Contract no. **688320**

MADFORWATER

DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries

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Deliverable Full title	**Effects of water stress on food security and socio-economic development**
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1 Introduction

World population is expected to rise above 9 billion persons by 2050 (FAO, 2009) posing significant challenges for the agricultural sector, which will have to ensure sustainable food production to feed this growing global population. However, most of this expected population growth will occur within developing countries, many which are already facing considerable levels of food insecurity.

Despite significant progress towards the achievement of global food security in the last decades most recent data show that the number of people suffering from hunger has increased in the last three years, evidencing that unless significant efforts are made, Sustainable Development Goal (SDG) 2 (Zero Hunger) may not be met by 2030 (FAO et al., 2018). Northern African countries are not an exception. Even if their relative situation within the Near East and North Africa (NENA) region regarding food security is more positive than in other countries - Northern Africa being the only sub-region that achieved the Millennium Development Goal (MDG) hunger target for 2015-, the last food security reports show that the Prevalence of Undernourishment (PoU) has increased since 2014 (FAO et al., , 2018). This trends may be reinforced by constrained access to key resources such as land and water.

According to the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE, 2015), water is a crucial resource for different aspects of food security. First, access to safe drinking water and sanitation is determinant for nutrition and health. In addition, irrigation agriculture represents 16% of cultivated area but is responsible for 44% of total crop production, and it is a source of income stabilisation and resilience of livelihoods for many smallholder farmers that are often more vulnerable to food insecurity.

Within the Mediterranean, the NENA region presents the lowest per capita availability of arable land and is one of the most water scarce areas in the World (FAO, 2017a), and current water crises in the region are likely to worsen in the future (World Bank, 2018a). Being irrigation agriculture the principal water user as well as an important economic driver in the region, the impacts of water stress on agricultural activity will likely affect food security and socio-economic development (FAO, 2017a).

Trying to contribute to the water and food challenge, the project MADFORWATER aims to "*develop an integrated set of technological and management instruments for the enhancement of wastewater treatment, treated wastewater reuse for irrigation and water efficiency in agriculture, with the final aim to reduce water vulnerability in selected basins in* Egypt, Morocco and Tunisia" (MADFORWATER Description of Action – part B – page 1). Through the development of integrated strategies that bring together technologies and economic instruments for water management the project aims to contribute to increase food security and agriculture sustainability, decrease water pollution and boost economic growth and employment in agriculture and the water treatment sector. (MADFORWATER Description of Action – part B – page 5).

In this context, the objective of WP1 is to analyze water stress and water vulnerability in the three Mediterranean African Countries (MACs) in MADFORWATER, Egypt, Morocco and Tunisia, with a focus on its drivers, specially WW treatment and reuse and water efficiency in agriculture, and potential impacts on food security and socio-economic development. In line with this objective, task 1.3, coordinated by UPM, is specifically devoted to the analysis of the effects that water stress and vulnerability may have on food security and socio-economic development. As a result of task 1.3 activities, this Deliverable (D1.3) "Effects of water stress on food security and socio-economic development" presents an econometric modeling approach developed to assess the effects of different dimensions of water stress and vulnerability on selected indicators for food security and socio-economic development. The estimated model is then used to assess future state of food security under climate change, considering the impact that climate change and socio-economic scenarios may have on drivers of water stress and food security, such as precipitation, GDP and population.

The assessment developed in this deliverable will also be taken into account for the water vulnerability assessment framework developed in task 1.4 (led by WER), that will contribute to the evaluation of the integrated water & land management strategies (IWLMSs) developed in WP5 and WP6.

The document is organized in 5 sections. Following the introduction (Section 1), Section 2 introduces briefly the current situation of food security in the Mediterranean region, and it summarizes the main challenges with a special focus on water scarcity as a key driver of food insecurity. In the same section (subsection 2.2), a general framework for appraising the linkages between water scarcity and food security is also presented.

Section 3 presents the empirical analysis of water stress effects on food security and socio-economic development. For this, a first subsection (subsection 3.1) elaborates on the approach adopted for considering water stress and food security, including the screening of potential indicators to be included in the model. Then it reviews the data and variables selected (subsection 3.2), and explains the methodology developed (subsection 3.3) based on econometric modelling with panel-data, before presenting the results obtained for the two models estimated for food security and socio-economic development respectively (subsection 3.4). Finally, the section presents maps for selected indicators of current food security and recent improvements in the Mediterranean countries and future changes under climate change according to predictions built with the estimated models (subsection 3.5).

Section 4 presents three country reports in which we analyze the current state of food security and socio-economic development in the MADFORWATER countries and how these may be affected by water stress related variables.

Finally, the main conclusions obtained in the analysis of water stress effects on food security are presented in Section 5, elaborating on potential implications and the role that the MADFORWATER technologies and strategies may play in contributing to food security and socio-economic development.

2 Food security, water stress and socioeconomic development.

2.1 Current situation and future prospects for food security, water stress and socio-economic development in the Mediterranean region.

Food security in the Mediterranean represents a major strategic challenge in terms of quantity and quality. This challenge will be magnified because of climate change, which may reduce the productivity of certain food systems and undermine the livelihoods of people who are already vulnerable to food insecurity. In addition, the prospect of greater variability and an increase in extreme weather events means that risk management, both locally and internationally, will be even more important than today. Population growth will continue until 2050 and will be accompanied by unprecedented levels of urbanization. These changes will occur mainly in developing countries, many of which will most likely become middle-income countries. As a result of all this, a rapid increase in the demand for food may be expected, both in terms of quantity and quality (WHO, 2010).

According to recent estimates, about 40% of the world's population is malnourished, half by deficit and the other half by excess (FAO, 2016a). Countries in the NENA region have traditionally paid special attention to food security because of the naturally constrained availability of key natural resources (such as land and water) in the area. Indeed, food security levels in the region are similar to more developed countries and PoU is well below average global levels (FAO, 2017a). However, there are significant differences across countries in the region, many of which are explained by access to key resources and the presence or absence of conflicts.

Despite progress made in the last decades, food security is still an important issue in countries of the southern arc of the Mediterranean, stretching from Morocco in the west to Syria in the east. This region faces structural weaknesses linked to natural constraints (low rainfall and poor soil), in addition to demographic dynamics and climate change, which leads to overexploitation of the soil, water resources and increased dependence on international markets for basic food products (FAO,2017).

Over the years, the Mediterranean population has increased rapidly. This fact, together with socio-economic, and geopolitical dynamics have led to a continued increase in food requirements, which has resulted in most Mediterranean states becoming net importers of cereals. In average, two thirds of the domestic consumption of cereals is covered through purchases on international cereal markets (OECD, 2016). Maghreb countries and Egypt show growing dependence on foreign markets for their food, especially grains and oilseed crops that are the basis of their diet. Arabic Mediterranean countries, while accounting for only 3% of the world's population, have represented, in average, for each harvest campaign since the start of the 21st century, around 15 to 17% of the world imports of cereals, and between 17 and 20% of wheat in particular (OECD, 2016). The evolution of the prices of these essential food products, and their availability (both in terms of quality and quantity), are top-ranking preoccupations for the public authorities, but also for the populations, whom are very sensitive to the slightest increase in cereal prices. UN projections indicate that NENA countries will remain in the horizon 2050, the region of the world that is most dependent on cereals imports, with a deficit that could reach 114 million tons (OECD, 2016).

Environmental degradation in the Mediterranean has reached a level that requires immediate action (UNEP, 2010). With urbanization and rising incomes, typical dietary patterns are shifting towards consumption patterns based on animal products, requiring more water, land and energy. In this context of increased pressure on resources and potential exacerbation under future socio-economic and climatic changes, the problematic nature of current levels of chronic undernutrition in the region is underlined.

Figure 1 shows the evolution of the PoU in Southern and Eastern Mediterranean Countries during the period between 1999 and 2017.

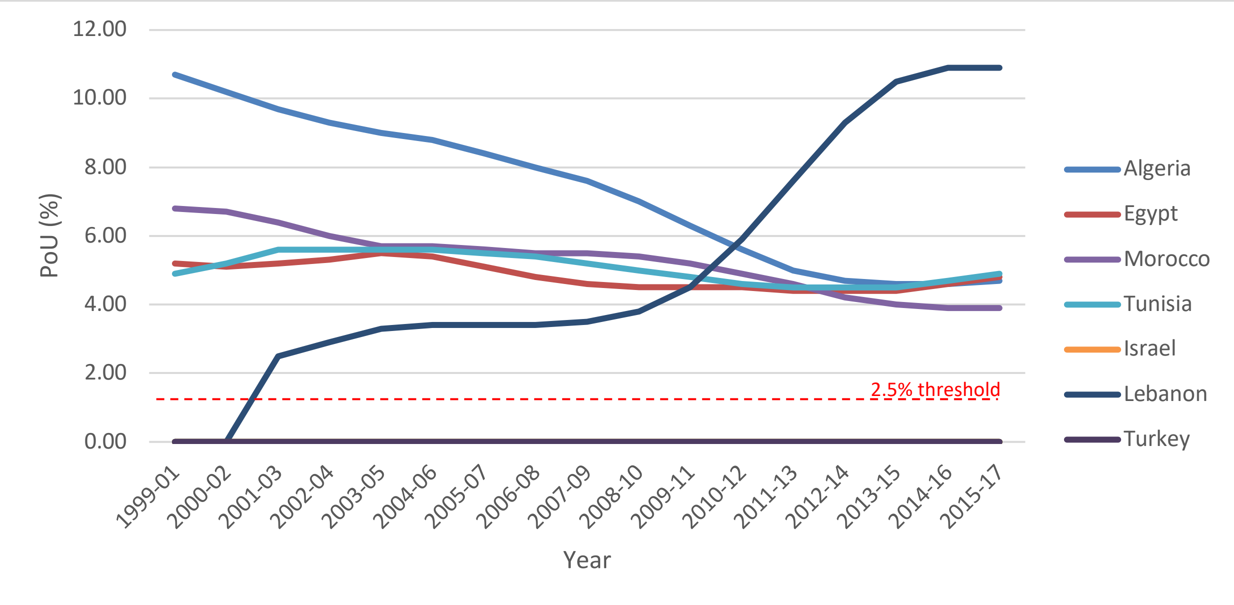

Figure 1. Evolution of PoU in Southern and Eastern Mediterranean Countries (1999-2017). The line corresponding to Israel is not visible as it is completely overlapped to that relative to Turkey.
*No data available for Syria, Palestine and Libya

Source: FAO, 2018.

The evolution of the PoU indicator differ widely from one country to another. According to Figure 1, different trends are present in Southern and Eastern Mediterranean Countries. First, Israel and Turkey show high levels of food security with PoU values below the 2.5% threshold (values in the graph are equalled to zero as the indicator is not reported for countries below the 2.5% threshold and the line corresponding to Israel is not visible in Figure 1 as it is completely overlapped to that relative to Turkey). These countries show also the lowest numbers for people undernourished (Figure 2), with less than 2 million in Turkey and less than 0.2 million in Israel. On the negative side we find Lebanon, which has witnessed a dramatic increase in the PoU, from values lower than 2.5% in 1999 to 10.9% in 2017, with also a significant increase in the number of people undernourished compared to the trends in other countries in the Mediterranean NENA region. This trend may be partly explained by the growing numbers of incoming displaced populations from neighbouring countries under conflict.

Among the countries showing a positive trend, the case of Algeria is noticeable with an important progress in PoU, which declined from 10.7% in 1999 to 4.7% in 2017. The number of people undernourished in Algeria also declined from 3.3 million to 1.9 million during the same period (1999-2017). Tunisia, Egypt and Morocco show also steady reductions in the levels of undernourishment, but present certain differences. In Morocco, PoU decreases from 6.8% in 1999 to 3.9% in 2017 and the number of people undernourished decreased from 2 million in the period 1999-2001 to 1.3 million in the period of 2014-2016, with an increase in the period 2015-2017. Morocco has made significant progress in the reduction of hunger resulting in the achievement of MDG1 on halving extreme poverty and hunger, with only 4.6% of population in rural areas classified as malnourished in 2015 according to FAO, compared with 7.1% in 1990 (Calo, 2016).

The PoU in Tunisia and Egypt varies between 6% and 4% during the period 1999-2017 (about 4.9% in 2017). The number of people undernourished in Tunisia (see Figure 2) varies between 0.5 and 0.6 million in the period 1999-2017, with a value of 0.6 in the period of 2015-2017 that represents 5% of the total population. In Tunisia, dietary deficiency problems are increasingly outclassed by overweight and obesity problems. The adequacy of intakes and needs in calories, iron, calcium and vitamins has started to become positive since 2005. However, some sections of the population, including rural residents in the North West, Central West and South regions, are still unable to meet their calorie needs; a 0.7% energy deficit is also recorded in the South East of the country (INS, 2018). In Egypt, the number of people undernourished increases from 3.7 million in 2007 to 4.6 million in 2017 (Figure 2). Anemia is the most prevalent micronutrient deficiency in Egypt. The most affected groups are pre-school children and mothers. According to criteria established by the World Health Organization (WHO), iron deficiency anemia is considered a moderate public health problem in Egypt (FAO et al., 2017).

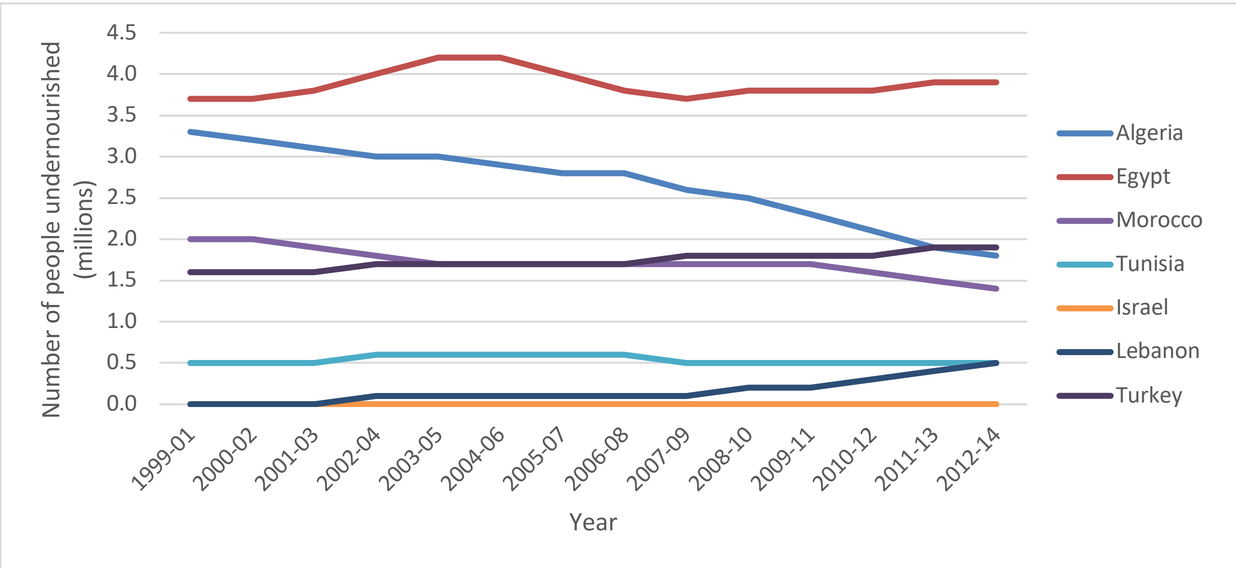

Figure 2. Evolution of the number of people undernourished in Southern and Eastern Mediterranean Countries (1999-2017).

Source: FAO, 2018.

Undernourishment levels may be explained by several factors, such as poverty, GDP per capita, population growth, and environmental degradation. For the NENA region as a whole, poverty has decreased but it remains above 10 % on average (FAO, 2016a). However, although variations exist between countries and subregions, it is generally higher in rural areas. Within the NENA countries, the Maghreb countries register the lowest rate of poverty compared with the region's average and other sub-regions within it.

Today, the principal challenge for the food and agricultural sector is to provide simultaneously enough food, in quantity and quality, to meet nutritional needs and to conserve natural resources for present and future generations. Securing food for growing populations while minimizing environmental externalities is becoming a key topic in the current sustainability debate. This is particularly true in the Mediterranean region, which is characterized by scarce natural resources and increasing climate-related impacts.

By 2050 the world's population will reach 9.7 billion, 32% higher than today (FAO, 2016a). Urbanization will continue at an accelerated pace, and about 66% of the world's population will be urban (compared to 54% today) (FAO, 2016a). To feed this larger, urbanized and richer population, FAO (2009) projected that a 60% increase in agricultural production is needed to provide an adequate food supply from 2006 to 2050 and the environmental burden from the food sector will likely grow in this same period, despite potential improvements in agricultural production efficiencies. Potential upcoming challenges for the agricultural sector, among others, include:

- The growth of population can lead to smaller size of farms and encroachment on marginal lands.
- Rapid upward and downward price movements make it difficult for farmers to anticipate and benefit from market conditions.
- Climate change is expected to accelerate the pace of extreme weather events and increase tensions over already limited resources of water and energy.

Prospects for the future are hampered by the rise of new constraints: depletion of water resources, land degradation, increased land pressure, disappearance of the Mediterranean diet favoring a worrying progression of non-communicable diseases of food origin, climate change, etc. (Rastoin et al., 2012).

Among the critical issues shaping food security is resource endowment, very specially land and water. According to FAO data (2012) 337 million people (25% of the total population) in the NENA region lack appropriate access to water resources. Agricultural expansion and intensification in the region has heavily relied on access to irrigation (FAO-AQUASTAT, 2012). However, the UN warns about the progress of deserts and the retreat of freshwater resources (FAO, 2009). Moreover, intensive groundwater pumping in coastal areas is leading to the growing phenomenon of marine intrusion. Thus, vast Mediterranean coastal areas are already affected by the intrusion of salt water following pumping, with an impact on available freshwater resources. The increasing threat of drought in the Mediterranean urges for policies that promote a more efficient use of water, water pricing policies, and better control of illegal water use. However, in the NENA region where the water stress situation is much more pronounced (Figure 3), these policies are less active even though it has been the site of great hydraulic civilizations.

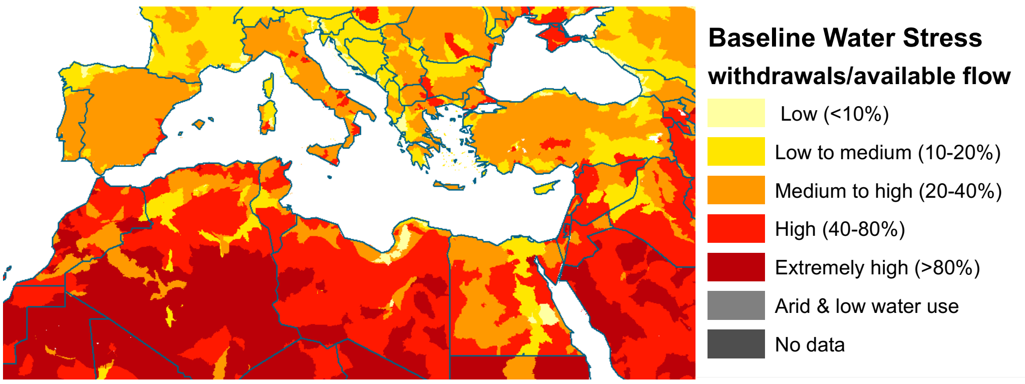

Figure 3. Water stress in the Mediterranean region.

Source: Aqueduct Global Maps 2.1. Gassert et al. (2014).

Historically, Mediterranean agriculture has evolved constrained by its geographical and climatic conditions. Regional characteristics are being further exacerbated in recent years as a consequence of climate change and its consequences are more accentuated where water and land resource endowment is lower. Climate change projected impacts in the Mediterranean point consistently to reduced water availability (Jimenez-Cisneros et al., 2014) and high vulnerability to reduced groundwater recharge, which will have likely negative effects on agricultural production in Mediterranean countries. Moreover, climate change negative effects on water resources and agricultural yields in Southern and Eastern Mediterranean countries will also affect the economic activities and livelihood that depend on them. The amount of available water per capita is constantly decreasing, which is especially problematic in the NENA region where agriculture is responsible for 70% of total water withdrawal. Agriculture in these countries uses large quantities of water because of the agro-climatic conditions of the region, but also because of non-optimal irrigation systems, and problems with a water pricing system that does not properly incentivize an efficient use. However, the water aspect is a major link between global warming and food insecurity. Indeed, there is a direct relationship between rainfall levels, water resources and agricultural yields (IPEMED, 2014).

