northern and Southern rim countries in particular, where the salient subject is the water sector. Water resources are unevenly distributed in time and in space; out of 1140 billion m3/year blue water generated per year, 90 % goes to the Northern rim countries whereas only 10 % is granted to these Southern rim countries.

Climate change in Eastern and Western Mediterranean Countries affect agriculture and water shortages are related to the extended droughts mostly due to high values of seasonal and year to year variability in precipitation. An important characteristic of Eastern and Western Mediterranean Countries is the presence of densely populated and technologically advanced societies. Because of the demographic pressure and exploitation of land for agriculture, the region presents, since ancient times, important patterns of land use change and important anthropogenic effects on the environment. The relative differences of temperature and precipitation will shape the agriculture patterns of the future and therefore it is important to develop strategic plans both to support agriculture resilience and development in new zones and to reduce carbon emissions related to agriculture (Andreassian, et al., 2014)

At present, agriculture covering about 50% of the total land area constitutes a major economic activity in the region, absorbing over 70% and 80% of total water demand in Eastern and Western Mediterranean Countries, respectively. Irrigated agriculture is the main consumer of water in Eastern and Western Mediterranean Countries (Table 2). The evolution of irrigation in all Mediterranean countries has been remarkable over the last half century, although northern and southern Mediterranean countries differ in relation to the rate of expanding their irrigated land and irrigation technologies used (Garrido and Iglesias, 2006).

In general, there is little development of new irrigation areas and the investments focus on rehabilitation of existing schemes, and improvement of irrigation technologies. But, nevertheless there is a rapid increase in the water demands in all countries as a result of the increase of economic and social activities together with the increasing demand for agriculture and for the ecosystems (Custodio, 2000).

Agriculture is one of the most threatened sectors from climate change in Eastern and Western Mediterranean Countries and also one that registers high CO_2 emissions. Yet, it can also be one of significant co-benefits with appropriate policies. There are necessities for the reduction of greenhouse gas emissions and issues to be dealt with regarding water, desertification and adaptation needs of riparian countries. In addition to the necessary impetus at the state level, the measures that will respond to realities must also be declined at the level of territories to multiply means of action (Monge-Barrio and Sánchez-Ostiz, 2018). Difficulties of access to water resources are also increasing in some territories. In addition, climate change would also affect local agriculture through its effect on crop yields. Climate change in Eastern and Western Mediterranean Countries increase the stress due to recurrent droughts and have strong negative effects on crops and on the capability to satisfy internal food demand, causing also the people migration from degraded land (IPCC, 2001).

The last report from the International Panel on Climate Change (IPPC, 2014), highlights the Mediterranean as one of the most vulnerable regions in the world to the impacts of global warming. The models issued by IPCC (2014) cast different scenarios for the Region, but all of them agreed on a clear trend in the pattern of some climatic parameters. In terms of the thermal regime, the base scenario from 1980-2000 was used to estimate an increase in average surface temperatures in the range of 2.2 and 5.1 °C for the period 2080-2100. For the same period, the models indicate pronounced rainfall regime changes in the Mediterranean, and estimate that precipitation over lands might vary between -4% and -27%. The general decrease in soil moisture in Eastern and Western Mediterranean Countries make droughts more frequent and more intense. Additional pressures, considering the very long coastline, occur due to sea-level rise and consequent increase of sea water intrusion in costal aquifers. Currently there is an increasing pressure on water resources in Eastern and Western Mediterranean Countries, derived from population dynamics, upgraded standard of living, economic and social development, and the use of water consuming technologies. Population growth in Eastern and Western Mediterranean Countries is the major factor affecting water resources, reducing the water availability per capita (Margat and Van der Gun, 2013).

Table 1. Water resources and Agriculture in Eastern and Western Mediterranean Countries Source: Computed with data from FAO/AQUASTAT (2016)

	Eastern Mediterranean Countries					Western Mediterranean Countries		
Countries	Egypt	Israel	Jordan	Lebanon	Palestine	Algeria	Marocco	Tunisia
Reference period (Latest value)	2008-2012	2003-2007	2013-2017	2003-2007	2003-2007	2008-2012	2008-2012	2008-2012
Fresh surface water withdrawal (Km^3/year)	65.8		0.3	0.4		4.8	8.3	1.2
Fresh groundwater withdrawal (Km^3/year)	8.0		0.6	0.7		3.0	2.3	2.1
Total freshwater withdrawal (Km^3/year)	73.8	1.4	1.1	1.1	0.4	7.8	10.4	3.2
Desalinated water produced (Km^3/year)	0.2	0.1	0.0	0.0		0.6	0.0	0.0
Direct use of treated municipal waste water	1.3	0.4	0.1		0.0		0.1	0.1
Direct use of agricultural drainage water	2.7		0.0	0.2				
Agricultural water withdrawal (Km^3/year)	67.0	1.1	0.6	0.8	0.2	5.0	9.2	2.6
Industrial water withdrawal (Km^3/year)	2.0	0.1	0.0	0.2	0.0	0.4	0.2	0.2
Minicipal water withdrawal (Km^3/year)	9.0	0.7	0.5	0.4	0.2	3.0	1.1	0.5
Total water withdrawal (Km^3/year)	78.0	2.0	1.1	1.3	0.4	8.4	10.4	3.3
Agricultural water withdrawal as % of total water	85.9	57.8	52.1	59.5	45.2	59.2	87.8	80.0
Industrial water withdrawal as % of total water	2.6	5.8	3.4	11.5	6.9	4.9	2.0	5.0
Municipal water withdrawal as % of total	11.5	36.4	44.5	29.0	47.9	35.9	10.2	15.0
Total water withdrawal per capita (m^3/inhab/year)	910.6	282.3	145.4	320.7	111.3	225.0	316.2	303.7

Table 2. Water use for irrigation and irrigated agricultural areas in Eastern and Western Mediterranean Countries. Source: Computed with data from FAO/AQUASTAT (2016).