2.2 Appraising water stress linkages with food security and socio-economic development.

Food security is a broad and flexible concept that includes a wide variety of aspects and dimensions. The first attempt to delimit the concept of food security dates back to the World Food Conference in 1974, when governments at the conference acknowledged the right of every man, woman, or child “to be free from hunger and malnutrition in order to develop their physical and mental faculties”. Some years later, representatives of up to 185 countries gathered at the World Food Summit of 1996 with the objective of eradicating hunger. From this summit, a goal emerged of halving the number of undernourished people in the world by 2015, and the most widely employed definition of food security was coined:

“Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary need and food preferences for an active and healthy life”

Building on this definition, in subsequent years, food security was recognized as multifaceted concept, and the need to further dig in the elements that determine a good status of food and nutrition security was recognized. As a consequence, four main dimensions of food security were identified (FAO, 2008):

- **Availability** refers to the physical supply of adequate food ready to be used by the population. As such, it is linked to food production, stock levels and trade.
- **Access** makes reference to the economic and physical disposal of food ready to be used by the population. Therefore, it is more linked to aspects such as income, affordability, market, the existence of conflicts and disasters, or prices, among others.
- **Utilization.** Even if food is available and accessible, an improper biological or social use of it may derive in an inadequate nutritional status of the individuals. Good utilization is related to a wide variety of factors, such as intra-household allocation of resources, gender inequality, education or health. A good education and health can contribute to design nutritious, safe and healthy diets, and to avoid diseases. Likewise, a proper social and intra-household allocation is key to ensure that everybody benefits from the improvements in access and availability.

- **Stability** takes into account the temporal dimension of food and nutrition security. Future needs must also be ensured for a country to be considered food secure. Some of the issues that affect stability relate to aspects such as climate, economy (employment, inflation) or political stability over time. An important distinction must be made between chronic or transitory episodes of food insecurity, depending on whether the persistence of the event is long-term or temporary/short-term.

In ensuring food and nutrition security, water management has been widely recognized as a crucial aspect (FAO, 2017a; HLPE, 2015). Particularly, water stress and scarcity is nowadays considered as a paramount risk for food security.

Water security is also a complex phenomenon comprising of many features and facets that must be taken into consideration for a proper analysis. From the traditional view of water stress as the lack of physical availability of water resources, approaches have evolved to a more multidimensional perspective aiming at accounting for other socioeconomic conditions such as economic, demographic, institutional or managerial aspects. That is the purpose of the framework developed by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, FAO Rome (HLPE, 2015), which represents a good illustration and reference point. . In a similar approach to the one used in the case of food security, the HLPE (2015) considers four dimensions of water that are connected to the different dimensions of food security:

- **Availability**, understood as the physical endowment of water resources.
- **Access**: Besides counting on sufficient water resources, they must be made available for the sectors and agents in the economy. Water access is related, among other issues, to the construction of infrastructures, a proper allocation of water among users, as well as to other political, institutional and socioeconomic factors.
- **Quality:** Even if water is available and accessible, it must be of adequate quality for the pertaining uses. Quality needs may vary across different final uses. For example, while high water quality is necessary for drinking and food preparation, water for irrigation may not in some cases be as demanding in terms of water quality.

  Stability: As with food security, stability of water resources is needed for a proper management and to avoid scarcity. Stability must depend on natural (disasters, natural cycles) as well as anthropogenic causes (ecosystem degradation or changes in return flows).

The channels through which water scarcity can impact food security and socioeconomic development are very complex and varied, and are summarized in Figure 4.

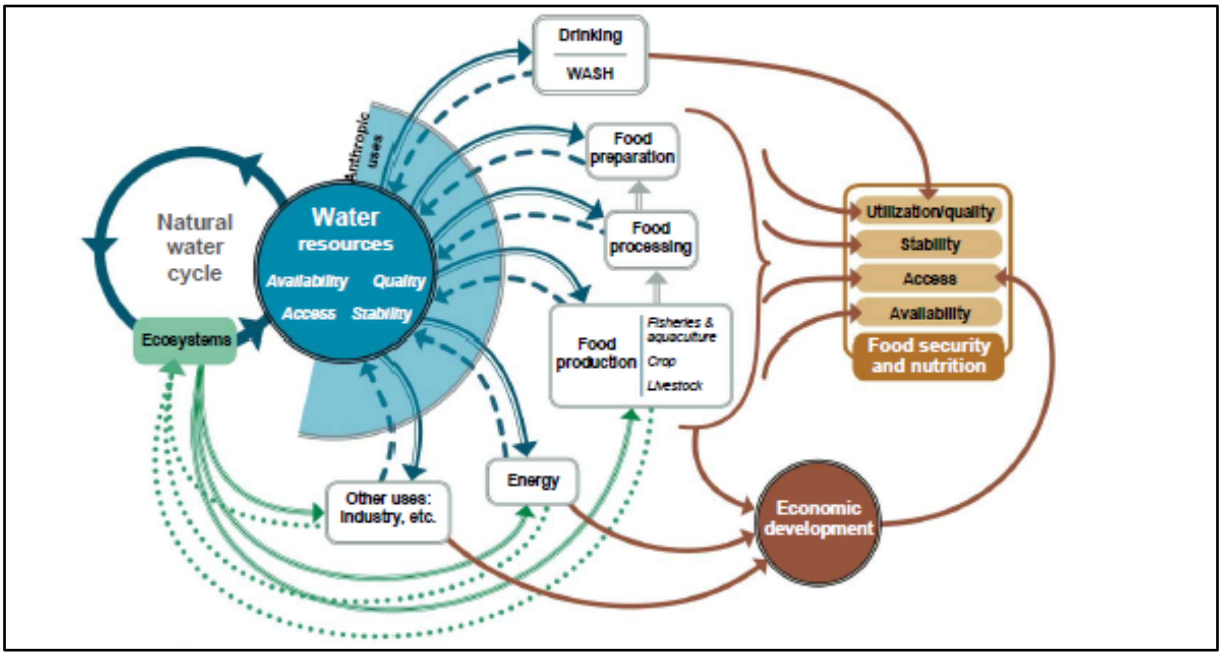

Figure 4. The multidimensional relationship between water stress, food security and socioeconomic development.

Source: HLPE (2015).

First, water is essential for drinking. An adequate access to drinking water sources of a certain level of quality, as well as for sanitation and hygiene (WASH) has proved key in ensuring good health and nutrition. Actually, diarrhea is currently the second cause of child death globally (HLPE, 2015), also causing morbidity problems, dysfunctions in the immune system and retardation in the development of physical and cognitive skills that can eventually impact on education and socioeconomic development (WHO, 2010).

Water is also necessary for food production (Crops, meat…), food processing (at the industrial sector) and food preparation (at the household level). Water quality is especially important for these functions, as a poor quality could lead to food contamination, impacting public health, food security and nutrition. Low water quality used in irrigation may also be the cause of an insufficient crop yield, affecting food availability and socioeconomic growth by diminishing the added value in the agricultural sector (FAO, 1985). In this respect, agriculture proves particularly important to monitor, as it accounts for approximately 70% of total water withdrawals globally (FAO – AQUASTAT, 2014).

Likewise, energy generation demands for a substantial proportion of water resources. Actually, a 15% of total global water withdrawals is estimated to be devoted to the energy sector, either for thermal, hydropower or nuclear plants (WWAP, 2009). Biofuels are also at the core of the problem, especially if they come from irrigated crops consuming significant amounts of water. Since a reliable energy supply is key for social and economic development, water stress will ultimately hinder economic development.

Finally, water is crucial for all the sectors in the economy. Thus, a sufficient availability and optimal allocation of resources proves essential for economic and social development. Moreover, economic growth is, in turn, one of the most important aspects for food security in all its dimensions (HLPE, 2015), as increasing income improves access to food, utilization (through higher education levels, gender equality and other factors), stability (by means of a stable macroeconomic and political environment) and eventually availability (securing food processing and production).

As a consequence, it must be concluded that a proper management of water resources has a paramount role in explaining food security and socioeconomic development across countries and should be therefore considered in the design of public policies addressing these issues.

3 The Effects of water stress on food security and socioeconomic development in the Mediterranean.

After an extensive review of the theoretical background, in this section the empirical analysis of the effects of water stress on food security and socioeconomic development will be implemented. First, we will explain the empirical approach and the state of the art behind the implemented empirical models. Afterwards, a description of the selected variables and indicators used in the analysis will be included. In a third subsection, the methodology employed will be covered. Finally, results will be discussed, leading to the elaboration of maps of food security risks in the Mediterranean, both currently and under different climate change scenarios for 2050.

3.1 Empirical approach

For the purpose of this deliverable, an econometric model is implemented in which our two variables of interest, food security and socioeconomic growth are regressed on a set of factors that are intended to explain them.

The abovementioned dimensions of food security, socioeconomic development and water management can be proxied in many different ways. Regarding food security, numerous approaches and indicators have been employed, most of them based on a descriptive analysis of widely available indicators from different international organizations (FAO, World Bank, etc…). Among the most used descriptive indicators we find those included within the FAO Food Security Indicators dataset, which was built after the recommendations provided by the Committee on World Food Security (CFS) Round Table on hunger measurement held in 2011, and gave rise to an initial set of indicators for the four above-mentioned dimensions of food security that is reviewed and updated every year. Several authors have tried to describe food security by means of composite indexes that build in some or all the dimensions of food security such as the Global Food Security Index (GFSI) developed by The Economist Intelligence Unit, first released in 2012 based on affordability, availability, and quality & safety of food. However, to our knowledge, the most ambitious study involving a systematic exploration of the general determinants of food security involving econometric techniques is Dithmer and Abdulai (2017). Although the main aim of the paper by Dithmer and Abdulai (2017) is to analyze the effects of trade on food security, they succeed at including a thorough review and selection of the main factors determining the level of food security observed at country scale. Therefore, we follow them as reference for the choice of main drivers and determinants of food security to be included in our empirical analysis/model. Then, we will include variables related to the different dimensions of water stress and vulnerability as additional explanatory variables to assess their effect on food security.

With respect to the socioeconomic development, there currently exist a wide variety of theoretical and empirical approaches to its measurement and the study of the factors influencing it. For the purpose of the analysis of this deliverable we will depart from one of the most commonly accepted frameworks, the Solow's model (Solow, 1956), in which initial level of income, population growth and physical capital investment are considered as factors explaining socioeconomic development. Particularly, we will use as reference the extension proposed by Mankiw et al. (1992) in which the Solow's model is augmented by human capital, and we will include our variables related to water stress as additional explanatory variables in order to test their influence.

Water scarcity is a relative and dynamic concept that can occur at all levels of supply and demand, but it is also a social construct: its causes are intimately related to the human intervention in the water cycle. However, approaches to measure water scarcity have differed greatly focusing on different dimensions of the concept (see e.g. Damkjaer and Taylor (2017) for a review on different metrics for water scarcity). Traditional measures of water scarcity usually involved either physical (hydrological) measures or metrics accounting for minimum human requirements. One of the most widely used indicator in this respect is the Falkenmark Index (Falkenmark et al. 1989) that measures available natural renewable water resources per capita and establishes several thresholds of water availability that could lead to potential conflict over water use (Jemmali and Sullivan, 2014). According to this indicator, bellow 1,700 m3/capita/year would already imply regular problems derived of water stress. Between 500 and 1000 m3/capita/year, limitation to human health, well-being and economic development would appear. And the threshold of under 500 m3/capita/year would signal major constraints to life. Other commonly used metrics try to include the consideration of the satisfaction of human needs. That is the case of the threshold of 50 liters/person/day marked by Gleick, (1996) as the one necessary to cover basic needs related to drinking, bathing, sanitation, and cooking.

However, following the recognition of water scarcity as a multi-faceted concept, measurement of water scarcity and security has evolved towards more holistic approaches aiming at considering water scarcity as a phenomenon related not only to physical aspects, but also to economic, institutional, political and managerial conditions. For example, building on the initially applied measures for physical water scarcity, other authors have tried to include other dimensions, such as the social or economic dimension relating to the access to resources and the capacity to properly use them. In line with this, Molden et al. (2007), for example, refer to physical and economic water scarcity, accounting for water uses and management in different sectors. Other attempts have tried to reflect the relevance of social vulnerability in water management and use. That is the case of the Water Poverty Index (WPI) (Sullivan, 2002; Sullivan et al., 2006), that considers water stress and scarcity from a four dimension perspective (Resources, Access, Capacity and Use). The "Resources" dimension would make reference to water availability (accounting also for quality). "Access" refers to how well population is provisioned with the resource. Intra-allocation of water resources, depending usually on aspects such as education, health, equality and affordability is included in the "capacity" category. Finally, "Use" accounts for the way in which water is managed across sectors and how it contributes to the economy (Sullivan et al., 2006). An extra dimension, environment, is also sometimes considered with the aim of capturing the environmental impacts of water management.

For the analysis intended in this report, we build on the construction of water scarcity provided by the WPI, as he four dimensions considered in the WPI account for the ones considered in the theoretical framework by HLPE, 2015 used as reference point for the analysis (Described in Section II), with the exception of stability. This is similar to the approach adopted by Scardigno et al. (2017) that explored the links between water scarcity and food security using as well a modified WPI to explore correlations between the GFSI and the dimensions of water poverty. In this report we follow Jemmali and Sullivan (2014), which apply the WPI to analyze specifically water conflicts in the NENA region, for the selection of the indicators to be used, as it intends to be an adaptation of the Water Poverty Index suitable for this region.

3.2 Data and variables.

The empirical analysis in this deliverable builds on an extensive database that was constructed during the duration of task 1.3. The mentioned database is based on our own elaboration matching data from different data sources (FAO, World Bank, FAO Aquastat, UNESCO, among others), covering all the countries in the Mediterranean region[1] and including up to 60 variables that after detailed analysis was limited to 29 selected variables. Variables are collected for periods that range from 1960 to 2017 depending on the availability of data and time coverage for each proxy and indicator. However, for the purpose of the econometric analysis, we had to remain with the period for which all the included variables had been gathered (2000-2015). More details on the data content, variables employed, definitions and data sources of the built database are included in Annex I. Therefore, in this section we will focus on the selection of variables and indicators to be employed for the measurement of the intended concepts.

The final selection of variables is as follows. For food security, after the Committee on World Food Security in 2011, a battery of indicators was designed in order to measure the evolution in the four identified dimensions of food security -availability, access, utilization and stability. However, for the purpose of our empirical analysis and development of the econometric model, only one variable must be chosen as a proxy indicator of the level of food security within a country. According to the framework provided by the Global Platform on Integrated Food Security Phase Classification (IPC Technical Manual 3.0., *forthcoming*), presented in the State of Food Security and Nutrition in the World 2018 report (see page 61 in FAO et al., 2018), the four acknowledged dimensions of food security, together with factors that determine nutritional security, drive actual food consumption in a country in terms of energy quantity and nutritional quality of food intake. Thus, we will use a measure of energy supplied in the diet as a proxy for food security. When only one indicator is showcased as a summary metric for the monitoring of public policies of food security, PoU or Average Dietary Energy Supply Adequacy (AvDESA) are usually the most common ones to be employed, being both variables intimately related to each other. The PoU is estimated as the percentage population whose dietary energy consumption is below minimum energy requirements (see Annex I). The AvDESA is a ratio between the average dietary energy supply and the estimated dietary energy requirement estimated for each country (considering its population composition). Figure 5 shows the relation between PoU and AvDESA in selected Southern and Eastern Mediterranean Countries for the period 2000-2015. As show in this figure both variables are inversely related. Therefore, when AvDESA increases PoU decreases (see Annex II for a graphical representation of recent trends of PoU and AvDESA in Southern and Eastern Mediterranean Countries).

However, for the PoU indicator, FAO does not publish the actual figures of the countries that exhibits values below 2.5%. In the Mediterranean region, particularly in the North Mediterranean region and in some parts of Middle East and North Africa, figures below this

[1] The Mediterranean region comprises of 22 countries: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, Turkey

threshold are rather common. As a consequence, using PoU as the reference variable would exclude a non-deniable proportion of the countries from the Mediterranean region from the analysis. Therefore, we decided to use AvDESA -elaborated by FAO as part of their set of food security indicators- as the reference variable for our analysis of food security.

a)	PoU (%) (2014-2016)	AvDESA (2014-2016)
Algeria	4.6	143
Egypt	4.5	152
Lebanon	5.4	125
Israel	< 2.5	160
Libya	-	140
Morocco	3.5	145
Syria	-	134
Tunisia	5	142
Turkey	< 2.5	158

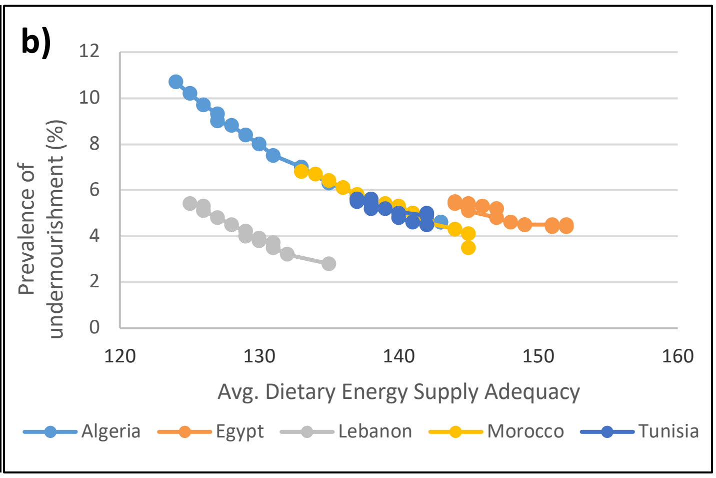

Figure 5. Relation between PoU and AvDESA in Southern and Eastern Mediterranean Countries. Panel a) shows the values of PoU and AvDESA for southern and Eastern Mediterranean countries in the period 2014-2016. Countries with a low PoU present high AvDESA (green rows), while countries with a higher PoU present lower levels of AvDESA (orange rows). Countries in the intermediate range of PoU are also in an intermediate range for AvDESA (yellow rows). Panel b) shows the relation between PoU and AvDESA for the period 2000-2016 (each point corresponds to one year) in selected countries.

Source: FAO, 2017b.

With respect to the variables that explain food security in each country, as explained above, we build on the work by Dithmer and Abdulai (2017) that build a model to explain food security, using trade, GDP per capita, GDP growth, inflation, arable land per capita, cereal yield, rural and total population, armed conflicts and natural disasters as explanatory variables. Particularly, we included trade in the model using the sum of exports and imports as a share of GDP (*Trade*). For the economic dimension we use the variables *GDPpercapita* and *GDP_growth*, and the variable *Inflation_index* as the annual inflation rate. Then we included *Arableland_pc*, which is the availability of arable land per capita, *CerealYield* with represents the harvested production of cereals per hectare. The variable *Ruralpopulation* represents the share of total population living in rural areas, while *Totalpopulation* refers to all residents in a country expressed in thousands of individuals. Conflicts and natural disasters are represented through the variables *Percent_ConflictNewDisplacements* and *Percent_DisasterNewDisplacements* which represent the percentage population internally displaced associated to conflicts and disasters respectively.

With regard to socioeconomic growth, following the model proposed by Mankiw et al. (1992), variables accounting for the initial level of income, population growth, physical capital investment and human capital are used as explanatory variables for GDP growth, which is the variable we use as indicator for socio-economic development (*GGDP*). The initial level of income is proxied by averages of five-year periods of GDP per capita (*InitialGDP_5yearavg*)[2]. Gross fixed capital formation (*Gross_fixed_cap)* as share of GRP is included as to account for the level of physical capital investment in an economy, while population growth is measured as the population growth rate adding a fixed coefficient equal to 0.05 (*PopGrowth_plus0.05*)[3]. Human capital is accounted for by including measures of the level of enrollment rates in education. Because the countries included in our analysis are in very different stages of socioeconomic development, we distinguish among different levels of education, that is primary, secondary and tertiary (*PrimarySchoolEnrollment, SecondarySchoolEnrollment*, *TertiaryEnrollment*). Finally, socioeconomic growth, which is the actual variable to be explained by the model, is measured as the % change in GDP.

For the measurement of the dimensions of water stress, based on Jemmali and Sullivan (2014) and taking into account the availability of data for the countries in the region, we finally work with a set of 10 variables. That is, for the "*Resource*" dimension, we consider total renewable resources, either internal (*Internal_WR*) or external (*External_WR*). "*Access*" is measured through the percentage of the population with access to at least basic sources (*Accesstoatleastbasicdwater*). "*Capacity*" is considered by means of three indicators: *GDPpercapita, Underfivemortalityrate and PrimarySchoolEnrollment*, as proxies of country's level of income, health and education respectively. Squared-GDP per capita (*sq_GDPpc*) is also included because a non-linear relationship with income was suspected. Finally, the three components of the "*Use*" dimension are accounted for. Domestic water use per capita is included as a two-way index[4] such as the one described in Lawrence et al. 2003 (*Domestic_use_index*), aiming at measuring excessive use of water resources at the household level. Water use or efficiency in the industrial sector (*RatioIndustrialwatereff*) is proxied by the ratio of the share of GDP derived from industry and the % of water used in this sector. Agricultural water efficiency (*RatioAgriculturalwatereff)* is computed in the same manner. For some of the indicators of water stress (particularly the ones related to availability and use), values were not available for all the years in the sample. In the cases in which that problem arises, in order not to lose substantial parts of the sample due to missing data in only a few indicators, we have considered them as constant in the years in between.