	Eastern Mediterranean Countries					Western Mediterranean Countries		
Countries	Egypt	Israel	Jordan	Lebanon	Palestine	Algeria	Marocco	Tunisia
Reference period (Latest value)	2008-2012	2003-2007	2013-2017	2003-2007	2003-2007	2008-2012	2008-2012	2008-2012
Agricultural water withdrawal (10^9 m^3/year)	67.0	1.1	0.6	0.8	0.2	5.0	9.2	2.6
Total water withdrawal (10^9 m^3/year)	78.0	2.0	1.1	1.3	0.4	8.4	10.4	3.3
Irrigation potential (1000 ha)	4420.0		85.0	177.5		1300.0	164.0	560.0
Area equipped for full control irrigation: actually irrigated (1000 ha)	3422.0	181.5	75.0	90.0	24.0	1012.0	1341.0	380.0
% of area equipped for full control irrigation actually irrigated (%)	100.0	80.7	95.1	86.5	100.1	86.0	92.0	82.7
Area equipped for irrigation: spate irrigation (1000 ha)						53.0	62.2	27.0
Area equipped for irrigation: total (1000 ha)	3610.0	225.0	103.4	104.0	24.0	1230.0	1520.0	486.0
Area equipped for irrigation: actually irrigated (1000 ha)	3422.0	181.5	76.2	90.0		1065.0	1448.0	405.0
% of the area equipped for irrigation actually irrigated (%)	100.0	80.7	94.0	86.5		86.6	97.5	89.0
% of the cultivated area equipped for irrigation (%)	97.7	59.0	32.1	38.4	11.8	14.6	16.2	9.5
% of irrigation potential equipped for irrigation (%)	81.7		121.6	58.6		94.6	91.4	86.9
Total agricultural water managed area (1000 ha)	3610.0	225.0	103.4	104.0	24.0	1230.0	1520.0	486.6

CLIMATE CHANGE, IMPACT ON WATER AND AGRICULTURE: CURRENT STATUS AND FUTURE PROSPECTIVE

Agriculture is of significant importance to Eastern and Western Mediterranean Countries in terms of employment, rural livelihoods, food security and exports. The livestock reflects cultural traditions and is dominated by sheep. Morocco and Egypt are the main producers of cereals, although harvested quantities vary substantially according to annual rainfall. Moreover, Egypt is an important producer of fresh vegetables (UNDP, 2011) and Tunisian olive oil and date exports possess organic certification from the EU. The economic importance of the agricultural sector (including fishing) varies considerably among Eastern and Western Mediterranean Countries; it represented between 2 % and 4 % of the Gross Value Added (GVA) of Israel (Ministry of Environmental Protection, 2015) , Jordan and Lebanon (Hadda et al., 2014) respectively in 2011 but a little over 15 % in Morocco and 20 % in Tunisia (Gaaloul, 2020).

The area of farmland in production in Eastern and Western Mediterranean Countries increased between 2003 and 2011. The strongest increases were in Egypt (+6.2 %) and Jordan (+9.2 %, 2003 - 2010). The major exceptions were Israel and particularly Palestine (Aliewi, et al., 2013) where the utilised agricultural areas declined sharply during the same reference period (by -13.0 % and -43.4 % respectively). The proportion of utilised agricultural area that was irrigated ranged from 4.5 % in Tunisia, through 39 % in Jordan and upwards of 50 % in Israel and Lebanon, to 67.7 % in Egypt (where agricultural activities are largely concentrated in the Nile valley and its delta).

Due to their high demand for pesticides, fertilizers and irrigation water, modern farming practices put excessive pressure on the environment. More than 26 million hectares (ha) of farmland are now under irrigation in Eastern and Western Mediterranean Countries, and in some areas up to 80% of the available water is used for irrigation. The rapid growth in tourism and urban development in coastal areas combined with the abandonment of small scale farming practices is putting tremendous pressure on the Western Mediterranean Countries' rich biodiversity (Ablain et al., 2016).

The importance of Eastern and Western Mediterranean Countries in terms of crop diversity, is illustrated by the fact that about one-third of the foodstuffs used by humankind comes from the Mediterranean climatic region, if not strictly from the topographic basin proper. Barley, wheat, oats, olives, grapes, almonds, figs, dates, peas and other innumerable fruits and vegetables as well as medicinal or aromatic herbs are derived from wild plants found in the Mediterranean region. (Navarra and Tubiana, 2013).

Analysis of Eastern and Western Mediterranean Countries farm structures reveals that there are a large number of small farms (less than 5 ha) on both the southern and the northern shores, especially in Tunisia (76% of farms on 27% of the agricultural area), Lebanon (77% of farms on 17% of farmland), Morocco (71% of farms on 24% of farmland), Algeria (67% of farms on 22% of farmland) and Tunisia (87% of farms on 13% of farmland) (Lowder, at al., 2016)

Agriculture in Eastern and Western Mediterranean Countries, is highly climate-sensitive and potential adverse changes in temperature, precipitation and the frequency of extreme events (e.g., droughts, heat waves, floods, forest fires) are likely to exacerbate existing inequalities between the rich and the more vulnerable poor populations. This deterioration will place a strain on institutions, food supply and rural growth. Additionally, these countries limited financial resources and underdeveloped institutional capacity to respond to natural climatic hazards pose a threat to future sustainable agricultural production and rural development.

The impact of the climate change on Eastern and Western Mediterranean agriculture is already evident in many areas and especially in arid and semi-arid regions. Frequent droughts, flash floods, heat spells and spring frosts triggered the decline of agricultural production, further depletion of water resources, soil erosion and impoverishment, land abandonment and desertification, and increased pressures on food security and socio-economic development particularly in marginal rural zones. Hence, in several areas of the Mediterranean, climate change has caused social unrest, conflicts, migration of population and geopolitical tensions.

At a larger regional scale, a set of complementary issues should be considered including the land use change, sea level rise, salinization, loss of coastal areas, population growth and migration, availability of resources (land, water and energy), market integrations and fluctuations, food (in)security, political/social/economic stability, changes in diets/habits and progress in implementation of innovations (plant breeding and genetics, irrigation and crop production technologies and agronomic management practices) (Zolin and Rodrigues, 2016).