Finally, we complement the selection of indicators from the WPI by testing in a different model (see model 3 in Table 3, results section) the inclusion of an indicator for precipitation, the logarithm of precipitation (*Precipitation_log*), will allow us to consider the direct impact of climate change on food security. This variable even if not considered in the WPI, may be relevant as well for two reasons. First, even if irrigation is crucial for agriculture in the region, for most countries included in the analysis a substantial share of agricultural land depends on precipitation as source of water (except for Egypt where more than 98% of agricultural land is irrigated, according to FAO-AQUASTAT, 2016). Second, it permits us to account partly for the

[2] This is common practice in the literature on the study of economic growth, as when working with panel data models such as the ones used in this paper, using annual data is not recommended because of the high volatility of growth rates (See for example Islam, 2005).

[3] This is also common practice in the model of economic growth proposed by Mankiw's et al. (1992), as the 0.05 rate is intended to account for technological growth and depreciation rate.

[4] See Lawrence et al. (2003), p. 6. Using the target of 50 l/day set by Gleick (1996), the index takes values between 0 and 1, where 1 equals 50 liters a day. According to Lawrence et al. (2003): "*Countries below the minimum have an index calculated such that the lower the value the more they are below the minimum. Countries above the minimum have a lower value on the index the higher they are above 50 litres. This gives some measure of 'excessive' use*".

stability of water resources. Stability is the only dimension of water resources considered by the HLPE (2015) framework as determinant of food security that is not covered by the WPI. By means of the use of the panel data econometric models described in next section (Section 3.3. Methodology), the inclusion of this variable allows to account for the effects on food security of both the level of precipitation within a country and the variations experienced over time in this indicator.

Descriptive statistics of the variables of the model are depicted in Table 1.

Table 1. Descriptive statistics of the variables included in the models for food security and economic growth.

	Variables	Mean	Standard Deviation	Min	Max
	Avg_DESA	134.3	12.35	105	160
FOOD SECURITY CONTROL VARIABLES	*Trade*	68.28	44.08	5.727	326.1
	GDP_Growth	4.054	6.306	-62.08	88.96
	Arableland_pc	0.274	0.207	0.0126	1.302
	CerealYield	2,632	1,778	107.2	7,570
	Ruralpopulation	39.50	19.85	0[a]	81.21
	TotalPopulation	35,524	23,375	31.80	99,747
	Inflation_index	4.701	0.212	4.502	7.378
	Percent_ConflictNewDisplacements	0.115	2.145	0	69.39
	Percent_DisasterNewDisplacements	0.0218	0.726	0	25.52
	Totalrenewable_WR	1,031	1,259	0.700	6,072
	Accesstoatleastbasicdwater	95.89	6.424	64.13	100
	Underfivemortalityrate	47.20	63.24	2.300	313.2
	PrimarySchoolEnrollment	90.53	11.08	36.86	100
	GDPpercapita	11,168	19,955	158.9	192,989
	sq_GDPpc	5.225e+08	2.504e+09	25,257	3.724e+10
	Domestic_use_index	0.260	0.260	0.00193	0.946
	RatioIndustrialwatereff	5.457	5.302	0.250	28.78
	RatioAgriculturalwatereff	0.467	1.336	0.0172	7.663
	Precipitation_log	9.688	3.305	-0.386	13.45
	TWW_Reuse	0.209	0.285	0.00200	1.300
ECONOMIC GROWTH CONTROL VARIABLES	*Gross_fixed_cap*	23.15	5.865	5.200	48.59
	PopGrowth_plus0.05	6.305	1.268	-0.814	12.06
	SecondarySchoolEnrollment	75.65	24.95	10.04	130.8
	TerciaryEnrollment	29.98	21.92	1.301	117.4
	InitialGDP_5yearavg	19,220	28,497	1,235	155,490

[a] This zero value corresponds to Monaco.

3.3 Methodology

For modelling purposes, we adopt a panel data[5] econometric approach. The empirical analysis uses a fixed effect model, including both country and year fixed effects, thus allowing to account for the extraordinary complexity and diversity of the Mediterranean countries, and enabling comparison across countries and over time.

The estimated models takes the following generic form for country *i* during period *t*:

$$Avg\_DESA_{i,t} = \beta \cdot X_{i,t} + \gamma \cdot W_{i,t} + \alpha_i + \delta_t + u_{i,t}$$

$$GGDP_{i,t} = \beta \cdot Z_{i,t} + \gamma \cdot W_{i,t} + \alpha_i + \delta_t + u_{i,t}$$

Where Avg_DESA and $GGDP_{i,t}$ are our variables of interest: "Average dietary energy supply adequacy" for the model of food security and "GDP growth" in the model of socioeconomic development. $X_{i,t}$ and $Z_{i,t}$ would be the general determinants of, respectively, food security and socioeconomic development, whose choice has been explained in Section 3.2. $W_{i,t}$ represents the set of variables related to water stress in the four explored dimensions. α_i depicts the country fixed effects that control for omitted time-invariant country-specific variables. δ_t are the time dummies controlling for common time trends affecting the countries in the dataset. Finally, $u_{i,t}$ is a random disturbance term.

3.4 Results

3.4.1 Food security model estimation

The first difficulty that we find is that two of the countries in the region (Monaco and Palestine) lack most of the indicators on food security, and more specifically the indicator of AvDESA that we use in this document. Therefore, these countries had to be excluded from the estimations. Some other countries such as Montenegro and Bosnia could not be included as well, due to missing data in some of the relevant indicators of water stress and management.

The results of the models of food security are depicted in Table 3. R^2 of the estimated models are rather high (around 0.7-0.8), except for the last case that will be explained later on. In order to improve readiness in the interpretation of the estimated results and coefficients, a color has been assigned to the variables related to the four dimensions of water stress: "*Resources*" takes the light-blue color, "*Access*" is highlighted in light red, the "*Capacity*" variables are stressed by means of the green colored area and the "*Use*" dimension is attributed a light orange shadow. Finally, the variable in grey is related to the Treated Waste Water at the country level.

Model 1 includes all the general determinants of food security, along with the considered variables of water stress, and both country and year fixed effects. An F-test that all the coefficients on the time dummies are zero is rejected, implying that the time effects are jointly significant and must therefore be included in the model for a proper specification. Also, the

[5] A panel dataset is one that has multiple observations on the same unit (in our case, the countries) over several years.

Hausman test is rejected, signaling that the random effects (RE) specification would yield inconsistent estimates. Consequently, we remain with the fixed effects (FE) specification. A test of the Variance Inflation Factor (VIF) found problems of collinearity among the variables of internal (*Internal_WR*) and external (*External_WR*) renewable water resources. Therefore, we included total renewable water resources (*Totalrenewable_WR*), accounting simultaneously for internal and external renewable resources, as a proxy of water availability instead. Table 2 includes the Variance Inflation Factor for the variables included in the empirical analysis. As a rule of thumb, values lower than 10 are considered as a sign of multicollinearity not being a problem (Hair et al. 1995). Apart from GDP per capita and Squared-GDP per capita, which are obviously related since one is a geometrical combination of the other, VIF values are within the expected ranges and the mean VIF remains below that threshold, implying that no multicollinearity problem is detected.

Table 2. VIF of the variables included in the model for food security.

Variable	VIF
Trade	6.11
GDPpercapita	63.11
sq_GDPpc	38.01
GDP_Growth	2.09
Percent_ConflictNewDisplacements	1.23
Arableland_pc	4.09
CerealYield	3.63
Ruralpopulation	7.03
TotalPopulation	2.27
Percent_DisasterNewDisplacements	1.19
Inflation_index	1.96
Underfivemortalityrate	10.26
PrimarySchoolEnrollment	7.66
Totalrenewable_WR	3.91
Accesstoatleastbasicdwater	3.9
Domestic_use_index	3.31
RatioIndustrialwatereff	3.3
Agr_waterefficiency	2.71
Mean VIF	6.4

With respect to the general determinants of food security, as expected, an increase in *ArableLand_pc* (number of hectares per person) and a higher level of GDP growth are expected to impact positively on food security. However, a lower % of the total population residing in rural areas is related to lower levels of food security. This is consistent with findings in other papers (See, for example Dithmer and Abdulai, 2017), indicating that urbanization processes may be related to higher calorie intakes. Finally, higher inflation indices are found to be positively related to food security.

Regarding the variables related to water stress, we find that *Totalrenewable_WR* (*"Resource"* dimension) is not significant in the model, while a higher level of access to at least basic drinking water services (*"Access"* dimension) is statistically significant and positively related to AvDESA. Regarding *"Capacity"*, we find that all the variables are significant on food security levels. Particularly, a lower rate of under-five mortality is related to higher levels of food security. Likewise, increases in GDP per capita and primary school enrollment rates seem to be associated with an improved food security. However, the relation with GDP is not linear -as shown by the negative and significant coefficient of *sq_GDPpc*- meaning that GDP impacts positively on food security but this impact becomes smaller as GDP increases. With respect to the variables of the "*Use*" dimension, we find that an adequate use of water at the domestic level and higher water use efficiency in the industrial sector tend to increase food security. However, agricultural water efficiency does not seem to affect it. This may be due to the fact that the index that we use (following the Water Poverty Index structure) is related more to water efficiency in terms of income generation (relative to other sectors) than to actual productivity of resources. Since agriculture is usually a sector with lower contributions to a country's GDP, and given that the purpose of this model is studying the effects of water efficiency in this sector on food security, probably it is more relevant to analyze water efficiency in terms of agricultural production. Therefore, we redesign this index and express it in terms of the ratio between Cereal Yield (as a proxy of agricultural productivity) and the share of total water consumption used in agriculture. Model 2 shows the results obtained when the index instead of the previous one. As suspected, when agricultural water efficiency is considered from the perspective of actual agricultural production with respect to water use in agriculture, it is found to be positively related to AvDESA. Results for the rest of variables of the model are robust to the change of specification.

Overall, our results seems to indicate that food security levels in the Mediterranean countries may be more dependent on access to the resource, the capacity to use that resources adequately (education, health and affordability) and the proper management or use of water resources across all the sectors in the economy (Domestic, industrial and agricultural), than to actual availability.

As a final step of the explanatory model, we report the elasticities (% increase in food security indicators for each % change in the considered variables) for the selected explanatory model (Model 2) (see Table 4). For a correct contextualization and interpretation, it should be noted that the levels of fluctuation in AvDESA do not range from 0, but countries usually depart already from a high level of the indicator (146, 133 and 144 in the case of Egypt, Morocco and Tunisia, respectively). Therefore, even small fluctuations in the dependent variable entail a great proportion of the improvements achieved in the last more than 15 years. Regarding the most relevant factors in explaining food security in the region, and paying particular attention to the variables related to water stress (main focus of our analysis), we can observe that, in what food security is concerned, *"Access"* is the most relevant dimension of water management. Its importance would be actually substantially higher than the one of other variables such as GDP per capita, that have been widely acknowledged as paramount for food security. In fact, the magnitude of the elasticity of *Accesstoatleastbasic* is three times higher than the one displayed by GDP per capita. However, it must be noted that while there is only one variable representing access to water resources in the model, there are several other variables related to economic development having an impact on food security. The second dimension of water stress in level of impact on food security would be "*Capacity*", mainly GDP per capita and under five mortality rates, with the rates of primary school enrolment being a bit less influential. Finally, "*Use*" is also an important dimension. Particularly, an adequate use of water at the domestic level seems to be the most important for food security among the considered sectors, with water use in industry and agriculture showing a similar level of impact.

As explained above, a third model is estimated including precipitation (Model 3). Precipitation is not included in the WPI used as theoretical background reference, but it may reflect stability of water resources availability. This variable was not included in previous estimations, as for several countries in the region (Greece, Israel and Libya) it was not possible to find data on precipitation levels that was homogenous with the employed source (United Nations. See Annex I for a more detailed description of variables and sources). However, given that the total renewable water resources available are not found significant, precipitation is included in a third model as it will permit to assess the effects of climate change in future food security. Precipitation levels are found to be significant and having a positive impact on food security. Some of the main drivers and determinants seem to lose its significance when the sample is reduced. This is usual, as in the subregion considered those variables may not be as impactful as for the Mediterranean region as a whole.

One last model (Model 4) is estimated in which all the countries with available data for food security are included at the expense of removing the variables that have problems of missing data (Precipitation, total renewable resources and agricultural efficiency). The purpose of this last model is to show that results are robust when the whole available sample is considered.

Finally, because this project is related to the use of treated waste water reuse (*TWW_reuse*), we decided to test its influence on food security. One problem that we found is that data for TWW is only available for 13 over the 22 Mediterranean countries, which significantly reduces the estimation sample. However, even with the encountered limitations, we found it an interesting and revealing exercise. Thus, Model 5 shows the main model (Model 1) with the inclusion of *TWW_reuse*. A significant and positive relationship is found between an increased reuse of TWW within a country and the levels of food security observed. When only main drivers of food security and *TWW_reuse* are used for the estimation (removing the water stress variables in an attempt to isolate the effect of this variable), similar results are reached (Model 6).

Table 3. Results for the fixed effects panel data models for food security, including both country and year fixed effects.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Trade	0.0152	0.0146	-0.0216	0.0228	0.0476***	0.00217
	(0.0183)	(0.0182)	(0.0176)	(0.0175)	(0.0133)	(0.0135)
GDP_Growth	0.113*	0.119*	0.102	0.0916	0.110**	0.186***
	(0.0649)	(0.0651)	(0.0703)	(0.0620)	(0.0468)	(0.0595)
Percent_ConflictNewDisplacements	-244.8	-245.7	-145.5	-280.1	-179.2	133.1
	(255.1)	(254.5)	(230.7)	(251.5)	(162.3)	(249.3)
Arableland_pc	65.15***	64.81***	66.96***	69.26***	-28.37**	-39.71**
	(13.56)	(13.54)	(12.40)	(13.04)	(13.69)	(18.21)
CerealYield	-7.39e-05	-4.33e-05	-0.000557	-3.90e-05	9.43e-05	0.000597
	(0.000358)	(0.000356)	(0.000359)	(0.000351)	(0.000270)	(0.000392)
Ruralpopulation	-0.520***	-0.525***	-0.651***	-0.464***	1.275***	0.0779
	(0.127)	(0.126)	(0.131)	(0.121)	(0.189)	(0.237)
TotalPopulation	5.03e-07	4.77e-07	8.97e-07	2.21e-07	7.75e-08	2.20e-08
	(1.08e-06)	(1.08e-06)	(1.06e-06)	(7.98e-07)	(7.24e-07)	(8.06e-07)
Percent_DisasterNewDisplacements	-41.23	-41.98	-60.92	0.1000	-19.73	-49.94
	(52.93)	(52.85)	(46.95)	(0.877)	(34.42)	(54.22)
Inflation_index	0.699***	0.697***	1.330***	0.674***	0.0709	1.058***
	(0.264)	(0.263)	(0.331)	(0.254)	(0.197)	(0.282)
Totalrenewable_WR	-0.000231	-0.000248	-0.000468		0.000200	
	(0.000709)	(0.000708)	(0.000712)		(0.000456)	
Accesstoatleastbasicdwater	0.262**	0.256**	0.395	0.247**	0.686***	
	(0.124)	(0.124)	(0.248)	(0.121)	(0.0903)	
Underfivemortalityrate	-0.511***	-0.511***	-0.169	-0.521***	-0.430***	
	(0.0989)	(0.0988)	(0.107)	(0.0973)	(0.0687)	
PrimarySchoolEnrollment	1.885***	1.871***	0.502	1.981***	-0.411	
	(0.619)	(0.618)	(0.717)	(0.609)	(0.478)	

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
GDPpercapita	0.000548*** (0.000179)	0.000527*** (0.000180)	0.000833*** (0.000186)	0.000569*** (0.000177)	0.000292** (0.000131)	-0.000166 (0.000159)
sq_GDPpc	-7.54e-09** (2.94e-09)	-7.27e-09** (2.94e-09)	-1.48e-08*** (2.85e-09)	-7.78e-09*** (2.89e-09)	-1.59e-09 (2.12e-09)	-7.04e-10 (2.67e-09)
Domestic_use_index	5.820*** (1.555)	5.818*** (1.552)	8.039*** (1.677)	5.805*** (1.529)	1.609 (1.060)	
RatioIndustrialwatereff	0.181** (0.0798)	0.178** (0.0796)	0.148* (0.0804)	0.209*** (0.0764)	0.0943 (0.0581)	
RatioAgriculturalwatereff	0.578 (0.381)					
Agr_waterefficiency		0.000240* (0.000141)	0.000122 (0.000126)			
Precipitation_log			1.373* (0.809)			
TWW_Reuse					2.373** (0.918)	2.488** (1.167)
Constant	117.8*** (14.53)	118.8*** (14.54)	89.57*** (28.62)	115.8*** (14.25)	42.06*** (11.27)	142.1*** (6.683)
COUNTRY FIXED EFFECTS	YES	YES	YES	YES	YES	YES
YEAR FIXED EFFECTS	YES	YES	YES	YES	YES	YES
Observations	223	223	171	229	171	185
R-squared	0.693	0.694	0.799	0.687	0.784	0.436
Number of Countries	18	18	15	20	13	13

Table 4. Elasticities for the selected model of food security (Model 2).

Variables	Elasticity
Trade	0.00917
	(0.0114)
GDP_Growth	0.00270*
	(0.00147)
Percent_ConflictNewDisplacements	-8.74e-05
	(9.23e-05)
Arableland_pc	0.0854***
	(0.0175)
CerealYield	-0.00120
	(0.00984)
Ruralpopulation	-0.131***
	(0.0325)
TotalPopulation	0.00145
	(0.00326)
Percent_DisasterNewDisplacements	-0.000142
	(0.000179)
Inflation_index	0.00687***
	(0.00258)
Totalrenewable_WR	-0.00169
	(0.00485)
Accesstoatleastbasicdwater	0.182**
	(0.0879)
Underfivemortalityrate	-0.0603***
	(0.0122)
PrimarySchoolEnrollment	-0.00234***
	(0.000837)
GDPpercapita	0.0586***
	(0.0198)
sq_GDPpc	-0.0208**
	(0.00837)
Domestic_use_index	0.0143***
	(0.00382)
RatioIndustrialwatereff	0.00701**
	(0.00310)
Agr_waterefficiency	0.00159*
	(0.000921)
Observations	223

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.4.2 Socio-economic development model estimation

Results of fixed effects panel data models for economic growth are displayed in Table 5. *Gross_fixed_cap* and *PopGrowth_plus0.05* exhibit the expected signs in the context of the Solow model, implying that higher levels of physical capital are related to higher economic growth and that higher population growth and depreciation rates hinders growth by raising the necessary threshold to realize growth potential (Solow, 1956; Solow 1999). Human capital contributes significant and positively to economic growth, being the rate of enrolment in primary school the most relevant indicator explaining human capital contribution to growth in the context of the Mediterranean region (See Model 7).

Table 5. Results for the fixed effects panel data models for economic growth, including both country and year fixed effects.

Variables	Model 7 Theoretical + water	Model 8 Theoretical + water + stress indicator
InitialGDP_5yearavg	-5.51e-05	-3.42e-05
	(8.94e-05)	(8.89e-05)
Gross_fixed_cap	0.302***	0.268***
	(0.0705)	(0.0714)
PopGrowth_plus0.05	-0.763***	-0.822***
	(0.282)	(0.280)
PrimarySchoolEnrollment	1.393**	1.160*
	(0.676)	(0.676)
SecondarySchoolEnrollment	-0.0483	-0.0453
	(0.0337)	(0.0333)
TerciaryEnrollment	-0.0273	-0.0463*
	(0.0265)	(0.0276)
Totalrenewable_WR	0.00139**	0.00134**
	(0.000652)	(0.000645)
Underfivemortalityrate	-0.110	-0.254*
	(0.124)	(0.139)
Accesstoatleastbasicdwater	0.0272	-0.159
	(0.183)	(0.199)
Domestic_use_index	-1.681	-0.0711
	(1.844)	(1.962)
RatioIndustrialwatereff	-0.138*	-0.0654
	(0.0722)	(0.0786)
Agr_waterefficiency	8.27e-06	-8.73e-07
	(0.000126)	(0.000125)
COUNTRY FIXED EFFECTS	YES	YES
YEAR FIXED EFFECTS	YES	YES
Waterstress		-0.104**
		(0.0469)
Constant	6.665	31.68
	(18.29)	(21.31)
Observations	212	212
R-squared	0.453	0.468
Number of Countries	18	18

With respect to the variables related to water stress, Models 7 and 8 seem to indicate that economic growth is better explained by water "*Availability*" (*Totalrenewable_WR*) and "*Capacity*" (*Underfivemortalityrate and PrimarySchoolEnrollment*), than by "*Access*" or "*Use*" of water resources across the sectors of the economy. Water stress (MDG 7.5 indicator), introduced in Model 8, also appears to be important in explaining economic growth. Particularly, higher levels of water stress are associated to lower levels of economic growth.