Climate change impacts will further increase risk in rainfed farming systems and may exaggerate current risk-hedging behavior by small farmers. By contrast it has been assumed that because productivity is higher in irrigation, the potential marginal gains of further improving land and water productivity are more limited. However, yields and water productivity are well below potential in many regions, notably Eastern and Western Mediterranean.

Countries; significant productivity increases can be expected in both yield and water use efficiency by better management of all farm inputs and with optimal use of nitrogen fertilizer. Irrigated agriculture, even with declining water availability, generally offers a more secure risk environment for more intensive management. Innovative thinking is required to encourage integrated farming systems that combine irrigation with rainfed production with livestock rearing and associated nutrient cycling. (Table 3).

Table 3. Climate Change impacts on farming systems
Source World Bank (2013) . Adaptation to a changing climate chnage in the Arab countries (FAO, 2017)

Farming system	Exposure: Expected Climate change – related events	Sensitivity: likely impacts on farming systems
Irrigated	Increased temperatures Reduced supply of Surface irrigation water Dwindling of groundwater recharge	More water stress Increased demand for irrigation and water transfer Reduced yields when temperatures are too high Salinisation due to reduced leaching Reduction in cropping intensity
Highland mixed	Increase in aridity Greater risk of drought Possible lengthening of the growing period Reduced supply of irrigation water	Reduction in yields Reduction in cropping intensity Increased demand for irrigation
Rain-fed mixed	Increase in aridity Greater risk of drought Reduced supply of irrigation water	Reduction in yields Reduction in cropping intensity Increased demand for irrigation
Dryland mixed	Increase in aridity Greater risk of drought Reduced supply of irrigation water	A System very vulnerable to declining rainfall Some lands may revert to rangeland Increased demand for irrigation
Pastoral	Increase in aridity Greater risk of draought Reduced water for livestock and fodder	A very vulnerable System, where desertification may reduce carrying capacity significantly Non-farm activities, exit from farming, migration

In fact, the impact of climate change on agricultural production could be negative for most areas of the Mediterranean with a large variability and reduction of yield. No changes or slight increase in yield are expected for autumn and winter crops while, for spring-summer crops, a remarkable decrease of yield is predicted due to temperature increase and shortening of the growing season. The possible increase in water shortage and in frequency and intensity of extreme weather events may cause higher yield variability and reduction of suitable areas for traditional crops.

The main effects on agricultural production are expected to be an increased variability of production, decrease of production in certain areas and changes in the geography of production. Agricultural production systems integrate agronomic (e.g., climate, soils, crops and livestock) and economic elements (e.g., material, labour, energy inputs, food and services outputs). These systems are affected by socio-economic and cultural processes at local, regional, national, and international scales, including markets and trade, policies, trends in rural/urban population, and technological development.

As a consequence of air temperature increase and the shortening of the growing season, the average Crop Water Requirements (CWR) are expected to decrease, for winter-spring and spring-summer crops, by 4 to 8% over the whole Mediterranean region. Hence, the average Net Irrigation Requirements (NIR) would decrease or remain steady. So, the air temperature increase could have a dominant role on the shortening of the growing season rather than on the increase of crop water requirements (Falkenmark and Rockström, 2006).

The impact of precipitation decrease would be limited only to the perennial and autumn-winter crops because most of spring-summer agricultural production in the Mediterranean is already characterized by very low rainfall. Thus, a slight increase of CWR and irrigation inputs could be expected for perennial crops like olive trees. Most of rain fed cropping systems could be negatively affected by climate change due to the expected increase in water deficit (i.e. difference between evapotranspiration and precipitation), and overall reduction of water availability for agriculture. The latter is due to projected increase of water demand by other sectors. Overall, climate change could likely intensify the problems of water scarcity and land degradation, and affect negatively the sustainability of agricultural production in the region.

Agricultural vulnerability to climate change described in terms of exposure to elevated temperatures, the sensitivity of crop yields to the elevated temperature and the ability of the farmers to adapt to the effects of this exposure and sensitivity by, for example, planting crop varieties that are more heat-resistant or switching to another type of crop. Developing metrics may be useful in order to facilitate the evaluation of policy options as well as to assess the long-term risks of climate change and perhaps identify thresholds beyond which foreseeable adaptation techniques may not be sufficient to ensure successful adaptation. These three key parameters are interlinked and the omission of one of those parameters will not permit considering the whole complexity of the vulnerability concept. Exposure and adaptive capacity influence sensitivity, while the degree of exposure may itself be influenced by the adaptive capacity of the system (Falkenmark and Rockström, 2004).

CLIMATE CHANGE IMPACTS ON AGRICULTURE IN THE SOUTHERN MEDITERRANEAN COUNTRIES

Agriculture is highly exposed to climate change in the in the Southern Mediterranean Countries, as farming activities directly depend on climatic conditions. But agriculture also contributes to the release of greenhouse gases to the atmosphere. However, agriculture can also help to provide solutions to the overall climate change problem by reducing emissions and by sequestering carbon while not threatening viable food production.

Climate Changes in Eastern and Western Mediterranean Countries assess the current level of knowledge of the observed climate variability and trends in the Mediterranean, and it includes description of available temperature and precipitation station and gridded data sets, reviewing issues linked to quality control harmonization and homogenization of data; data for the ocean circulation, sea level and waves are also discussed as the changes in extreme events (Lionello et al., 2006).

Eastern and Western Mediterranean Countries climate change during the last 60 years is based on homogenized daily temperature and quality controlled precipitation observational data and gridded products. The estimated changes indicate statistically significant Mediterranean summer temperature increase and a reduction in winter precipitation in specific areas. The analysis is provided with an overview of differences and similarities across countries in Eastern and Western Mediterranean (Table 4).

Table 4. Review of national circumstances regarding data availability and access to Climate Change on Agriculture in Eastern and Western Mediterranean Countries

	Countries	Review of national circumstances regarding data availability & access to Climate Change on Agriculture
Eastern Mediterranean Countries	Egypt	An Information System for Integrated Management Framework uses this data to provide an early warnings for agricultural activities.
		Agricultural activity in Egypt is vulnerable to CC. This Climate service (early warnings for agricultural activities)is a measure of adaptation of agriculture to CC.
	Israel	The Israel Climate Change Information Center (ICCIC) was created in 2011 by the Ministry of Environmental Protection at the University of Haifa with collaboration of researchers from University
		A survey of existing knowledge on the implications of climate change for Israel (published in May 2012);
		Policy recommendations and preparation of a plan for international marketing of the products of the ICCIC (published in September 2012);
		A guide on climate change adaptation by local authorities (published in August 2013).
	Jordan	Some on-going activities are likely to contribute to the rehabilitation of the network observation, enhancement of database as well as seasonal forecast and climate change modeling
	Lebanon	Develop its capacity to produce high quality climate services
		LARI's early warning system supports farmers to improve management of adverse impacts of climate variability on their agricultural activities, providing an agro meteorological support using SMS.
	Palestine	Cooperation with Ministry of Agriculture for the implementation of an Early Drought Monitoring System.
Western Mediterranean Countrie	Algeria	The National Climatological Centre provided products and climate services to its users (Department of Agriculture, Energy, the National Highways Agency)
		The Algerian National Climate Plan, under approval, is a framework that will enable the Algerian Meteorological Service to further develop its contribution to cope with CC through the provision of appropriate climate services.
	Marocco	The Moroccan meteorological service (DMN) has elaborated several climate change studies relate to: Past changes in precipitation and temperature, in extremes, Assessment of future climate change over Morocco
	Tunisia	Climate services are developed for some sectors

Because of global warming, the climate in Eastern and Western Mediterranean Countries is predicted to become more variable, and extreme weather events are expected to be more frequent and severe, with increasing risk to health and life. This includes increasing risk of drought and flooding in new areas and inundation due to sea-level rise in the continent's coastal areas.

Eastern and Western Mediterranean Countries will face increasing water scarcity and stress with a subsequent potential increase of water conflicts as almost all of the river basins in Eastern and Western Mediterranean Countries are transboundary. Agricultural production relies mainly on rainfall for irrigation and will be severely compromised in many Eastern and Western Mediterranean Countries, particularly for subsistence farmers. Under climate change, much agricultural land will be lost, with shorter growing seasons and lower yields. National communications report that climate change will cause a general decline in most of the subsistence crops.

Table 5 highlights some impacts of climate change in Eastern and Western Mediterranean Countries on key sectors and gives an indication of the adaptive capacity of this continent to climate change.

Eastern and Western Mediterranean Countries is located in a transition zone between the arid climate of North Africa and the temperate and rainy climate of central Europe, it is sensible to interactions between mid-latitude and tropical processes. Climate experts anticipate significant changes in climate and related physical impacts as presented in Table 6 (based on IPCC 2007, scenario A1B).

Table 5. Regional Impacts and Vulnerabilities to Climate Change on Agriculture in Eastern and Western Mediterranean Countries

Impacts	Sectoral vulnerabilities	Adaptive Capacity
Temperature • Higher warming (x1.5) throughout the continent and in all seasons compared with global average. • Drier Eastern Mediterranean, may become warmer than the south regions **Precipitation** • Decrease in annual rainfall in much of the Eastern Mediterranean, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached. • Decrease in rainfall in of the Western Mediterranean in much of the winter rainfall region. • Increase in annual mean rainfall in the Eastern and Western Mediterranean • Increase in rainfall in the Eastern and Western Mediterranean may be counteracted through evaporation **Extreme Events** • Increase in frequency and intensity of extreme events, including droughts and floods, as well as events occurring in new areas.	**Water** ▪ Increasing water stress for many countries of in the Eastern and Western Mediterranean ▪ 75 to 220 million people face more severe water shortages by 2020. **Agriculture and food security** ▪ Agricultural production severely compromised due to loss of land, shorter growing seasons, more uncertainty about what and when to plant. ▪ Worsening of food insecurity and increase in the number of people at risk from hunger. ▪ Yields from rain-fed crops could be halved by 2020 in some countries. Net revenues from crops could fall by 90% by 2100. ▪ Already compromised fish stocks depleted further by rising water temperatures. **Health** ▪ Alteration of spatial and temporal transmission of disease vectors, including malaria, dengue fever, meningitis, cholera, etc. **Terrestrial Ecosystems** ▪ Drying and desertification in many areas. ▪ Deforestation and forest fires. ▪ Degradation of grasslands. ▪ 25 to 40% of animal species in national parks in SEMRs expected to become endangered. **Coastal Zones** ▪ Threat of inundation along coasts in the Eastern and Western Mediterranean , and in many major cities due to sea level rise, coastal erosion and extreme events. ▪ Degradation of marine ecosystems including coral reefs of the Eastern and Western Mediterranean coast. ▪ Cost of adaptation to sea level rise could amount to at least 5–10% GDP.	The Eastern and Western Mediterranean has a low adaptive capacity to both climate variability and climate change exacerbated by existing developmental challenges including: • low GDP per capita • widespread, endemic poverty • weak institutions • low levels of education • low levels of primary health care • little consideration of women and gender balance in policy planning • limited access to capital, including markets, infrastructure and technology • ecosystems degradation • complex disasters • conflicts

Table 6. Main vulnerabilities to Climate Change and opportunities on Agriculture in Eastern and Western Mediterranean Countries Source IPCC (2007)

Air temperature	**An increase** in air temperature from +2.2 C° to +5.1 C° for the period 2080–2099 as compared to the period 1980–1999.
Rainfall	A significant **decrease** in rainfall, ranging between -4% and -27% over the same periods of time.
Extreme events frequent and	**Increase** in drought periods and in the frequency of days during which the temperature would exceed 30 °C. Extreme events, such as heat waves, droughts or floods, are likely to be more frequent and violent
Sea acidity	**At the present rate** of greenhouse gas emissions, the Mediterranean's acidity is expected to rise by +30% and +150% by 2050 and 2100, respectively.
Sea surface temperature	An average sea surface temperature rise of +0.75°C is expected at the scale of the Mediterranean Sea from 2000-2010 to 2030-2040.
Sea level rise	According to RCP 6, a mean and likely range of +0.33 to +0.63 m in the period 2081-2100

OVERVIEW OF IMPACTS AND THREATS FOR THE AGRICULTURE SECTOR

A large range of literature is available for the assessment of the impact that the agriculture sector has in the production of GHG and therefore on Climate Change, focussing on the possible climate change mitigation measures for the sector, both globally (Tantawi, 2014) and in the Southern Mediterranean (MREE-PAP RAC/PAM, 2015).