Table 6 reports the VIF for the variables included in the model. As it can be seen, all the values within the table remains below the usual rule of thumb of 10 (Hair et al. 1995) for considering the existence of problems of multicollinearity. Hausman test is also rejected, thus favouring the fixed effects specification. Year fixed effects are also found jointly significant and thus controlled for in the model.

Table 6. VIF of the variables included in the model for economic growth.

Variables	VIF
InitialGDP_5yearavg	4.79
Gross_fixed_cap	2.45
PopGrowth_plus0.05	2.12
PrimarySchoolEnrollment	3
SecondarySchoolEnrollment	4.58
TerciarySchoolEnrollment	4.15
Water_stress	2.08
Totalrenewable_WR	2.48
Underfivemortalityrate	8.62
Accesstoatleastbasicdwater	4.07
Domestic_use_index	2.08
RatioIndustrialwatereff	3.16
Agr_waterefficiency	1.82
Mean VIF	3.02

3.5 Future prospects for food security in the Mediterranean under climate change:

Climate extremes are behind some of the recent negative trends concerning food insecurity in the World, and the already experienced and projected future climate change pose a threat to all dimensions of food security (FAO et al., 2018). Thus, enhancing food systems' resilience and adaptive capacity under climate change becomes a priority, to which sustainable and efficient water management and use can importantly contribute.

In this section we explore future climate change scenarios and their impacts on food security in Southern and Eastern Mediterranean countries. For this, first we summarize current food security conditions, and then we present projections for AvDESA.

Using the estimated model for food security we simulated the effects of climate change in future food security for the 2050s time horizon. For this, we selected a set of climate change and socio-economic scenarios from the new scenarios developed within the frame of the IPCC, including Representative Concentration Pathways (RCPs) and Shared Socio-Economic Pathways (SSPs) (see Moss et al., 2010; Van Vuuren et al., 2011; O'Neil et al., 2014). The selected scenarios present alternative optimistic and pessimistic futures as a combination of RCPs 4.5 (intermediate stabilization scenario) and 8.5 (very high emission scenario) with socio-economic scenarios SSP1 (scenario with low emissions and little challenges for mitigation and adaptation to climate change) and SSP3 (high fragmentation, regionalized energy and land policies, slow growth, high challenges for both mitigation and adaptation).

From these scenarios, we selected those variables that will have an impact on food security (according to our model), namely precipitation, determined by future CO_2 concentrations (i.e. RCPs), and GDP, GDP growth, and rural population dynamics, which are determined by the socio-economic scenario (SSPs). Climate data were downloaded and spatially downscaled following Ramirez and Jarvis (2010), using the CCAFS-Climate data portal (CGIAR Research Program on Climate Change, Agriculture and Food Security). We used an ensemble for 30 available General Circulation Model (GCM) projections for the IPCC RCP 4.5 and RCP8.5 scenarios. Data for the socio-economic scenario variables were obtained from the SSP Public Database version 1.1 (2012-2016)[6]

3.5.1 Current situation

In Figure 6, maps a) and b) reflect the current situation of the selected indicators of food security for the countries of the NENA region, PoU and AvDESA. Measures of food security can suffer from both transitory increases and backlashes due to, among other reasons, extreme weather events such as droughts or floods or to the incidence of temporary conflicts. In order to avoid taking an extreme value as a reference for our analysis of the effects of climate change on food security, mean values for the last three years of the sample (2013-2015) were considered instead[7].

As maps a) and b) show, Israel and Turkey are the countries that show the highest levels of food security, with a PoU under 2.5% and AvDESA levels around 160. On the opposite side, with the lower level of food security from among our selected countries, we see Lebanon with a PoU of 5.3% in the last year after surpassing the 5% threshold in 2013, and an AvDESA ratio of 125. With also AvDESA levels lower than the average we find Syria and Lybia (134 and 140 respectively), for which, however, there are no available data on PoU.

[6] Available at: https://tntcat.iiasa.ac.at/SspDb

[7] Values of the selected indicator reported by FAO are three year averages to avoid misinterpretations driven by errors in measurement. Thus, the value taken as reference point for the changes in future food security under climate change are actually average values for the period 2012-2016.

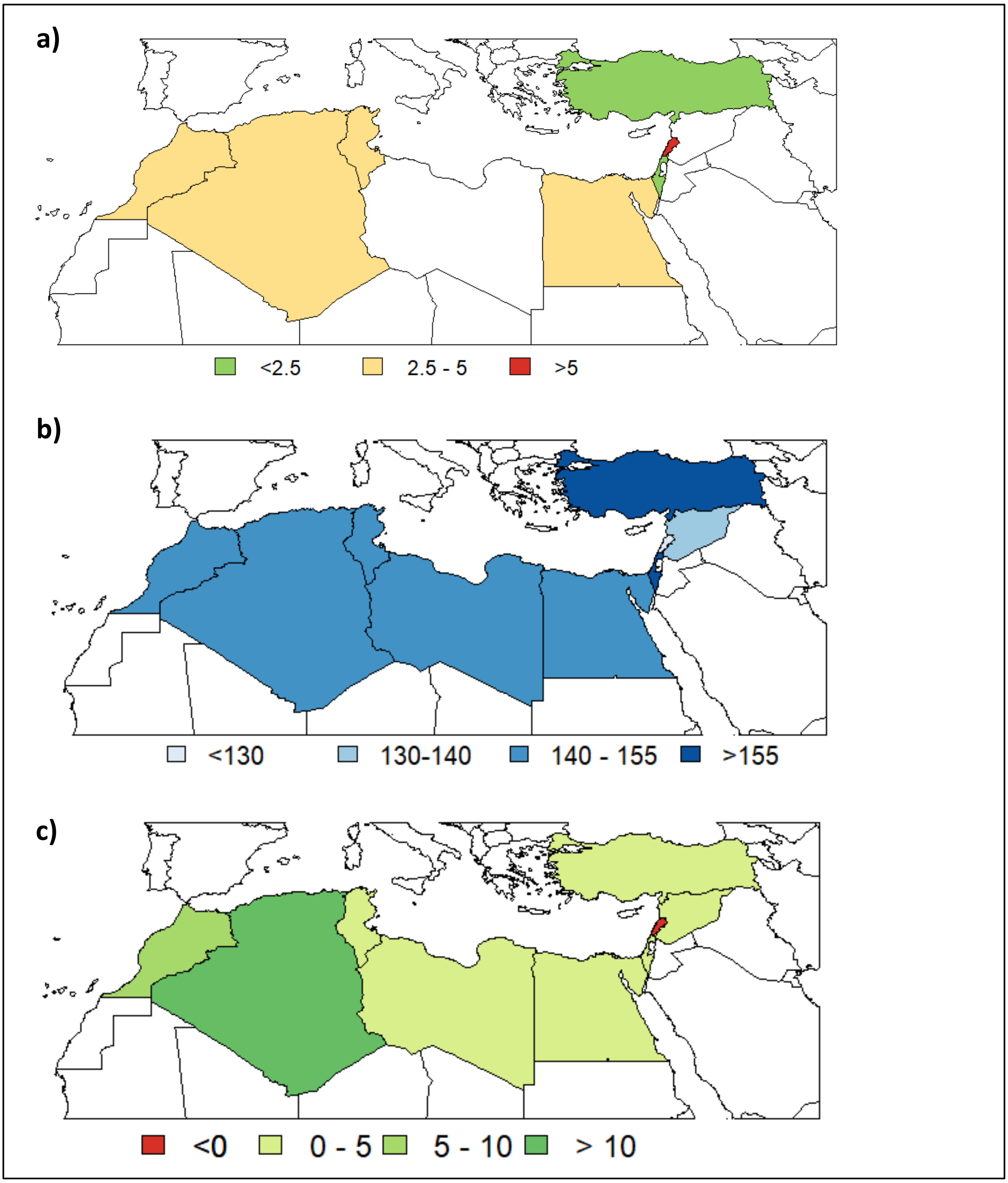

Figure 6. Current state of food security in Southern and Eastern Mediterranean countries.
Map a) PoU, mean value for the period 2013-2015; Map b) AvDESA, mean value for the period 2013-2015; Map c) Progress made in the AvDESA from 2000 to 2015[8].

Source: own elaboration based on data from FAO (2017b).

[8] Average of last 3 years.

The MADFORWATER countries are located within an intermediate range with PoU levels between 2.5 and 5 % and AvDESA levels higher than 140 and up to 155. However, it must be noted that Tunisia is at the limit between the intermediate and low range, with an average PoU of 4.7% between 2013 and 2015, reaching 5% in 2015, and an AvDESA ratio of 142. Despite a notable progress during the period 2005-2012, Tunisia has experienced a sharp increase of PoU in the last years, partly due to political and economic instability (Ouertani, 2016). Egypt and Algeria show similar levels of PoU, 4.4 and 4.6 respectively, but different levels of AvDESA. While Algeria shows an AvDESA ratio of 143 in 2015, the value of the ratio in Egypt for the same year is 152, indicating higher inequality levels in this country regarding food distribution. Finally, Morocco shows a higher level of food security with an average PoU of 4% between 2013 and 2015, but reaching 3.5% in 2015, and an AvDESA of 145.

In our analysis, due to data availability and other reasons that have been previously outlined in section 3.2, AvDESA is the variable selected as the basis for the predictions. Because of this, we focus on this variable to look at the progress made in food security in recent years. Map c) shows the evolution experienced in this particular indicator in the timespan considered in our sample (2000-2015).

As it can be observed, most countries in the region have experienced improvements in the levels of the indicator during the last 15 years, with the only exception of Lebanon whose food security levels have been greatly impacted by the growing influx of refugees from neighbouring countries under conflict. Particularly, Algeria has led those improvements, with an observed increment of about 15%. Morocco, with a 9% increase, follows Algeria among the countries with the highest level of improvement, with Egypt in the third place after an improvement of around 4%. Israel (3.5%) has experienced a more moderate - although also not deniable – increase, followed by Libya (2%). Finally, Turkey, Syria and Tunisia show stable values along the period, but explained by different reasons. In the case of Turkey, its food security level was already high at the beginning of the period, while conflicts and economic instability may have hampered progress in Syria and Tunisia.

3.5.2 Future scenarios

The econometric model developed in previous sections allow predictions of our dependent variable for food security (AvDESA) under changes in the variables related to the RCP and SSP scenarios that were included as explanatory in our model. Therefore, we used it for the simulation of the effects of the future scenarios of climate change on food security. For this purpose, values of the explanatory variables were taken from the abovementioned downscaled RCP and SSP scenarios and employed as inputs for our simulations. Moreover, when computing out-of-sample predictions based on fixed effects panel data models, accounting for the fixed effect has been found as the best performing specification (Baillie and Baltagi, 1999; Baltagi, 2008). Thus, we included it in our forecasting of food security.

For the generation and elaboration of the maps of food security in 2050, several combination of scenarios have been considered. A first round of simulations (Maps d) and e)) take into account only the effects of climate on food security, thus including the changes in the climatic variables related to the different RCP scenarios (i.e. precipitation). The second round of estimations (leading to maps f), g) and h)) aims at showing the net effect on food security once the evolution of the socio-economic variables (i.e. GDP, GDP growth, rural population dynamics) based on SSP scenarios are considered. Therefore, the final estimated scenarios remain as follows:

1) Scenario 1: RCP 4.5 (Map d).
2) Scenario 2: RCP 8.5 (Map e)
3) Scenario 3: Combination of SSP1 and RCP 4.5[9] (Map f).
4) Scenario 4: Combination of SSP3 and RCP 4.5 (Map g).
5) Scenario 5: Combination of SSP3 and RCP 8.5 (Map h).

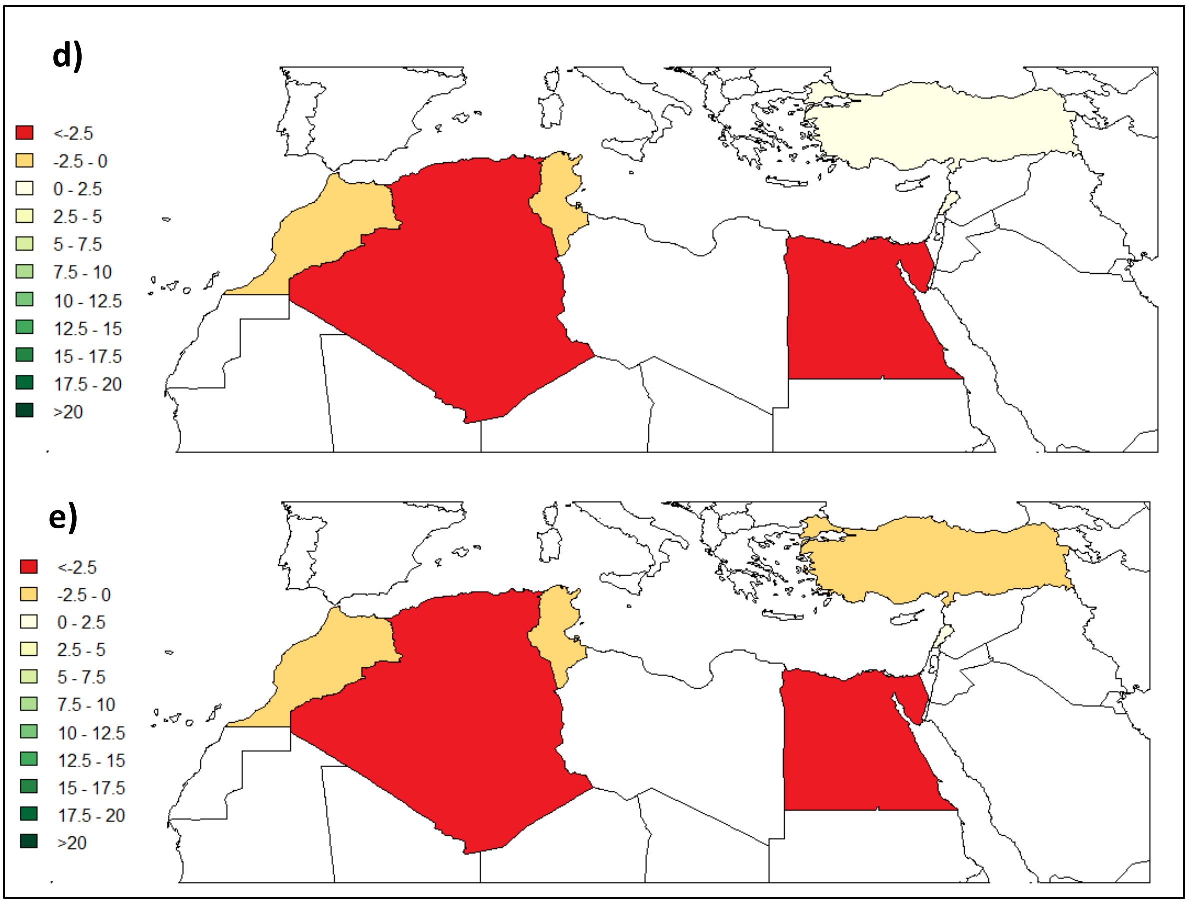

Figure 7. Projected change in AvDESA in Southern and Eastern Mediterranean countries from 2015 to 2050 under climate change scenarios.
Map d) intermediate emissions scenario RCP4.5. Map e) extreme emissions scenario RCP 8.5.

Maps d) and e) in Figure 7 depict the % change in AvDESA under the RCP 4.5 and RCP 8.5. These maps reflect that, when only the effects of climate are considered, the evolution of food security is negative for most of the countries in the region, being slightly worse under more extreme (RCP 8.5) than for the intermediate (RCP 4.5) emission scenario. Most negatively affected countries would be Algeria and Egypt, with projected reductions of AvDESA between 2.5 and 3%, for which projected changes in precipitation under climate change are more negative. Tunisia and Morocco would experience reductions of AvDESA of about 1% and 0.8% respectively in the most negative climate scenario, while the rest of countries would lose about 0.5%. This changes may not be considered as a large impact. However, in relative terms, this may imply significant loses with respect to the progress made from 2000-2015. Particularly, a 2.5% reduction of AvDESA in Egypt would mean losing 47% of the progress made in food security from

[9] Since SSP1 reflects a situation characterized by low emissions, the combination of SSP1 and RCP8.5 (characterized by high emissions) were deemed incompatible and thus not simulated.

2000 to 2015. A 1% reduction of AvDESA in Tunisia would mean losing 28% of the progress made in food security from 2003 to 2012. Finally, a 0.8% reduction in Morocco would imply a 9% of the progress made in food security from 2000 to 2015.

The last three scenarios are depicted in Figure 8. Maps f), g) and h) show that even though climate is expected to have a negative impact on food security, when the evolution of the socioeconomic variables is considered jointly with climate changes, the net observed change in the indicators of food security is predicted to be positive. And, as expected, the observed positive effects are higher for the optimistic SSP1 socioeconomic scenario than for the more pessimistic SSP3. In the same vein, the combination of the more moderate emissions scenario (RCP4.5) with the pessimistic SSP3 yields small improvements in food security but higher than the ones observed when SSP3 is employed in combination with the more extreme RCP8.5. That implies that the positive effect of socioeconomic development (as measured by increases in GDP, GDP per capita and a decrease in the share of rural population implying the existence of urbanization processes) may be more than enough as to compensate the negative effects of climate on food security, even leading to improvements in the selected indicator by 2050.

At the country level, results show that the MADFORWATER countries would be the countries where food security conditions would evolve most positively, with improvements between 17 and 21% in the most positive scenario (RCP4.5+SSP1). For the more negative SSP3 scenario combinations, Tunisia and Morocco would experience improvements in AvDESA, around 6.5% for Tunisia and 4% for Morocco. Egypt, however, would see more moderate improvements (around 2.5%). Results for other countries show how Lebanon could be the country in which food security would experience robust improvements across scenarios due to socio-economic development (improvements between 12 and 16% depending on the scenario).

Overall, the results of our predictions for food security under the SSP and RCP scenarios of climate change seem to indicate that although climate will predictably have a negative impact on food security in the NENA region, socioeconomic development would more than compensate for these negative effects, likely leading to general improvements in food security. This can be mainly explained by the high expected increases and growth rates in socioeconomic variables such as GDP and GDP per capita, together with intense urbanization processes that have been found to be usually accompanied by higher calorie intake and changes in dietary patterns leading to a higher adequacy in average energy supply (Dithmer and Abdulai, 2017).

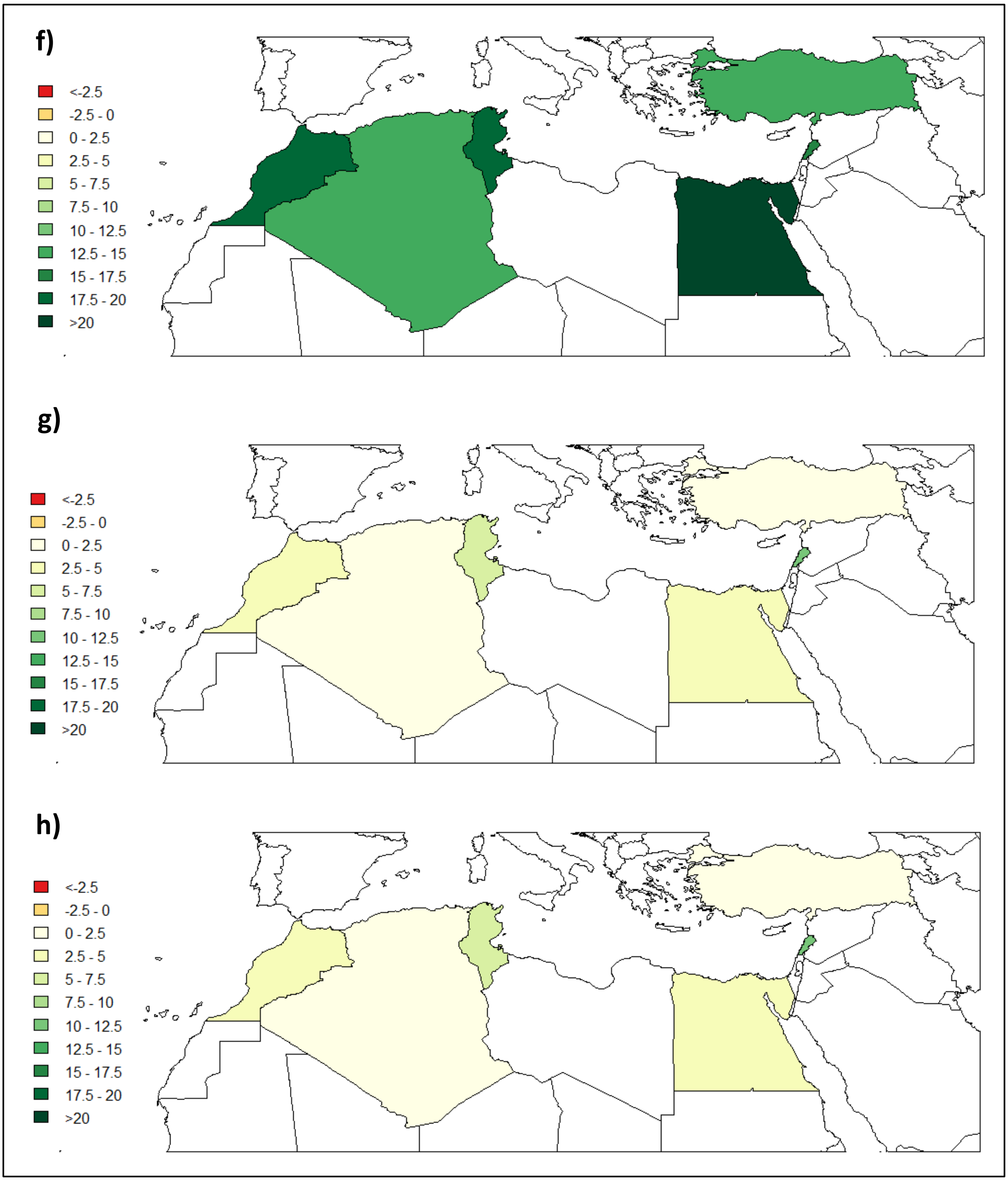

Figure 8. Projected change in AvDESA in Southern and Eastern Mediterranean countries from 2015 to 2050 under combined climate change and socio-economic scenarios.