Nevertheless, the proportion of grey literature and scientific studies on the potential effects that Climate Change is having on the agriculture sector, and that it is expected to have in the future, remains relatively limited. This analysis (Table 7) aims at addressing such shortage and provide initial evidence on this aspect, as a basis for more effective adaptation measures for the sector across the region. The analysis is provided with an overview of differences and similarities across countries in Eastern (Naddaf and Mansour, 2015) and Western.

The sector in fact appears to be already exposed to certain pressures, although with some differences across the two shores, while other areas of impacts are not yet perceived but might rapidly grow in the near to longer future. The cross-analysis of the patterns emerging across countries allows to identify the different degrees of threats for the sector due to climate change pressures across the various countries assessed in this study. An illustrative overview is provided by table 7 below, with an overview of impact across revenues, assets and services for the sector today and its aggravation in the mid to long-term future.

IMPACT ASSESSMENT OF CLIMATE CHANGE ON FARMING SYSTEMS IN EASTERN AND WESTERN MEDITERRANEAN COUNTRIES

Improving the resilience of farming systems to climate change is one of the major challenges; agriculture has to face in Eastern and Western Mediterranean Countries. Resilience is commonly defined as a measure of system stability and persistence near or close to a state of equilibrium. Different studies and authors claim that the difference in farm strategies, and consequently resilience to cope with climate change in the South Mediterranean area, can be explained by the diversities observed in terms of cultivated cropping systems (cereals vs. orchards; rain-fed vs. irrigated), types of farming systems (small farms vs. big farms; mixed farms vs. cereal farms) and the availability and quality of water, land and labour resources.

Few approaches are available for measuring the resilience of agricultural systems, and particularly at farm level, and the role that diversities can play in improving this resilience. One first group focuses its analysis at field level and on biophysical components such as yield, variability in relation to the effect of water and temperature stresses, CO2 rise and soil water index. At farm level analyse the evolution of capital stock (cultural, human, natural, social), and quantify financial resilience through indicators of farm profitability, liquidity, solvency and financial efficiency.

The proposed methods do not take into account the possible interactions between the biophysical characteristics of the farm and the socio-economic resources and strategies that determine the productive potential of the system at field, farm, and regional levels. To assess the economic and environmental performance of farms, it is necessary to represent the agricultural system in agronomic and economic terms. This approach must address the complex interactions between agricultural management, environmental impacts, and economic results. The environmental impacts of crop management, such as the effect of water and nutrient management are often estimated using cropping system simulation models. The biophysical data provided by cropping system models and other methods are then used to feed bio-economic farm models. These can simulate farm responses under well-defined external conditions and compute the environmental and economic impacts of farmers' decisions on crop selection and management

The current resilience behaviour of the dominant farming systems in Eastern and Western Mediterranean Countries this area, by considering their structure (specialization vs. diversification), their dominant activities (cereal, livestock, forage and orchards), irrigation levels, and their potential trajectories under climate change. Two main conclusions can be drawn:

• The resilience of farming systems mostly depends on the combination of activities that initially exist on the farm,offering more or less adaptation possibilities. Mixed farms are the most resilient but only if they are able to apply supplemental irrigation on winter cereals, and to provide fodder for livestock bought on the regional market. The diversity of cropping systems (including the level of coverage of crop water needs by irrigation) may increase the resilience of the farming systems. This result concerns most of the cereal plains in the Mediterranean area such as Medjerda in Northern Tunisia, Saïss in Northern Morocco and Bekaa in Center-East Lebanon where water is potentially available in sufficient quantity. In the absence of irrigation, as it is the case in Central and Southern Tunisia, these farms are identified as non-resilient and are destined to gradually disappear.

• The specialization process that started in several South Mediterranean countries in the 60 s in response to political incentives to intensification will be exacerbated by the effects of climate change. Indeed, the reduction in rainfall conjugated with excessive use of limited water resources will force farmers to:

(i). Increasingly irrigate more profitable crops and therefore be more specialized by abandoning rain-fed winter cereals and forage crops. In the Mediterranean area, this concerns especially the farms which benefited from the installation of public irrigation systems such as in the Cap Bon—Tunisia. These farms are often very intensive (especially with regards to irrigation) and are at the limit of resilience to climate change. Moreover, their resilience, when water becomes very limiting, will depend mainly on their ability to adopt water saving management practices.

(ii). Be more dependent on the market, and therefore less resilient, for the purchase of forage and concentrate for farms dominated by livestock. This result relates especially to farms that historically were diversified, and which became progressively specialized in livestock production. These farms often

have limited access to water resources, which explains their dependence on the market for the purchase of fodder and concentrate. This is the case of many farms in North Africa for which the resilience depends largely on their ability to expand, to mobilize pasture for animals or to provide fodder in a highly volatile market.

(iii).Be not only depending on the availability of water but also on its quality (salinity). This concerns in particular the farms that were originally quite diversified with important access to irrigation. These farms evolved to be more specialized in fruit trees production with or without association of cereals. This is the case for most farms dominated by orchards such as those in Sidi Bouzid area (Center Tunisia), in the Nile Delta (Egypt) or in the Souss region (Morocco) which are now identified as highly vulnerable to climate change and increased soil salinity accumulation (Plan Bleu, 2011).

INTERACTIONS BETWEEN THE VARIOUS SECTORS OF THE ECONOMY FOLLOWING CLIMATE CHANGE IN THE SOUTHERN MEDITERRANEAN COUNTRIES

Interactions between climate change, water and agriculture are numerous, complex and region-specific. Climate change can affect water resources through several dimensions: changes in the amount and patterns of precipitation, impact on water quality through changes in runoff, river flows, retention and thus loading of nutrients; and through extreme events such as floods and droughts. Interactions between relevant weather variables that effect agricultural production, such as temperature and precipitation, are difficult

Table7. Overview of the impact of climate change on the Agriculture sector through time

		Currently (2017)		Near future (2020-2030)		Longer term (2030-2050-2100)	
Areas of impact		East	West	East	West	East	West
Direct effects on costs	Risks and insurance	Green	Green	Red	Red	Red	Red
	Climate variability	Green	Green	Red	Red	Red	Red
Direct effects on demand	Water resources	Green	Green	Red	Red	Red	Red
	Agriculture Production	Green	Green	Red	Red	Red	Red
	Sea level rise and Coastal erosion	Green	Green	Red	Red	Red	Red
	Vector borne-diseases	Green	Green	Red	Red	Red	Red
	Energy	Green	Green	Red	Red	Red	Red
	Biodiversity loss	Green	Green	Red	Red	Red	Red
	Infrastructural issues	Yellow	Green	Red	Red	Red	Red
	Greenhouse Gas (GHG) Emissions	Green	Green	Red	Red	Red	Red
	Fisheries	Green	Green	Red	Red	Red	Red
Broader indirect effects	Ecosystems	Green	Green	Green	Red	Red	Red
	Public health	Green	Green	Red	Red	Red	Red
	Coastal Zone	Green	Green	Green	Red	Green	Red
	Winds and other storms	Yellow	Green	Green	Red	Green	Red
	Livestock	Green	Green	Red	Red	Red	Red

(Red) High impact (high impact, requiring major action and immediate action)

(Green) Medium impact (increasing impact, requiring minor action, monitoring and medium-term action)

(Yellow) Negligible impact (the impact is limited but requires follow-up) to characterize. Moreover, scientific evidence underlying projected impacts on freshwater has significant limitations when it comes to informing practical, on site adaptation decisions. These complex interactions multiply the uncertainties concerning the impact of climate change on agriculture.

These changes in the water cycle can in turn deeply affect agricultural production in practically all regions of the Eastern and Western Mediterranean Countries and have destabilizing impacts for agricultural markets, food security and non-agricultural water uses. There is thus a strong case for considering agricultural water management and policy in the context of climate change. In the same way, a sound analysis of mitigation and adaptation strategies in the agricultural sector to climate change should place more emphasis on the water cycle (Sahnounea, et al., 2013).

As a consequence of climate change, agricultural in Eastern and Western Mediterranean Countries and more particularly, economies specialized in the growing of large-water consuming products - will be the most affected. This is especially the case of Tunisia and, to a lesser extent, Morocco and Egypt in our sample.

In addition, in addition to the rise in temperatures and the depletion of water resources, the development of all in Eastern and Western Mediterranean Countries, of our analysis, which are entering a phase of intensive industrialization of their economy, will generate a soaring demand on energy. This phenomenon is taking place at a time when the natural reserves are on the decrease and when carbon-intensive productions, which represent a majority in the zone, increasingly suffer from their bad reputation. The basic infrastructures and power production will be negatively affected. The high-energy demand periods will increasingly coincide with the most constraining periods for production: the summer season, and during the extreme events of the heat wave type. Following population growth, the coastal cities will receive an additional number of people, while their vulnerability will increase due to sea level rises and extreme events.

There is a clear connection between water scarcity, food insecurity and social instability, which in turn can trigger and intensify migration patterns. Lastly, the environment and the poorest populations, already made more vulnerable, will experience a worsening situation. Climate change will increase the loss of ecosystem and the proliferation of epidemics, especially in the regions further south, inducing catastrophic losses for the people, the environment and the economy in all the countries of the region and exacerbating the development and income disparities between the countries of the Northern rim and those of the Southern rim of the Mediterranean.

An illustrative cross-analysis, policy options and Climate Change impacts on agriculture in Eastern and Western Mediterranean is provided by table 8.

It allows users to explore the complex issues surrounding impacts, vulnerability and adaptation to climate change at Eastern and Western Mediterranean Countries scales through four screens:

(i). Impacts – how different amounts of future climate and socio-economic change may affect urban, rural and coastal areas, agriculture, forestry, water and biodiversity;

(ii). Vulnerability – which areas or ‘hotspots’ in Eastern and Western Mediterranean Countries may be vulnerable to climate change under a specified scenario, before and after adaptation;

(iii).Adaptation – how adaptation options can reduce the impacts of climate change; and

(iv). Cost-effectiveness – the relative cost and potential of adaptation measures to reduce the impacts of climate change.

Adaptation to climate change must also occur through the prevention and removal of maladaptive practices. Maladaptation refers to adaptation measures that do not succeed in reducing vulnerability but increase it instead. Examples of measures that prevent or avoid maladaptation include: better management of irrigation systems; and removal of laws that can inadvertently increase vulnerability such as relaxation of building regulations on coasts and in floodplains. Reduced water availability and increased frequency and intensity of heat waves will render ecosystems more vulnerable, since climate change is too fast to allow ecosystems adaptation. Particularly affected are traditional crops (wheat, olives, grapes), both because there is less available time for biomass accumulation and because of higher temperatures and water stress on crops.

In order to properly carry out risk analyses and adaptation measures (Table 9), the concept of adverse impact must be properly evaluated. Direct impacts from climate change upon welfare and human life values have to be distinguished. Direct impacts on welfare, such as the need for investing into adaptation types of infrastructure, might be the easiest to evaluate. Equity and ethical considerations must be parameterized. Changes due to climate change should not lead to impacts affecting only the poorest.