Map f) RCP 4.5 + SSP1; Map g) RCP 4.5 + SSP3; Map h) RCP 8.5 + SSP3

4 Reports on water stress effects on food security and socioeconomic development in the MADFORWATER countries.

This section includes three reports on the effects of water stress on food security and socio-economic development. For each country a review of recent trends on food security and socio-economic development is provided. Then according to the model developed in the previous section, a reflection is made about the water stress related variables that were found significant for explaining food security and socio-economic development according to the model. Based on this we identify key issues for water management and use and potential avenues for contributing to food security and socio-economic development through improved management and use of water resources.

4.1 Water stress effects on food security and socioeconomic development in Egypt.

4.1.1. Current situation of Food security and socio-economic development

Egypt faces several development challenges despite its status as a middle-income country, some of which are fighting poverty, food insecurity and malnutrition. According to the World Food Programme (WFP, 2015), Egypt was ranked 108 out of 188 countries in the 2015 UNDP Human Development Index, up two places from the previous year, and ranked 131 out of 155 countries on the Gender Inequality Index.

Egypt is the world's largest importer of wheat, so it is vulnerable to fluctuations in food prices. Egypt's fast growing population places increasing pressure on its diminishing agricultural sector and exacerbates food insecurity. Between 2005 and 2015, the population grew from 73 million to nearly 88 million people. More than a quarter of the population (22.3 million) is below the poverty line, of which 3.7 million are considered extremely poor and cannot meet their minimum food needs. Between 2009 and 2011, the prevalence of poverty rose from 22 % to 25 %, affecting 21 million people. The average household spends 40.6 % of its income on food, and one in three Egyptians has poor dietary diversity (FAO et al., 2015).

Figure 9 shows the evolution of the **reference indicators for food security** in Egypt for the period considered in the empirical analysis of this deliverable (2000-2015)[10]. As it can be seen, both AvDESA and PoU follow similar although opposite trends. After an initial period in which both indicators point at a deterioration in the situation of food security in Egypt (from 2000-2005), the trend seems to be towards a steady improvement. Only in the last year, the PoU has experienced a slight increase. However, looking at most vulnerable groups we find that about 20 % of children under five suffer from chronic malnutrition, or stunting, and about 27 % of children under five suffer from anaemia, while 37 % of women between 15 and 49 years-old are overweight and 48 % are obese (World Bank, 2018b). Thus, substantial challenges for food security still remain for the country.

[10] A more thorough description of the variables outlined in the graphs, along with their source and unit of measure can be found in Annex I.

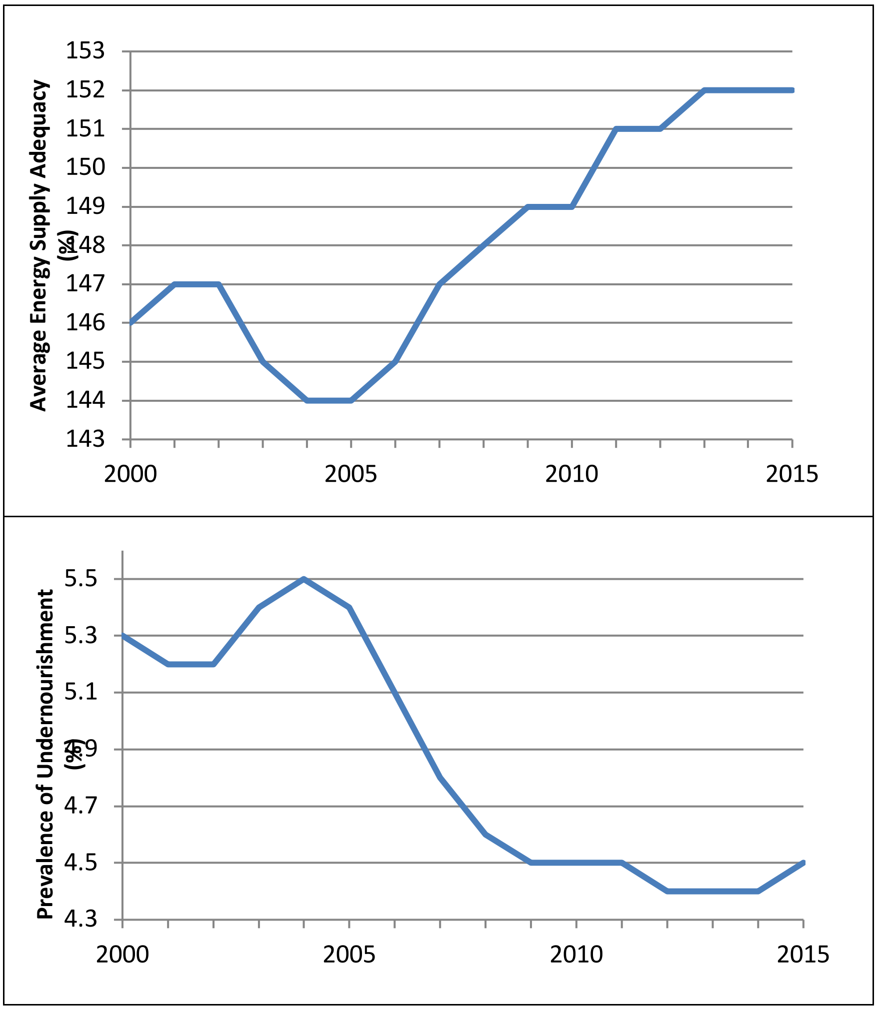

Figure 9. Levels and evolution of AvDESA and PoU in Egypt (2000-2015).

Source: see Annex I on database description

Figure 10 shows the Level and the evolution of GDP per capita and GDP growth for Egypt during the period of reference for this deliverable (2000-2015). GDP per capita has increased at a regular pace (except for the first years, which may explain the negative trend in food security indicators during that same period), going from 1428$ (current $ dollars) to around 3547 (current $ dollars) in 2015.

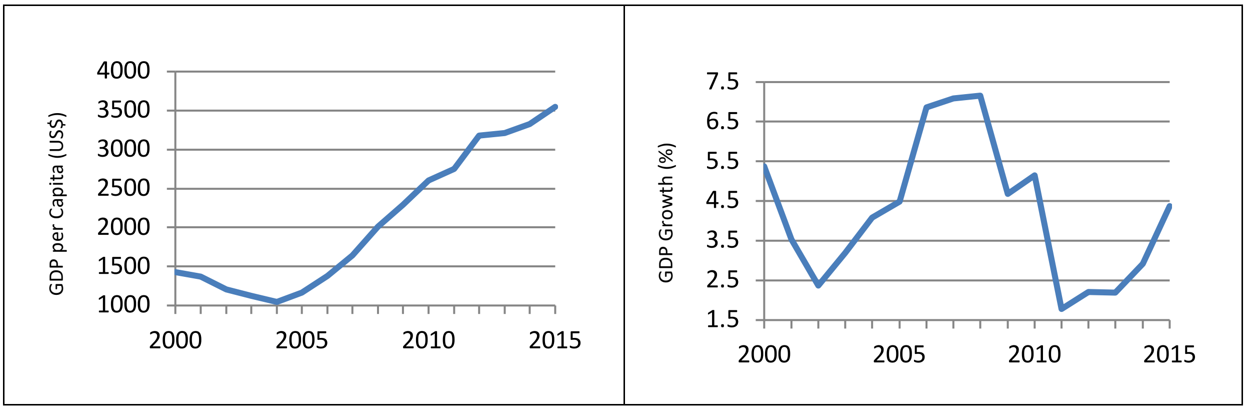

Figure 10. Level and evolution of GDP per capita and GDP growth in Egypt (2000-2015).

Source: see Annex I on database description

Agriculture is among the major economic activity in Egypt and a generator of economic growth. About 24 million Egyptians (or more than one-quarter of the population) work in the farming, forestry and fishing industries. . The average value share of agriculture in the GDP from 1965 to 2017 for Egypt during that period was 18.34% with a minimum of 11.27% in 2012 and a maximum of 29.5% in 1974 (World Bank, 2018b). Today, Egyptian peasants experience serious economic, social and environmental conditions, which partly explain an exodus towards cities, being urbanization a serious threat to agriculture in Egypt.

4.1.2. Recent evolution of variables that affect food security and socio-economic development

Figure 11 shows values from 2000 to 2015 of indicators related to **socioeconomic and land use aspects** which are, according to our models, expected to contribute to food security in Egypt. Particularly with respect to the significant variables in our model, urbanization trends (as measured by a reduction in rural population) could be contributing to an improved food security. An increasing population, limited arable land and the impact of climate variability and extremes have driven migration to urban areas. The trend in per capita arable land should be expected, on the contrary, to go against the observed trends in food security, while the increase in inflation[11] could have favored it.

Displacements due to conflicts and disasters have not been either very frequent or intense in the country. They are mainly confined to 2015 in the case of conflicts, and 2008, 2014 and 2015 (although much smaller in these two last years) in the case of disasters, with apparently (as expected) no direct impact on food security. Trade is increasing in the period previous to the Great Recession (around 2007), while decreasing afterwards. However, this factor is not expected in principle to be significant for food security in the Mediterranean region.

Rising population increases food demand causing pressure on food production in Egypt, especially with the limitations in cultivated land and the high dependence on food trade. Egypt is a heavily populated country, with the largest population in Africa. Egypt's current population annual growth rate is close to 2%, which is faster than the world's average of 1.2%. The country's population increased from approximately 70 million in 2000 to 97 million in 2017 (World Bank, 2018b).

High population growth rates, increasing per capita income and urbanization are major factors behind rising food demand, especially cereals. Egypt's dependency on food imports increased over the years, especially for cereals and wheat, with Egypt being the largest wheat importer worldwide (FAO et al., 2015). The cereal import dependency ratio increased from 35 % in 2000 to 46 % in 2011.

[11] For convenience in the analysis, in Figure 11 Inflation does not represent the inflation index included for estimation purposes following Dithmer and Abdulai (2017), but the actual inflation rates experienced in the country during the studied period.

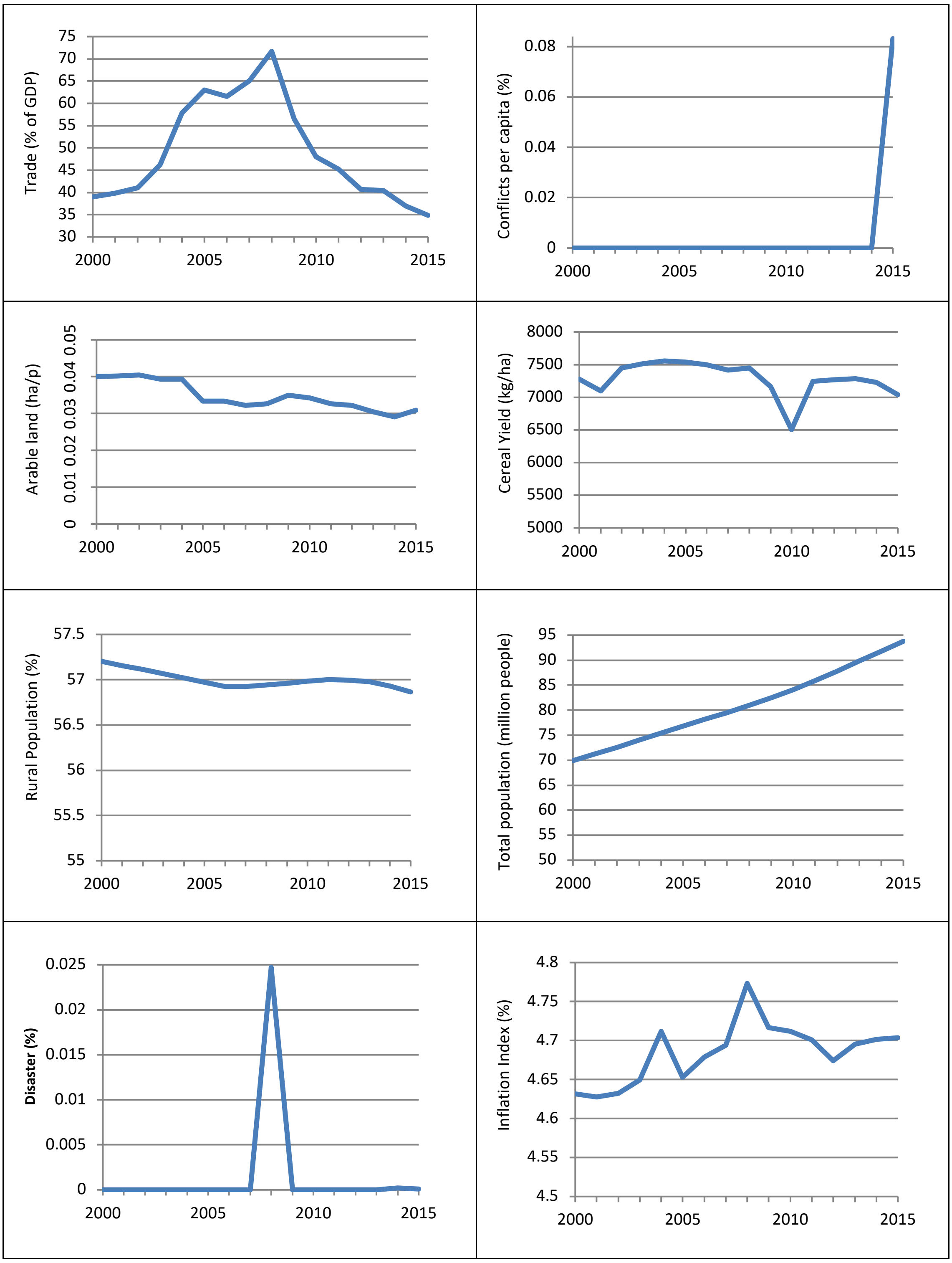

Figure 11. Level and evolution of the main drivers of food security considered as control variables in the econometric model for food security in Section 3 in Egypt (2000-2015).

Source: see Annex I on database description

Water shortage and the degradation of water quality is another major challenge facing Egyptian agriculture. In Egypt more than 85% of the water withdrawal from the Nile is used for irrigated agriculture, which represents almost 99% of total agricultural land. Thus, water availability therefore may have a direct influence on national food security (FAO-AQUASTAT, 2016).

Egypt is dependent on the Nile River as the major source of its water supply for all economic activities and services. In 1959, an agreement was signed between Sudan and Egypt on the exploitation of Nile water. Egypt's quota was fixed at 55.5 billion m3/year. This quota represents the main source of water in Egypt by 90% of the country´s water budget. Overexploitation of water resources cause future problems such as water deficiency. According to the Ministry of Water Resources and Irrigation, Egypt uses 127% of its total renewable resources. In addition, the average per capita fresh water availability in Egypt has decreased from 1893 m^3 in 1959 to 700 m3 in 2012 (MWRI, 2014).

As predicted by our econometric model, the observed trends in food security indicators can be in part explained by **water stress and management** in the region. Figure 12 shows the level and evolution of the variables related to the four dimensions of water stress considered in the WPI, focusing on the indicators selected in the empirical analysis in Section 2.

During the period, water availability (as measured by total renewable water resources) in Egypt goes from 59.7 Km^3 in 2002 to 58.5 Km^3 in 2014. As shown in Figure 12, the trend in total renewable water resources is not monotonically increasing, experiencing improvements until the middle of the period and decreasing afterwards. Nevertheless, the "*Resources/Availability"* dimension is not expected to affect food security levels as much as others. "*Access"*, on the other hand, keeps increasing during the period of analysis, with a positive impact on food security in the country according to model estimations. With respect to this indicator, it should be noted that although the level of access was already quite high at the beginning of the period (98.25% of population covered), the SDG 6 (Clean Water and Sanitation) target of universal access to at least basic drinking water services had not been reached by the end of the period of study and is still to be met. Thus, country efforts towards the achievement of SDG 6 will have a likely positive impact on food security. In the same vein, in terms of *Capacity* the three variables considered point at substantial improvements in this dimension of water poverty, with predicted positive impacts on food security. Under five mortality rates evolve from 45 (per 1000 live births) to lower than 25. Primary School Enrollment rate in Egypt goes from 85% to 95% at the end of the period which constitutes a significant capacity improvement. However, poverty, which is also extremely linked to food insecurity, represents the main barrier to education in Egypt that precludes further improvements of this particular indicators, with at least 1.6 million children involved in child labour according to the World Bank (2018b).

Finally, regarding the "*Use*" dimension, the evolution for the domestic and agricultural sectors should be expected to contribute negatively to food security in the country. The evolution in *Domestic_use_index* seem to indicate that adequateness of water use at the domestic level has reduced along the period. A reduction in this indicator means that Egypt is further from the 50l/day target, either by excess or by deficit. According to our results in Section 3 a higher level of this index contributes positively to food security levels, possibly due to its impact on health, hygiene and other aspects that are closely related to a good nutrition and also as it implies a rational use of resources in those countries where basic needs are covered. Therefore, the reduction in this indicator should be in principle expected to impact negatively on food security. Agricultural efficiency has worsened along the period, both in terms of GDP generation (*RatioAgriculturalwatereff*) and agricultural production (*Agr_waterefficiency*), with an expected negative impact on food security. However, the trend in industrial efficiency in water use should on the contrary influence food security in a positive manner. Food processing, textile manufacturing, cement and fertilizer production are the main industries in the country (El-Gohary, 2015). A growing industrialization in Egypt, characterized by the concentration of new industries in the metropolitan areas along the Nile Delta, north and south of Cairo, and in the Alexandria metropolitan area (MWRI, 2011), seems to be accompanied by a progress on the efficiency of use of water resources in the sector that may be positively contributing to food security in the country.

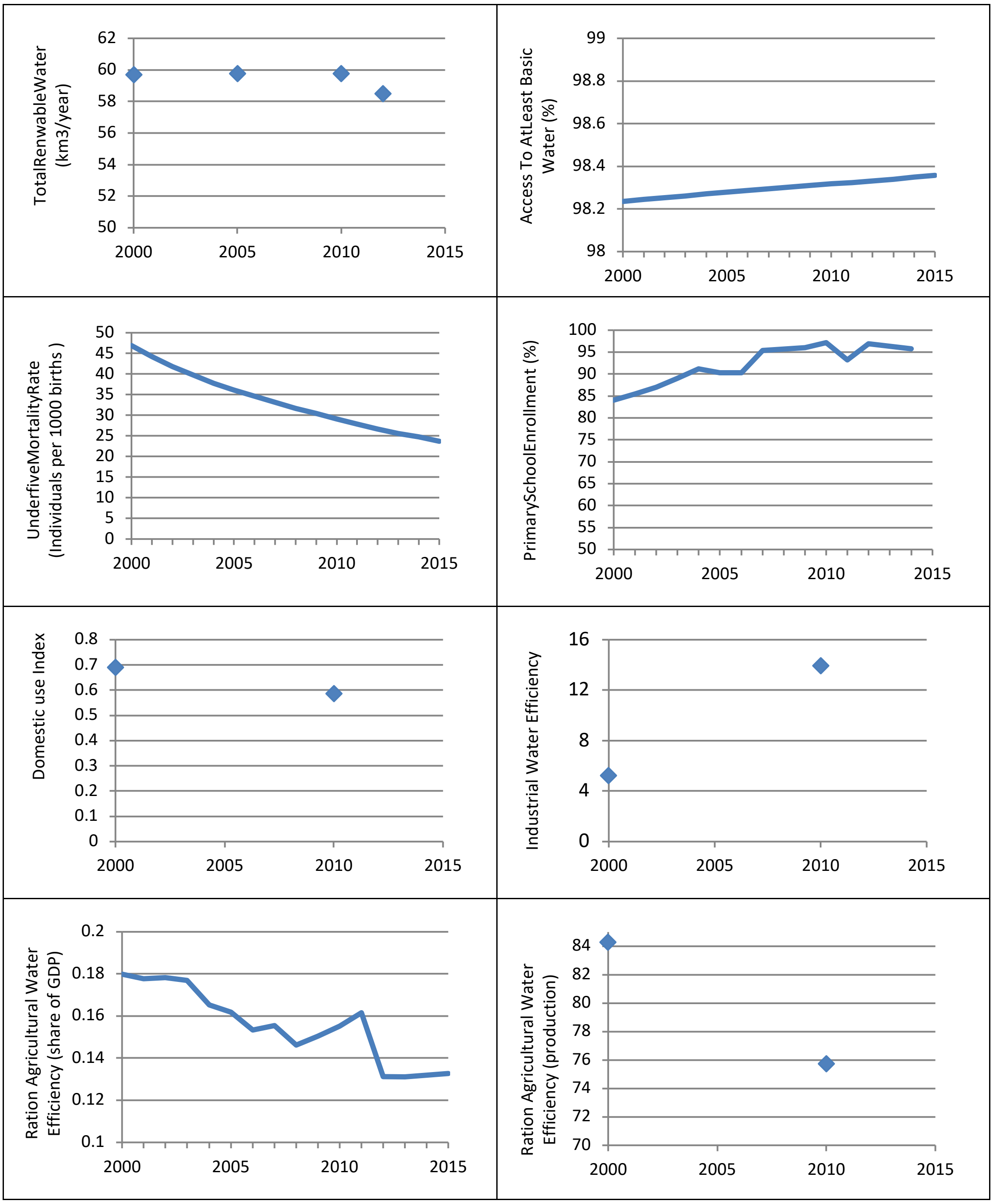

Figure 12. Level and evolution of variables of water stress and management in Egypt (2000-2015).