Table 8. Cross-analysis: policy options and Climate Change impacts on Agriculture in Eastern and Western Mediterranean Countries

	National Climate Change Policy (2013-2020)		National Water Strategy (2016-2025)	
Areas of impact	**East**	**West**	**East**	**West**
Risks and insurance	Yellow	Blue	Yellow	Blue
Climate variability	Blue	Blue	Yellow	Blue
Water resources	Blue	Blue	Blue	Blue
Agriculture Production	Blue	Blue	Blue	Blue
Sea level rise and Coastal erosion	Blue	Yellow	Blue	Yellow
Vector borne-diseases	Blue	Blue	Blue	Yellow
Energy	Blue	Blue	Blue	Blue
Biodiversity loss	Green	Blue	Green	Red
Infrastructural issues	Green	Green	Green	Yellow
Greenhouse Gas Emissions (GHG)	Yellow	Yellow	Yellow	Yellow
Fisheries	Green	Yellow	Green	Green
Ecosystems	Green	Blue	Green	Blue
Public health	Yellow	Blue	Yellow	Blue
Coastal Zone	Blue	Yellow	Yellow	Yellow
Livestock	Blue	Blue	Blue	Blue
Decline of landscape	Yellow	Yellow	Yellow	Yellow

- Blue: Fully considered
- Yellow: Consider the key components
- Green: Weakly considered
- Red: Do not consider or no specific knowledge

In Eastern and Western Mediterranean Countries we should first tackle what could happen over the next ten years (droughts, floods, wind storms…), and what could happen in the next decades (including demography, technology, soil exhaustion, water scarcity…

The evaluated climate change risks and opportunities for agricultural production was done within a risk management framework which looks at the risks and opportunities for the agricultural sector, the magnitude of the impact, the likelihood of the impact and the priority given for investment and action. Changing climatic conditions, such as increases in temperatures and changes in precipitation trends, combined with increased extreme events pose a serious threat to crop yields in Eastern and Western Mediterranean Countries.

Furthermore, these changes may lead to problems associated with an array of agronomic issues, including increased salinity, damage to soil structure (reducing land productivity) and exposure to new pests and diseases that challenge existing plant and animal genetics and management.

Additionally, changes in temperature, precipitation and water availability will also affect the livestock sector in terms of animal health, nutrition, husbandry and livestock-related infrastructure. Changing climatic conditions will adversely affect fodder and forage production and rangeland biomass, which could lead to volatile feed prices, increased competition for community grazing lands and increased water scarcity. Given these constraints there could be shifts in production from intensive to less intensive livestock systems and an increased risk of losses for small-scale producers, who comprise the majority of the rural population in Eastern and Western Mediterranean Countries.

The challenge for the agricultural sector in Eastern and Western Mediterranean Countries is significant, with nine downside risks and only two upside opportunities identified in this report (Table 10). Five of the risks identified are classified as high priority in terms of investment and action. From this assessment, it is clear that a strong focus on the development and adoption of adaptation measures is required in order to help ensure that agricultural systems in Eastern and Western Mediterranean Countries remain resilient in the face of a changing climate.

The importance of taking a proactive approach to adaptation in Eastern and Western Mediterranean Countries is further illuminated by the significant synergistic benefits for agriculture and rural livelihoods via such an approach. With Eastern and Western Mediterranean Countries low levels of current productivity, challenging climate and high reliance on rain-fed agriculture, the benefits of immediately implementing adaptation measures are clear especially for vulnerable rural communities. These benefits are further increased when considering the enhanced resilience these communities will achieve in the face of increased agricultural vulnerability under climate change. Moreover, some of the measures for adaptation could also be beneficial in meeting EU standards and increasing competitiveness in EU markets.

A number of the adaptation options for different sectors, including agriculture, livestock and water resources (Table 11) discussed in these documents include technologies which are ready for immediate implementation and are proven to increase productivity. Unfortunately, many of these options and associated action plans have not been implemented because of constraints associated with a variety of economic and social factors. In order to effectively prioritize adaptation options and focus investment within an action planning framework, in-depth analysis of effectiveness, cost efficiency and feasibility of adaptation options is required.

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Table 9. Adaptation measures in key vulnerable sectors highlighted on Agriculture in Eastern and Western Mediterranean Countries

Vulnerable sectors	Reactive adaptation	Anticipatory adaptation
Water Resources	Protection of groundwater resources	Better use of recycled water
	Improved management and maintenance of existing water supply systems	Conservation of water catchment areas
	Protection of water catchment areas	Improved system of water management
	Improved water supply	Water policy reform including pricing and irrigation policies
	Groundwater and rainwater harvesting and desalination	Development of flood controls and drought monitoring
Agriculture and food security	Erosion control and dam construction for irrigation	Development of tolerant/resistant crops (to drought, salt,
	Changes in fertilizer use and application	Research and development
	Introduction of new crops	Soil-water management
	Soil fertility maintenance	Diversification and intensification of food and plantation crops
	Changes in planting and harvesting times	Policy measures, tax incentives / subsidies, free market
	Switch to different cultivars	Development of early warning systems
	Educational conservation and management of soil and water	
Human health	Public health management reform	Development of early warning system
	Improved housing and living conditions	Better and improved disease/vector surveillance and monitoring
	Improved emergency response	Improvement of environmental quality
		Changes in urban and housing design
Terrestrial ecosystems	Improvement of management systems	Creation of parks, protected areas and biodiversity corridors
	Promoting agroforestry to improve forest goods and services	Identification/development of species resistant to climate change
	Development/improvement of national forest fire management plans	Better assessment of the vulnerability of ecosystems
	Improvement of carbon storage in forests	Monitoring of species
		Development and maintenance of seed banks
		Including socioeconomic factors in management policy
Coastal zones and marine	Protection of economic infrastructure	Integrated coastal zone management
	Public awareness to enhance protection of coastal and marine ecosystems	Better coastal planning and zoning
	Building sea walls and beach reinforcement	Development of legislation for coastal protection
	Protection and conservation of coral reefs,mangroves, sea grass and littoral vegetation	Research and monitoring of coasts and coastal ecosystems

Table 10. Climate Change Risks and Opportunities for the Agricultural Sector in Eastern and Western Mediterranean Countries

	Detail of Risk / Opportunity	Magnitude	Likelihood	Priority
Risk	Crop area changes due to decrease in optimal farming conditions	High	High	Medium
	Crop productivity decrease	Low	High	Medium
	Increased risk of agricultural pests, diseases, and weeds	Low	Medium	High
	Crop quality decrease	Low	High	Medium
	Increased risk of drought and water scarcity	High	High	High
	Increased irrigation requirements	High	High	High
	Soil erosion, salinization, and desertification	High	High	High
	Sea level rise	High	High	High
	Deterioration of conditions for livestock production	Medium	Low	Low
Opportunity	Crop distribution changes leading to increase in optimal farming	High	Medium	High
	Lower energy costs for glasshouses	Medium	High	Medium