Source: see Annex I on database description

A final aspect of water management worth of being explored, as it relates directly to the objectives of MADFORWATER, is the evolution of **treated wastewater reuse** (See Figure 13). Reuse of wastewater is presented by the Government as a necessity as unconventional resource and is taken into account in the forecast balance of water resources in the country. Produced municipal wastewater was estimated at 7078 million m³ in 2012, up from 3760 million m³ in 2001 (FAO-AQUASTAT, 2016). With 372 municipal wastewater treatment plants in Egypt in 2012

(382 in 2014), treated municipal wastewater was estimated at 4013 million m^3 from which 290 million m^3 were used for agriculture. Figure 5 depicts values of TWW Reuse for the period 2000-2015 in Egypt. It can be seen that although still low, levels of reuse of treated wastewater are increasing in Egypt for the studied period, with predicted positive impacts on food security according to the results of Models 5 and 6 (Section 3) in which this indicator was introduced.

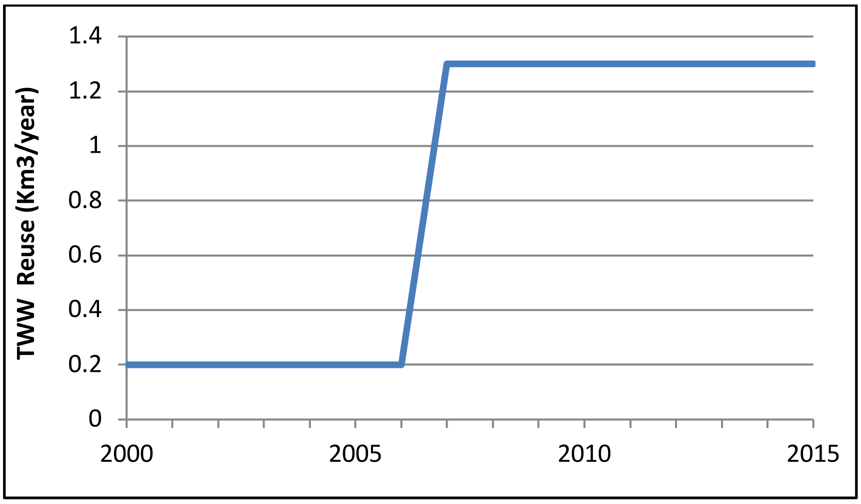

Figure 13. Level and evolution of treated wastewater reuse in Egypt (2000-2015) a).
a) The graph assumes constant values based on available data: 1993 (0.2 Km^3), 2007 (1.3 Km^3) and 2010 (1.3 Km^3)

Source: see Annex I on database description

Despite the promising potential of treated wastewater reuse in Egypt, it encounters several limitations, such as the huge financial resources required to increase the national coverage of wastewater collection, and to upgrade the level of treatment of wastewater, and the Egyptian wastewater reuse code that restricts in the uses of treated wastewater of different qualities for edible crops (FAO-AQUASTAT, 2016).

4.2 Water stress effects on food security and socioeconomic development in Morocco.

4.2.1. Current situation of Food security and socio-economic development

Food security is a major issue and constant challenge in the developing world. In Morocco, as in other Mediterranean countries, food security is not fully assured. According to FAO, the PoU decreased significantly relative to the 1990s (peaking at 8% around 1995) (FAO, 2016b) and is below 4 % in 2016 (FAO, 2018). In 2004, almost 25 % of children of less than 5 years of age were subject to slow developmental growth (FAO, 2011), a figure that has been reduced to 15% in 2012. However, the prevalence of malnutrition is increasing at an alarming rate. These trends are due to the inadequate nutrition of young children, drought in certain rural areas and high levels of poverty in certain regions. Almost one woman out of ten suffers from a chronic deficit in energy intake, while almost 40 % are overweight or obese (FAO, 2011).

Figure 14 depicts the level and evolution of the selected food security indicators for Morocco during the period of reference for this deliverable. AvDESA in Morocco is increasing along the period, ranging from less than 135 in 2010 to up to 145 by 2015, indicating substantial improvements in food security in this country. Compared to the other target countries in

MADFORWATER, observed values for this indicator in Morocco are within the same range of the ones displayed by Tunisia, and a bit lower than the ones in Egypt.

With respect to PoU, Morocco departed at the beginning of the period from substantially higher levels than Egypt and Tunisia. However, Morocco made substantial efforts in the reduction of the percentage of people considered as undernourished during the period, reaching by 2015 the lowest level among the three MADFORWATER countries (around 3.5%[12]).

It is also worth commenting that, contrary to Tunisia and Egypt that experienced a worsening in the situation for the first years of the period of study (until around 2005), in Morocco the trend has been towards continuous and steady improvement in the selected indicators for food security. Only in the last year of the sample, the level of AvDESA has stagnated. However, the PoU continued the downward trend in the last years of the analysis, while neighboring countries and global trends experienced an upturn in the indicator.

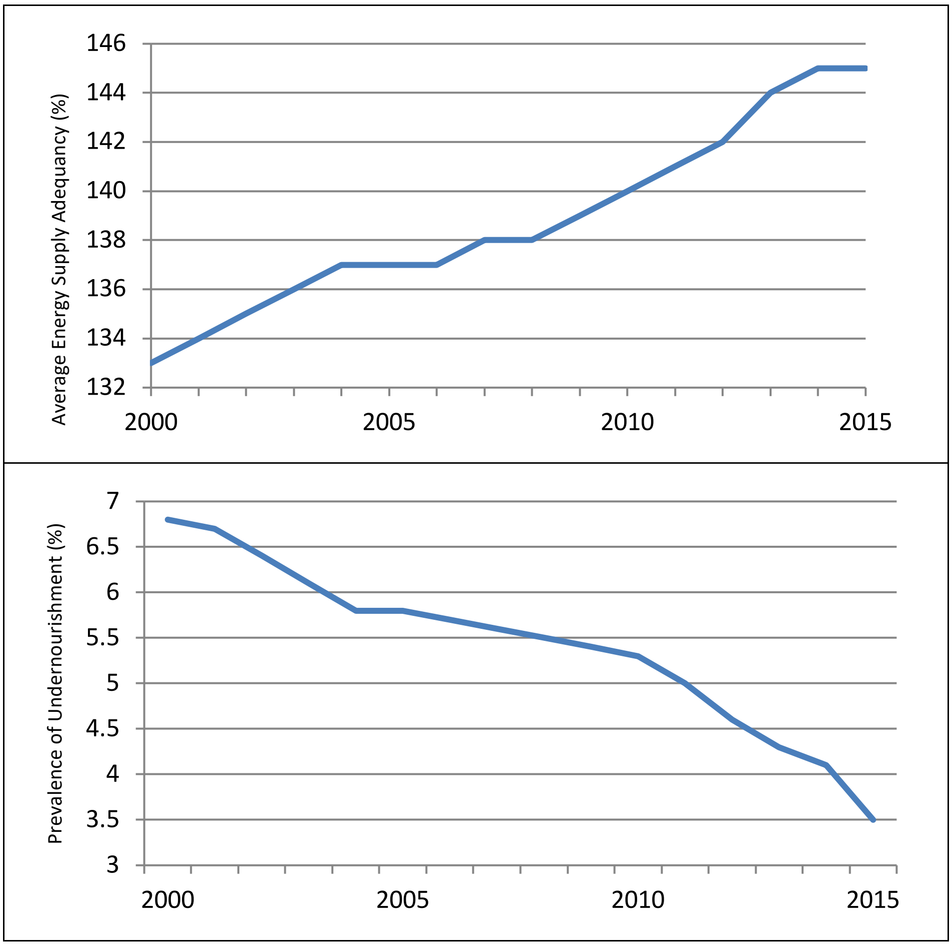

Figure 14. Levels and evolution of AvDESA and PoU in Morocco (2000-2015).

Source: see Annex I on database description

Agriculture is a primary economic engine and a strategic sector for food security and for the socio-economic development of the country. Agriculture contributed to 14.6 % of total GDP

[12] This data has been corrected to 3.9% in the 2018 FAO release of Food Security Indicators (11 September 2018)

in 2012 (FAO-AQUASTAT, 2015a). Approximately 50 % of the total active population and 80 % of the active rural population is employed by the sector (World Bank, 2012).

Figure 15 shows the Level and the evolution of GDP per capita and GDP growth for Morocco during the period of reference for this deliverable (2000-2015). GDP per capita has more than doubled during the period, passing from 1332$ (US current dollars) to 2892$ by 2015. The GDP growth fluctuate between 2% and 8% during the same period, with a downward trend in the last part of the time series.

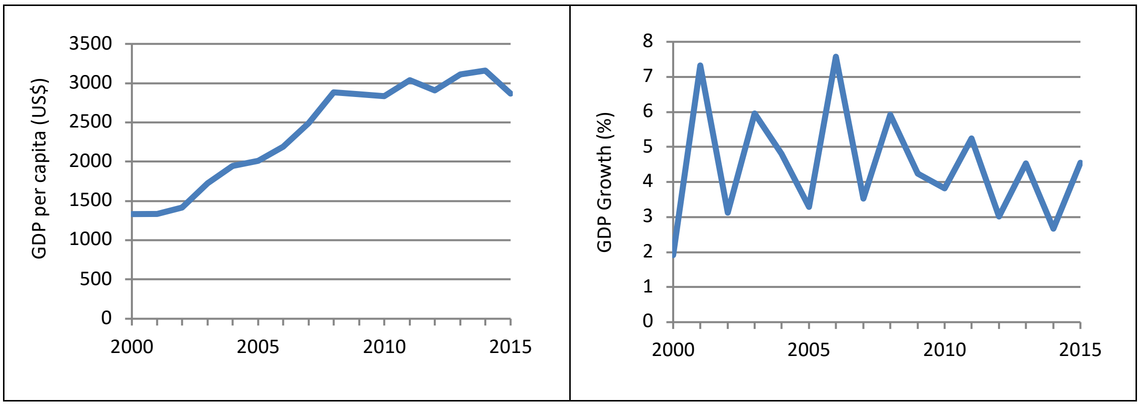

Figure 15. Level and evolution of GDP per capita and GDP growth in Morocco (2000-2015).

Source: see Annex I on database description

Reducing poverty is an important priority of the government and is a necessary condition to improve the state of food security and sustainable development in Morocco. From 2001 to 2014, poverty has substantially declined in Morocco. Consumption per capita increased at an annual rate of 3.3%, monetary poverty and vulnerability fell to 4.8 and 12.5% respectively (World Bank, 2018c). In 2005, Morocco launched the National Human Development Initiative to reinforce programs for rural development and poverty reduction by encouraging revenue-generating activities, job promotion, value-added production and natural resource conservation. In 2008, Morocco launched a new agricultural strategy called the Green Morocco Plan (MAPM, 2009). This plan rests on two pillars: the promotion of a modern and high value-added and high-performing agriculture and the promotion of a viable agriculture in mountainous, oasis and semi-arid areas by supporting small farmers and combating rural poverty in marginal areas. The success of this plan in promoting food security has been widely acknowledged (Ghanem, 2015; The Guardian, 2015), as it has contributed to strengthen the agricultural sector and supporting rural livelihoods. Increased investment in agriculture – e.g. mechanization, irrigation, and fertilization – and enhancing exports from strategic sectors such as fruits and vegetables are some of the main contributions of this plan to boost the economy of the country's agricultural sector. However, a stronger emphasis on small farming is still required.

4.2.2. Recent evolution of variables that affect food security and socio-economic development

According to our model, food security may be also expected to be affected by additional aspects related to socioeconomic and land use issues. Figure 16 shows values for the indicators selected in the empirical section (Section 3), from 2000 to 2015. The positive rates of inflation[13] are related to higher food security levels in the Mediterranean (see results of our econometric model in Section 3.4). On the other hand, the decrease in rural population signals the existence of urbanization processes that are normally accompanied by higher calorie intake and thus higher levels in our indicator of food security (Dithmer and Abdulai, 2017). Rural population in 2017 was about 38% of the country's total population (World Bank, 2018b), and concentrates nearly two-thirds of the poor population.

Population growth has on the other side negative effects on arable land, especially in the peripheral areas of medium and large urban centers. The phenomenon of urbanization affects irrigated lands, with losses of irrigated land above 6000 ha during the year 2013 (FAO-AQUASTAT, 2015a).

A growing population may have as well a negative impact on the availability of arable land per capita. A decreasing trend in per capita arable land is observed for Morocco (from 0.3 to 0.24), most likely driven by the remarkable increase in population (from around 29 million in 2000 to close to 35 million inhabitants in 2015). This may have a negative impact on food security, especially in the long term as land resources become scarcer.

On the other hand, Cereal yield has increased from 2000 to 2015 but remains conditioned by the climate factor, availability of water resources and land. Cereal production represents about 65% of the total cultivated area in Morocco and more than 30% of total irrigated land (FAO-AQUASTAT, 2015a). The expansion of cereals throughout the years has sometimes been made on marginal lands, making production even more vulnerable to changes in the climate and precipitation. As a result, the productivity of cereal agriculture is highly unstable from year to year. Moreover, the demand for cereal in Morocco is not met by domestic production. For example, in 2007, national cereals production covered only 50 % of demand (FAO – AQUASTAT, 2012b). Cereal imports increased from 38.5 million quintals in 2003 to 98.2 million quintals in 2010.

[13] For convenience in the analysis, in Figure 16 Inflation does not represent the inflation index included for estimation purposes following Dithmer and Abdulai (2017), but the actual inflation rates experienced in the country during the studied period.

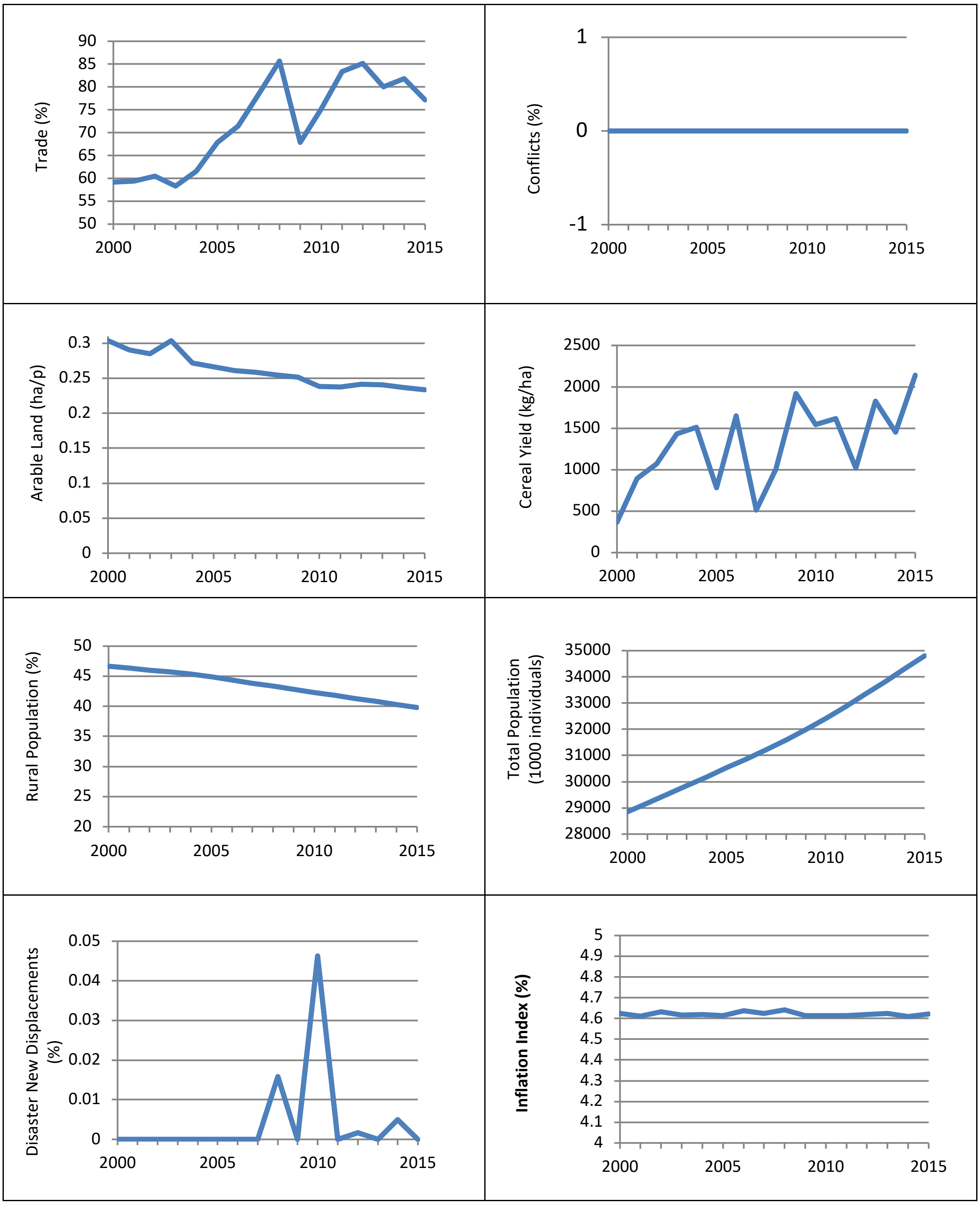

Figure 16. Level and evolution of the main drivers of food security considered as control variables in the econometric model for food security in Section 3 in Morocco (2000-2015).

Source: see Annex I on database description

In relation to the evolution of the food security-related **water stress and management** indicators**,** Figure 17 depicts the values for the variables considered in the empirical section of this report, that illustrate the trend in the four dimensions of water stress and management usually included in the analysis: Availability, Access, Capacity and Use (see section 3).

Total renewable water resources in Morocco are estimated at 29 Km^3/year, slightly more than 1000 m3/person/year. In terms of intensity of use of water resources by economic sectors, agriculture remains the highest consumer of water. Water demand for the year 2010 was 14,649 million m³, of which 13225 million m³ where devoted to irrigation (more than 90 % of the total demand), 1,063 million m³ for the communities, 212 million m³ for industry and 149 million m³ for the environment. The confrontation between the mobilized water resources and the water demands of the different sectors shows that the needs are not satisfied and that there is a water deficit of about 4,000 million m³ (El Badraoui and Berdai, 2011).