Low
Medium
High

Table 11: Adaptation Options for the Agricultural Sectors of Eastern and Western Mediterranean Countries

Sector	Adaptation Option
General	- Invest in research and extension services to enhance the capacity and delivery of information to the agriculture sector, with particular reference to climate change and the implementation of adaptation options - Improve early warning and weather information systems, including frequent publication and distribution of agriculture-specific weather forecasts (e.g. short-term and seasonal forecasts, drought monitoring, etc...) - Invest in the monitoring and detection of new pests and disease for the crop, livestock and forestry sectors through improvements in the sanitary and photosanitary regimes - Introduction of a weather-based crop insurance program
Rain-fed Cropping	- Development of new genetic varieties of crops with higher resilience to increased temperatures, lower precipitation and drought and potential for increased production via carbon fertilization - Increase farming system water-use efficiency and reduce soil erosion via improved surface management techniques – including the adoption of minimum and zero tillage practices - Development and adoption of improved agronomy and risk management techniques - Land reclamation measures to increase the water holding capacity of soil via the application of manures, implementing measures that increase soil organic matter and the possible application of polymers
Irrigation	- Rehabilitation of existing irrigation and delivery schemes to improve access and system water-use efficiency - Modernization of on-farm distribution systems - Introduction of new irrigation techniques and improvement of existing techniques to enhance field-level water use efficiency
Livestock	- The adoption of improved animal breeds and grass/legume seed stock with increased resilience to projected climate conditions - Improved farmhouse micro-climate management through the use of thermal insulating construction materials and modern ventilation systems to protect livestock from extreme conditions and increase productivity - Improved pasture management by matching stocking rates to pasture production and integrating pasture improvement to increase feed value

Adaptation and mitigation are sometimes closely linked with potential trade-offs and synergies. Naturally, the stronger the current mitigation policies are, the less the need will be for adaptation in the long run. On the one hand, agricultural mitigation practices that increase nutrient and water retention and prevent soil degradation can increase resilience to droughts and flooding. On the other hand, adaptation measures that reduce tillage, increase crop rotations and promote green cover can contribute to mitigation efforts.

Most agricultural GHG mitigation and soil carbon sequestration practices, such as adoption of no-till or green fallowing, have complex site-specific water resource and water quality effects. For example, the adoption of no-till is likely to reduce sediment and nutrient runoff, but may increase herbicide runoff. Changes in land use, such as conversion of cropland to green fallow; may have these effects and affect water resources. If these co-effects are significant, then they should be explicitly addressed when designing policies to mitigate GHG emissions and sequester carbon. However, this may come at greater implementation costs.

Table 12 summarizes the main linkages between mitigation practices and water resources and quality. The linkages presented in the table 12 need to be considered as very general because of the regional specificity of water quantity and quality effects and the inherent uncertainty even at local scales as well as because in some cases, overall effects are ambiguous even in qualitative terms.

CONCLUSIONS

Southern Mediterranean countries is one of the world's regions that are most vulnerable to climate change. It is already experiencing the increasingly severe effects of a changing climate like higher average temperatures and the incidence of extreme events such as unprecedented heat

Table 12. Summary linkages by mitigation activity on water resources and quality

			Water runoff	Nutrient and pesticide runoff and leaching	Nutrient runoff from livestock manure	Fossil fuel use	Irrigation water withdrawal
Direct land use change		Crops to pasture	+	+		+	+
		Crops to forest	+	+		+	+
		Marginal and pasture lands to crops and bioenergy	-	-		-	-
Agriculture management practices	Cropping management	Tillage chnage and landscape contouring	+	±		+	+
		Crop mix and perennials	+	+			±
		Irrigation management	+	+		+	+
		Ferliliser and nutrient management		+		+	
		Other chemical use reduction		+			+
	Animals	Manure management			+		
		Breeding and animal species choice		+	±		+
Bioenergy	Energy form and process	Liquid fuels			±	+	
		Electricity		+		+	
		Pyrolysis-Biochar	+	+		+	
		Conventional crops and their residues	±	±		+	
		Energy crops	±	+		+	
		Animal wastes			+	+	
		Processing by products		+		+	

\+ means that water quality or quantity situation improves

\- denotes the worsening of the situation

± means that overall impact is not determined, but would depend on specific case waves, severe droughts, and major floods. Climate change affects the agriculture sectors in several ways. Water is a core input of agricultural production, so it is crucial for adaptation planning to improve our knowledge of the impacts of climate change on agricultural production. These impacts threaten the environment, society, and economy, and can place human security at risk. The assessment of relevant publicly available sources to build more resilient agricultural and water systems in face of the challenges posed by climate change has confirmed that:

- **Adaptation of agricultural water management** requires combining the development *of flexible and robust systems of water allocation*, to allow for efficient reallocation of water in a context of strong uncertainty about future water supply and non-stationary climate with a time consistent, long-run incentive strategy for matching water demand and supply. Water allocation system that allow both price and quantity to fluctuate in response to system shocks are desirable both under the existing environment and as a means for providing adaptive capacity with respect to climate change. The path to such more efficient, flexible and robust allocation systems is not always easy and can take time, hence the need to start a gradual improvement approach, including the following aspects of the problem:
- **Socio-economic negative impact of Climate Change for the agriculture** sectors: The climate change issue is global, long-term and involves complex interaction between demographic, climatic, environmental, economic, health, political, institutional, social and technological processes. It has significant international implications in the context of equity and sustainable development. Climate change adaptation refers to any action that diminishes the negative impacts of climate change, or conversely, that derives benefit from opportunities created by that change.
- **Climate change mitigation practices may have positive or negative implications on agricultural water management and on water quality:** The potential synergies and trade-offs between mitigation and agricultural management practices are, however, site-specific and for many cases, there are substantial knowledge gaps. Although this is a complex matter, it is important to recognise these linkages in the design of mitigation policies, to reduce the risk of conflict between mitigation and water policy objectives, and to maximise potential synergies.
- **Fostering an enabling policy and market environment for adaptation of agricultural and water systems:** Policy and market drivers form the overarching environment within which adaptation strategies take place. Police failure can increase the cost of adaptation measures.

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