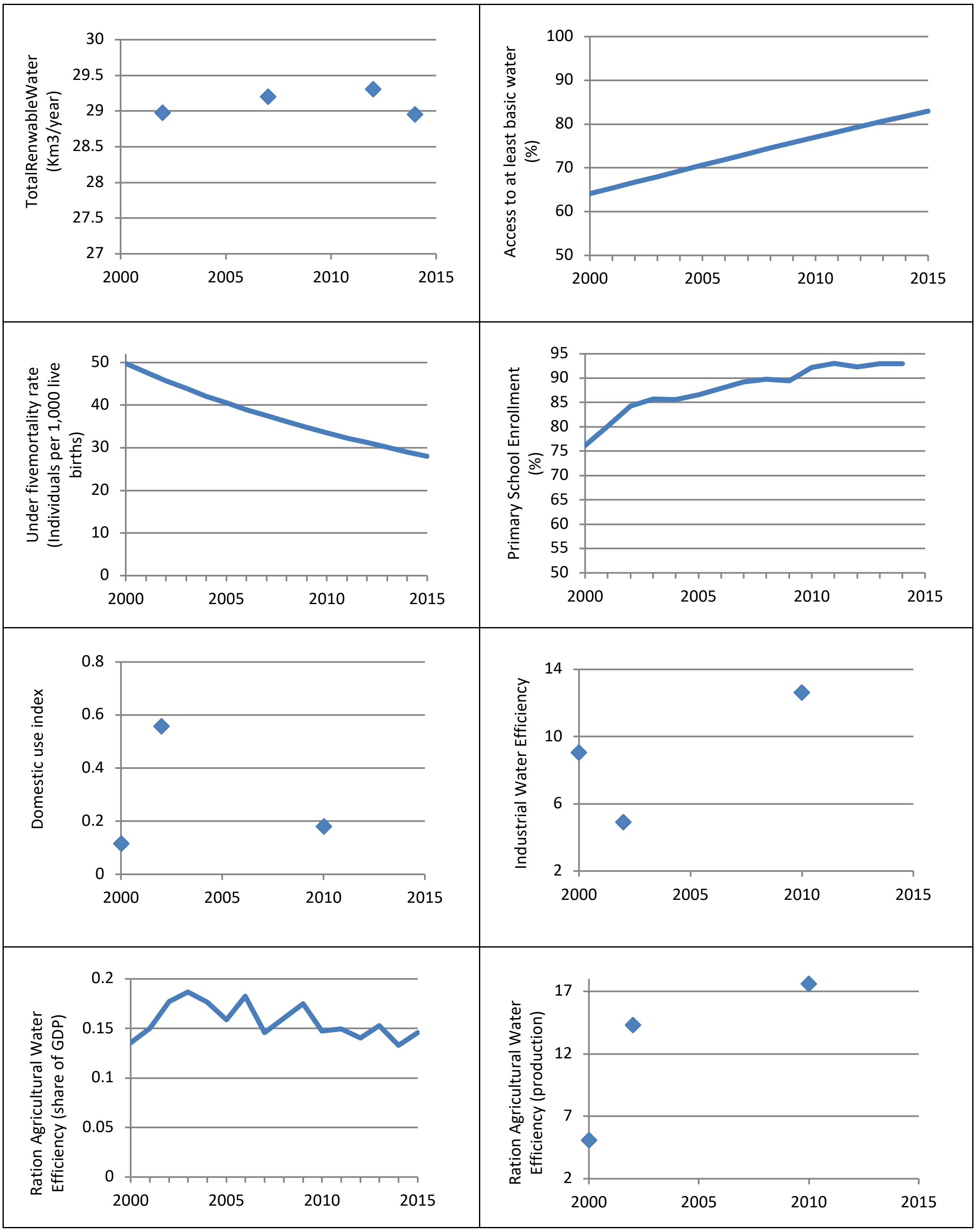

Figure 17. Level and evolution of variables of water stress and management in Morocco (2000-2015).

Source: see Annex I on database description

As it can be seen in Figure 17 that the observed trends in food security in Morocco have been accompanied by a positive evolution in most of the indicators of water stress and management that may have an impact on food security. Particularly, access to at least basic drinking water services has substantially increased in Morocco from 2000 to 2015, going from a 65% to the current figure at around 85%. Likewise, the evolution of the variables indicating "*Capacity*" has been very positive. Under five mortality rates have considerably reduced during the period, going from 50 (per 1000 live births) to lower than 30 during the period. In Morocco, current enrollment rates in primary education are close to 95%, from the initial 76% in 2000. Altogether, the evolution of these indicators point at a substantial improvement in the allocation of water resources in the population through improvements on health, education, equality and affordability, with a predicted very positive impact on food security. With respect to the use of water resources in the main sectors of the economy, the trends are mixed. Regarding adequacy of domestic water use, substantial improvements were achieved at the beginning of the period, but some of them were lost in the last years. Water efficiency in the industry sector has also experienced a significant boost, going from around 9 percentage points of GDP generated for each percentage point of total water withdrawals[14] to up to more than 12, although it suffered from a backlash at the middle of the considered period (reaching the level of 5 percentage points of GDP for each of total water withdrawals). Regarding agricultural efficiency in the water sector (*RatioAgriculturalEfficiency*), it has been fluctuating along the period. However, as we explained in a previous section, since added value in the agricultural sector is not generally very high, when analyzing food security it may be more relevant to explore agricultural water efficiency/productivity in terms of food production[15]. When expressed in this terms, as we can see in the corresponding chart within Figure 17, agricultural water productivity is increasing during the period. Therefore, overall it could be said that water use has also improved during the period in Morocco, leading to an improved food security in the region.

Regarding the variable measuring "*Availability*" (*Totalrenewable_WR)* the evolution of this indicator has been positive along most of the period (until 2011), while decreasing afterwards. However, according to the explanatory econometric model developed in Section 3, this variable is not in principle as relevant in explaining food security trends.

Finally, it is worth commenting on the state of **treated wastewater reuse** in the region, as it is one of the crucial aspects of water management addressed in MADFORWATER. According to the FAO-AQUASTAT statistics employed in our analysis, the level of direct treated wastewater reuse in Morocco was quite low (at a 0.07 km3/year) in 2008. Annual volumes of wastewater discharges have risen sharply over the last three decades. They increased from 48 million to 600 million m3 between 1960 and 2005 and reached 700 million in the year 2010 (FAO-AQUASTAT, 2015a). According to forecasts, these discharges will continue to grow rapidly reaching 900 million m3 by 2030. During 2011 only 12% of the collected wastewater was reused for irrigation, covering an area of 550 ha. According to projections of the Ministry of Energy, Mines, Water and Environment of Morocco, this rate will increase to 22% covering an area of 4000 ha in 2020 (MEMEE, 2013).

[14] Recall that this ratio was obtained as the % share of GDP due to industry divided by the % of total water withdrawals that correspond to this sector.

[15] Agr_watereff is computed as the ratio of cereal yield (kg per ha) and % of total water withdrawals devoted to agriculture.

The Green Morocco Plan (2008) and the National Water Strategy (2009) consider the mobilization of unconventional water resources and the reuse of treated wastewater as a complementary resource that can mitigate local water deficits, and emphasizes the relevance and value of reclaimed water (Malki et al., 2017). In order to cope with water scarcity and attenuate the impacts on groundwater, policy makers encourage the reuse of treated wastewater as a substitute resource for agricultural practices. Several pilot projects for the reuse of treated wastewater in agriculture have been carried out, such as the Ouarzazate wastewater reuse project (1990-1998), the Ben-Sergao project (Agadir 1991-1994), the Drarga project (Agadir) (FAO et al., 2011) and the Tiznit pilot project. The Tiznit treatment plant is based on a natural lagoon system that extends over 39 ha with a total capacity of 5800 m^3/day. It is intended for the irrigation of the perimeters Doutourga and Attbane, that irrigate about 430 ha of several crops such as fodder (beans, alfalfa…) and fruit crops (olives…) (Malki et al., 2017). Within the Tiznit area, wastewater reclamation and reuse has contributed to the food security of the region (Malki et al., 2017; MEMEE, 2013).. The high-quality treated wastewater coming out of the treatment plant and being used to irrigate alfalfa and olive trees demonstrates the safe and effective use of reclaimed water in irrigating high-value crops, and its potential contribution to the country's food security (Malki et al., 2017). However, the acceptability of this type of water by farmers is still a major issue in the country. The reuse of treated wastewater in agriculture is not fully accepted by farmers in Morocco, who have a negative perception of treated wastewater, because of its unsightly appearance (color, smell…) and its reputation of being dangerous for facing risks of bacteria and parasite disease. Moreover, the prohibition of the export of agricultural products irrigated with treated wastewater discourage farmers to reuse treated wastewater in irrigation (Choukr-Allah, 2005).

In sum, challenges still remain to effectively cope with scarcity of water resources under the effects of climate change, the over-exploitation of groundwater resources, the need for an improved mobilization of water resources, particularly in the agricultural sector, and deterioration of the quality of water resources and reuse of treated wastewater. Addressing this challenges in an effective manner may importantly contribute to underpin food security in the country and consolidate the observed positive trends, by strengthening management of water quantity and quality and promoting productivity of water resources in agriculture.

4.3 Water stress effects on food security and socioeconomic development in Tunisia.

4.3.1. Current situation of Food security and socio-economic development

Food security ranks first among the priorities of Tunisia for development. A series of structural reforms started, programs the country has implemented to achieve integrated development and promote rural areas and rural populations, and women in particular, as well as the solidarity mechanisms the country has created, have given positive results with strong impacts on the improvement of the quality of life of its population (ITES, 2014). Tunisia ranked 53rd out of 113, in terms of food security index in 2016, gaining 2 places since 2012 (55th rank), according to the preliminary results of the strategic review on food and nutrition security in Tunisia, conducted by the Tunisian Institute of Strategic Studies (ITES, 2014). Tunisia is cited by FAO (FAO - Ministère de l'Agriculture de Tunisie, 2013) among 12 countries around the world whose achievements in the field of food security are encouraging. With a score of 5.5 in the 2016 Global Hunger Index, Tunisia is categorized as having "low" levels of hunger and it has made considerable progress in addressing malnutrition (ITES, 2014). However, last data reported in

2017, shows a small regression in the state of food security, coinciding with a generalized trend in many countries which have witnessed an upturn in the food insecurity rates (FAO et al., 2018) in the last period reported.

Figure 18 shows the level and evolution of the two indicators of food security chosen as reference for the analysis in this deliverable. In Tunisia, AvDESA departs from a 142 ratio level, higher than the one in Morocco and only slightly lower than Egypt in that period. However, this indicator does not show any improvement along the period. Actually, until 2006 a substantial decrease is experience. The second period succeed at recovering that loss, but no gains are achieved.

With respect to PoU, a similar interpretation can be made. In the first part of the period (until 2005) Tunisia even experiences an increase in this indicator, showing a regression in one of the most important aspects of food security. A second period from 2005 to 2014 shows substantial improvements (reduction), reaching even a lower level than in the initial period. However, in the last year of the sample, part of this recovery in the indicator is again lost.

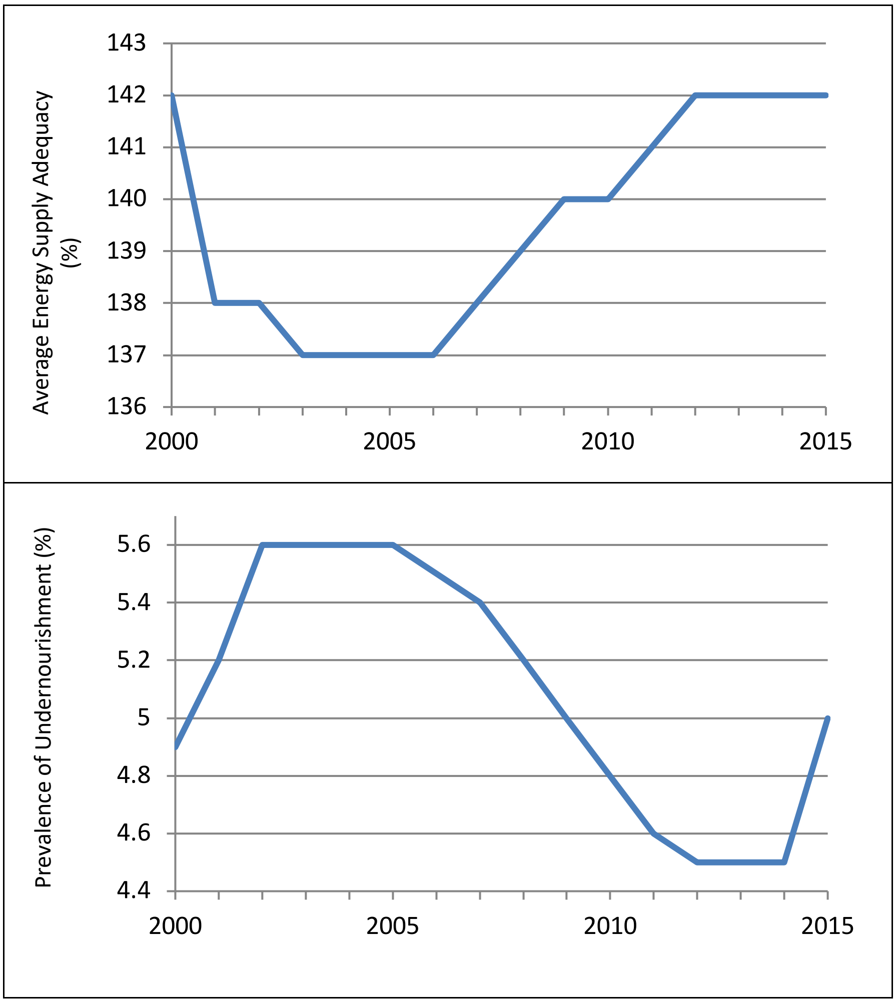

Figure 18. Levels and evolution of AvDESA and PoU in Tunisia (2000-2015).

Source: see Annex I on database description

It is worth commenting that, although at the beginning of the period Tunisia departs from a well-located situation as compared to the three countries in MADFORWATER (similar situation as in Egypt and better than in Morocco), the absence of significant changes and improvements along the period places Tunisia in the last position in both indicators by the end of the period.

In consolidating food security, Tunisia has made a special effort to fight poverty. The poverty rate was curbed to 15.2% in 2015 with respect to a rate of 42.1% in 1990 (INS, 2018). Poverty levels are higher in rural areas (26%) than in urban environments (10%). However, living condition indicators have constantly improved in these areas, especially in terms of fresh water supply, health, education and electrification.

However, still wealth and socio-economic status, together with other interrelated factors such as poor dietary diversity, physical inactivity and eating habits – with Tunisians getting a high proportion of their calories from wheat based foods – explain the levels of undernourishment and stunting, but also increasing obesity and overweight in certain sectors of society. Particularly regarding the variables that according to our model should influence food security, as the Figure 19 shows, in the last years, coinciding with the regression in the indicator of PoU and food security, the GDP per capita suffers from a drawback. Regarding the rest of the period, it seems to keep increasing until 2008 when it starts to fluctuate without showing any stable additional improvement. The trends in GDP growth fluctuate between 2% and 6% along the period, except for the year 2011 which shows negative rates (coinciding with country reforms right after the Arab Spring in Tunisia) with fluctuating and decreasing levels afterwards. Deteriorating trends exhibited in 2015 for both per capita GDP and GDP growth coincide with an increase in undernourishment rates (PoU).

Tunisia is expected to continue to face social and economic challenges over next years. Although not reflected in the figures below, GDP growth in 2016 was around 1.1%, increasing to 1.95% in 2017 (World Bank, 2018b). Since the 2011 revolution, the country has struggled to enact economic reforms meant to curb public spending and help create jobs, while the tourism industry has not yet recovered from two major attacks in 2015 that significantly affected tourist numbers.

Figure 19. Level and evolution of GDP per capita and GDP growth in Tunisia (2000-2015).

Source: see Annex I on database description

4.3.2. Recent evolution of variables that affect food security and socio-economic development

Risk of food insecurity is highly determined by additional drivers including population growth, degradation of agricultural land and degradation of natural resources, including water, and climate change. Within the variables that according to our models affect food security and socio-economic development, we distinguish between control variables and water-related variables.

Some of the trends exhibited by control variables (Figure 20) seem to have accompanied the evolution of food security in the region. The reduction in arable land per capita, even if driven to a great extent by population growth, should also be expected to impact negatively food security levels.

In Tunisia, the control of population growth is seen as a key issue in easing the pressure on consumer goods, agricultural land and services and enabling the state, by reducing burdens, to implement its social policy in the country benefit of all population. Tunisia surpassed the ten million inhabitants mark in 2005, which corresponds to a tripling of its population since 1956 (3,448,000 inhabitants) and a doubling since the beginning of the 1970s. In 2017, the Tunisian population was above 11.4 million inhabitants, from which about 67% corresponds to urban population and 33% to rural population (FAO-AQUASTAT, 2015b). The rural population decreases with a rapid urbanization (projected to reach 75% in 2025) due to preferential migration to coastal cities and more job opportunities in these regions. According to the official projections of the National Institute of Statistics (INS), the evolution of the population in the coming years increase around 1.1% in 2020 and an additional 0.9% in 2025 (INS, 2018).

The inflation rates remain stable with a slight increase displayed in the last years of the considered period however, this may have not led to increased food security levels in Tunisia. These trends may have in part compensated the improvements experienced in the indicators of water stress in the region for the same period.

In arid and semi-arid countries like Tunisia, the scarcity of water resources is a highly limiting factor for increased food production. When water resources are limiting agricultural production, food imports seem to be a way which is used consciously or unconsciously to fill the water deficit. Tunisia is among the 20 countries in the world classified as water-poor countries. Because of this, it has pursued a policy of total mobilization of resources, regional planning and strict management of continental waters in order to prevent any occasional or local shortage of water and to meet the country's needs for economic activities, and especially agriculture and food production.

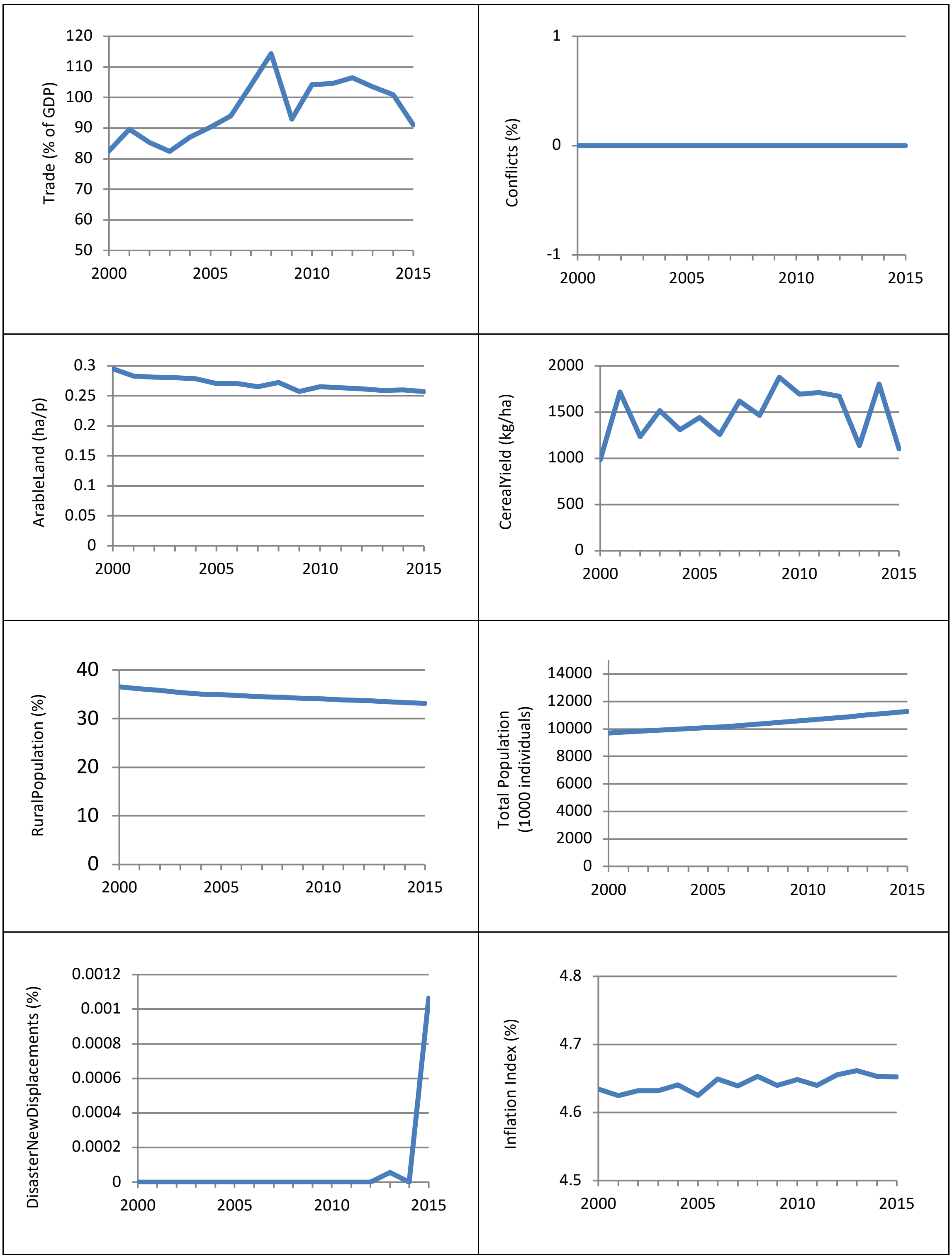

Figure 20. Level and evolution of the main drivers of food security considered as control variables in the econometric model for food security in Section 3 in Tunisia (2000-2015).

Source: see Annex I on database description

Thus, the observed trends in food security are expected to be explained among other factors, by the level of water stress and water management in Tunisia. Figure 21 shows the trends in the main indicators of water stress that may be affecting food security along the period. The selection of those indicators was made in Section 3 on the basis of our conceptual framework of study explained in Section 2 and taking the WPI indicators as a reference (See Section 3.1 for more information).

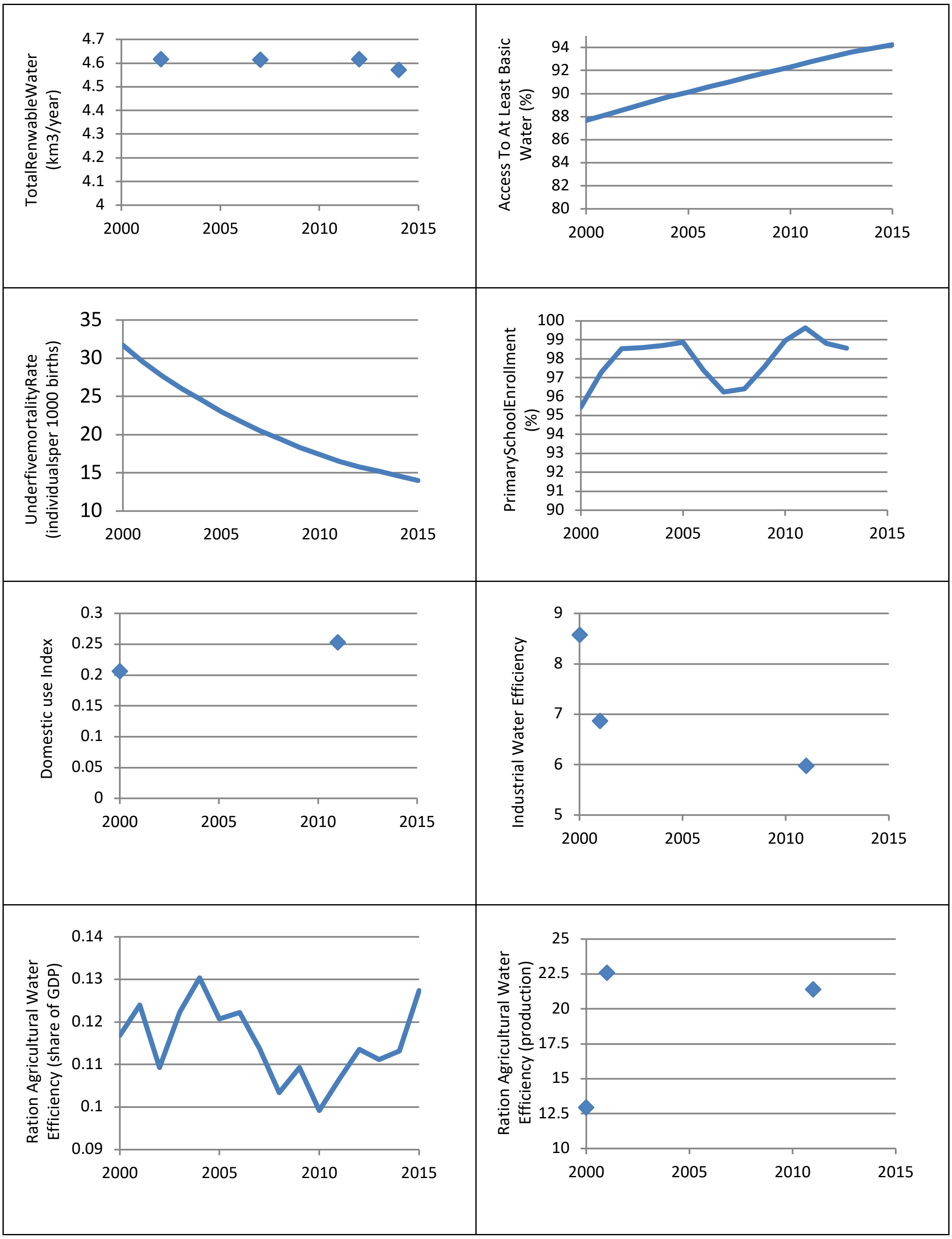

Figure 21. Level and evolution of variables of water stress and management in Tunisia (2000-2015).

Source: see Annex I on database description

Water resources in Tunisia are estimated at 4700 Mm3, including 650 Mm3 of non-renewable resources, representing a rate of 13.8% of the total resource (GDRE, 2009, FAO-AQUASTAT, 2015b). As a result, annual water resources availability per capita is only 450 m3, a low rate that places the country as subject to absolute water scarcity (below 500 m^3 per capita). Total renewable resources in Tunisia depart from around 4.61 km^3/year and they keep approximately constant until the last years in which a decrease is observed, showing an incipient trend towards a reduction of water availability in this country. Access to water, another crucial factor influencing food security in arid and semi-arid regions where it has become critical for agriculture and poverty reduction, seems to have experienced substantial increases during the reference period. Positive economic performance along the period considered has led to a significant improvement of living conditions. The country has reached respectable levels of GDP per capita and good social welfare, as evidenced by large coverage of water supply and sanitation in urban and rural zones (Besbes et al., 2018). Nevertheless, it should be noted that as compared to the other countries within the same subregion, the evolution of this indicator has not been as outstanding, with an improvement of only 6 percent points and a level that is still distant from the SDG 6 that refers to universal access to water and sanitation. Regarding the "*Capacity*" dimension, under five mortality rates have also substantially decreased during the period. Actually, the value of Tunisia for this indicator is the best among all the countries in MADFORWATER. It seems that Tunisian efforts to reduce poverty and to maintain and improve infant health, and reduce mortality may have been positive related to food security along the period considered. With respect to primary school enrollment rates, trends show a regression between 2005 and 2007, and again at the end of the considered period, coinciding with a worsening of food security in the last years of the time series.

With respect to the use of water in the different sectors in Tunisia, employment of this resource at the domestic level seems to improve within the studied years. In a similar vein, agricultural water efficiency (in terms of agricultural production, which is the one used in our analysis) suffers from significant improvements at the very beginning of the period, although keeping constant or even slightly decreasing afterwards. The situation of agricultural water efficiency in terms of value added to GDP is, however, rather different. Fluctuating and decreasing around 2010, it experiences a substantial backlash during this year, but improves afterwards. A possible explanation revolves about the Arab Spring that took place in Tunisia from the end of 2010 towards the middle of 2011, and could have generated distortions in the prices of agricultural production. Industrial water efficiency, on the other hand, seems to worsen steadily.

Most of the indicators of water stress should be pointing at an average improvement (as it is actually the case from 2005 to 2014) in the situation of food security in the region during the observed period. There is no specific trend in the studied variables for water stress that can be directly linked to the worsening of the situation from 2000 to 2005. It may therefore be the case that the positive effects of the trends in water management have been compensated by the negative impact of other policies and indicators in that period as to compensate them.

In the case of the stagnation and reduction of food security levels suffered in the last years of the considered period, some causes can be found in the evolution of water stress in our data, as many of the indicators such as total renewable resources, primary school enrolment rates, industrial water productivity and agricultural water productivity also experience a deterioration during that last subperiod pointing at a worsening in food security.

Irrigation plays an important role in Tunisian agriculture, thus management of water resources in agriculture is crucial to the country, which is therefore obliged to apply new concepts, new paradigms, to optimize the use of different types of water resources. The use of **treated wastewater reuse** is considered a promising strategy for agriculture**,** to which the objectives of MADFORWATER can contribute. In Tunisia, the use of treated wastewater is one of the priorities for national water policy, with a target of 50% utilization rate for irrigated agriculture (FAO-AQUASTAT, 2015b). The rate of wastewater reuse in recent years reached a maximum of about 20% of total collected wastewater (FAO-AQUASTAT, 2015b). Figure 22 shows an increasing steady trend in the use of treated wastewater in Tunisia, which, according the econometric model developed in Section 3, should have a positive impact on the level of food security in the country.

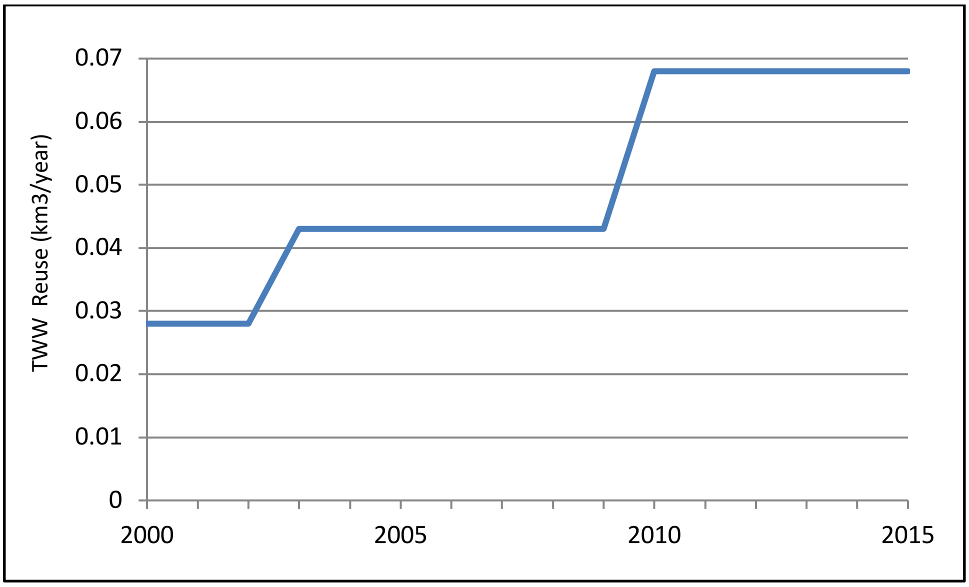

Figure 22. Level and evolution of treated wastewater reuse in Tunisia (2000-2015).
a) The graph assumes constant values based on available data: 2001 (0.028Km^3), 2003 (0.043Km^3), 2010 (0.068Km^3)

Source: see Annex I on database description

However, the use of treated wastewater in agriculture is still constrained by many factors. Besides the many technical factors related to treatment technologies, quality of treated wastewater and irrigation technologies adapted to its use, a major constraint may be social acceptance. According to fieldwork developed by the authors in the Nabeul Governorate, social constraints arise from negative perceptions deeply rooted among farmers and the general public regarding the use of treated waste water for agriculture and the potential health risks from contamination**.**

5 Concluding remarks

Recent data and international reports evidence that progress towards World food security in recent years may be lesser than expected, underlining that unless additional efforts are made to reduce food insecurity, the SDG 2 target of ending hunger will not be met by 2030. The Mediterranean region has made significant progress on food security along the last decades. This is especially true for Northern African countries where food security indicators show optimistic values as compared to other NENA sub-regions. However, limited access to key resources, such as land and water, together with economic and political instability may endanger the achievement of the food security goals.

Water is a key resource for food security as recognized by the international HLPE on Food Security in their 2015 report. At the household level water is crucial for nutrition and health. Also, it is a key resource for many economic activities, very specially agriculture and food production. Ensuring population access to water resources may contribute to underpin food security in Mediterranean countries. However, demographic pressures, socio-economic development and an uncertain evolution of climate may put additional pressure on water resources and food security.

Within this context, in this report an empirical approach is employed to ascertain the effects of water stress on food security and socioeconomic development in the Mediterranean region, with a particular focus on the Southern and Eastern Mediterranean countries.

In an attempt to consider water stress from a multidimensional perspective, we focused on the four dimensions considered in the WPI (Sullivan, 2002; Sullivan et al., 2006) that may be expected to impact differently on food security, that is “resources” (i.e. physical availability and endowment of water resources), “access” (i.e. disposability of the available resources for the population), “capacity” (i.e. intra-allocation of water resources depending mainly on education, health and affordability) and “use” (i.e. adequate management of water resources in the domestic, industrial and agricultural sectors of the economy). Moreover, in order to analyse the likely impact of MADFORWATER on food security and socioeconomic development, an additional indicator reflecting the level of use of treated wastewater in the region was considered.

With the purpose of evaluating the effects of water stress on food security and socio-economic development, an econometric modelling approach was implemented by means of panel data models including both country and year fixed effects for the period 2000-2015, and employing an extensive database covering up to 60 preliminary variables and 29 finally selected variables, for all countries in the Mediterranean. The estimated model for food security was then employed to predict the state of food security in 2050 under the effects of climate change and socio-economic development for the countries in the region (using different combinations of the SSP and RCP scenarios of the IPCC). Model development and projections faced several limitations related to constrained data availability for certain countries and variables. Accounting of water-related variables is a challenging task for most countries, where information about certain water related issues is sparse along time. Scarcity of data makes it difficult to apply empirical methods and identify statistically significant patterns. However, despite this limitation the models tested evidenced robust linkages between water stress and food security.

Our results seem to reflect **some interesting facts and issues**. Regarding **the effects of water stress and management on food security**, we find that food security levels in the Mediterranean seem to be **more influenced by access to the resource by the population** (as measured by access to at least basic drinking water), the capacity to use those resources properly (through **higher levels of education, health and affordability**), and **an adequate management and use of water resources** reflected in an improved water efficiency across the domestic, industrial and agricultural sectors, **than to actual availability of water resources. In addition, an increased use of treated wastewater in the region is expected to have a positive impact on food security.**

Particularly, access to at least basic drinking water resources by the population seems to be the most relevant dimension in ensuring food security in the region. Capacity is found to be second in importance, with affordability (i.e. GDP per capita) and health (i.e. level of under-five mortality rates) being highly related to food security, and education (i.e. rate of primary school enrolment) found only of slight less importance. Finally, regarding the use dimension, management across all the sectors in the economy seem to be relevant in explaining food security in the region. Particularly, an adequate management and use of water at the domestic level is found as the most important among the three considered sector, but improvements in efficiency in both the industrial and agricultural sector are also expected to impact positively in food security in the Mediterranean.

A detailed analysis of food security and key water variables in the 3 MADFORWATER countries show different situations. In **Egypt**, a significant decrease of undernourishment levels has been sustained by positive economic growth in the period. Increased urbanization levels, though at a low pace, may have also been responsible of increased calorie intake. The *Access* and *Capacity* dimensions of water use evolve favourably in the country supporting food security. However, rational and efficient use of water resources in the domestic sector and water productivity in agriculture should be further reinforced.

With respect to **Morocco**, data for the 2000-2015 period show a salient progress on food security indicators, being the country among the MADFORWATER MACs that shows the best evolution up to 2015 and lowest levels of undernourishment nowadays. Besides policy efforts to improve agricultural competitiveness and rural development, positive trends in key aspects of water management and use may have underpinned food security improvements. Particularly, a remarkable improvement in the *Access* and *Capacity* dimensions of water, as well as on water use efficiency may have contributed positively to food security.

In the case of **Tunisia**, food security indicators show mixed trends along the considered period (worsening up to 2005, sharp improvements up to 2012, and subsequent deterioration). These irregular trends may be explained by economic and political instability in recent years. Moreover, although improved *Access* to water resources may have had positive effects on food security, moderate improvements in *Capacity* indicators and a lack of clear improvements regarding water use efficiency in the industry and agricultural sectors, may contribute to stagnation of food security in Tunisia in recent years.

Regarding socioeconomic development, we found that higher levels of **water availability as well as an improved allocation and capacity** of the population to use those resources properly (through higher levels of education and health) **seem to have a positive influence on economic growth**. In addition, **water stress seem to be an important factor in explaining socio-economic development**, with regions experiencing higher levels of water stress suffering from lower economic growth rates on average. However, other dimensions such as access to water resource or the efficiency in their use across the sectors in the economy does not appear as influencing in explaining economic growth as they are in the case of food security.

Finally, with respect to the state of food security in the Mediterranean NENA countries by 2050, we found that climate change will predictably lead to a worsening in the situation of food security in the region. However, the effects of the likely improvements experienced in socioeconomic development during this period seem to be enough as to compensate the negative impacts of climate change, thus leading to overall improvements in the levels of food security in the region.

Altogether, our results in this deliverable reflect that the activities developed in MADFORWATER could have a very positive impact on food security and socioeconomic development in the region through very different and varied channels. First, because improvements in both the levels of irrigation efficiency (i.e. agricultural efficiency) and treated wastewater reuse are expected to lead to improvements in food security, partially offsetting the negative impact of climate change by 2050. Secondly, because although it was found that socioeconomic development could be enough as to compensate for the projected negative effects of climate change on food security, our results show that socioeconomic development in the region is dependent on the level of water availability and water stress. Since one of the objectives of MADFORWATER is to increase the level of use of treated wastewater reuse in the region, with the corresponding improvements in the physical availability of water resources and a reduction of water stress levels in the targeted countries, the impact of the MADFORWATER activities is expected to ensure and foster socioeconomic growth in the region, thus promoting food security.

6 Abbreviations

AvDESA	Average Dietary Energy Supply Adequacy
CC	Climate Change
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CFS	Committee on World Food Security
CGIAR	Consultative Group on International Agricultural Research
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FE	Fixed Effects
GCM	General Circulation Model
GDP	Gross Domestic Product
GFSI	Global Food Security Index
HLPE	High Level Panel of Experts
IFAD	International Fund for Agricultural Development
INS	Institut National de la Statistique (Tunisie)
IPC	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
IPEMED	Institut de Prospective Economique du Monde Méditerranéen
	The Mediterranean world Economic Foresight Institute
ITES	Institut Tunesien des Études Stratégiques
	Tunisian Institute of Strategic Studies
IWLMSs	Integrated Water and Land Management Strategies
MAC	Mediterranean African Country
MADFORWATER	DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries
MDG	Millennium Development Goal
MEMEE	Ministère de l'Énergie, des Mines, de l'Eau et de l'Environnement
	Ministry of Energy Mines Water and Environment
MWRI	Ministry of Water Resources and Irrigation
NENA	Near East and North Africa
OECD	Organization for Economic Co-operation and Development
PoU	Prevalence of Undernourishment
RCP	Representative Concentration Pathways

RE	Random Effects
SDG	Sustainable Development Goal
SSP	Shared Socio-Economic Pathways
TWW	Treated Waste Water
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
UPM	Universidad Politécnica de Madrid
VIF	Variance Inflation Factor
WER	Wageningen Environmental & Research
WFP	World Food Programme
WHO	World Health Organization
WP	Work Package
WPI	Water Poverty Index
WWAP	World Water Assessment Programme

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8 Annex I. Database description.

The creation of the database involved an extensive process of gathering data from a wide variety of sources and processing them until they are in usable format for the analysis. This annex aims at describing more thoroughly the extent and content of the built database.

VARIABLES	Source	Unit	Definition
Indicators of food security			
Average Dietary Energy Supply Adequacy	FAOSTAT	(%) (3-year average)	The indicator expresses the Dietary Energy Supply (DES) as a percentage of the Average Dietary Energy Requirement (ADER). Each country's or region's average supply of calories for food consumption is normalized by the average dietary energy requirement estimated for its population to provide an index of adequacy of the food supply in terms of calories.
Prevalence of Undernourishment	FAOSTAT	% of population (3-year average)	Population below minimum level of dietary energy consumption (also referred to as prevalence of undernourishment) shows the percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.
General determinants of food security			

VARIABLES	Source	Unit	Definition
Trade	World Bank	Export and imports as % of GDP	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.
GDP_Growth	World Bank and World Health Organiztion (WHO)	Annual %	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.
Percent_ConflictNewDisplacements	Own elaboration based on: The Internal Displacement Monitoring Centre (internal-displacement.org) UNESCO: for total population	% of total population	Number of case of internally displaced persons, associated with conflicts (new displacements) divided by total population

VARIABLES	Source	Unit	Definition
Arableland_pc	FAOSTAT	Hectares per person	Arable land (hectares per person) includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.
CerealYield	FAOSTAT	Kilograms per hectare	Cereal yield, measured as kilograms per hectare of harvested land, includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage and those used for grazing are excluded.
Ruralpopulation	United Nations Population Division's World Urbanization Prospects: 2018 Revision	% of total population	Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population.
TotalPopulation	United Nations Population	Thousand individuals	

VARIABLES	Source	Unit	Definition
	Division's World Urbanization Prospects: 2018 Revision		Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates.
Percent_DisasterNewDisplacements	Own elaboration based on: The Internal Displacement Monitoring Centre (internal-displacement.org)	% of total population	Number of case of internally displaced persons, associated with disasters (new displacement associated) divided by total population
Inflation_index	International Monetary Fund	Annual %	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used.
Indicators of water stress			
Totalrenewable_WR	FAO AQUASTAT	km3/year or 10^9m3/year	Total Renewable Water Resources (TRWR): The sum of internal renewable water resources (IRWR) and external renewable water resources (ERWR). It corresponds to the maximum theoretical yearly amount of water available for a country at a given moment.

VARIABLES	Source	Unit	Definition
Accesstoatleastbasicdwater	WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene	Annual %	The percentage of people using at least basic water services. This indicator encompasses both people using basic water services as well as those using safely managed water services. Basic drinking water services is defined as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tubewells, protected dug wells, protected springs, and packaged or delivered water.
Underfivemortalityrate	World Bank (Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation: UNICEF, WHO, World Bank, UN DESA Population Division)	Individuals per 1,000 live births	Under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to age-specific mortality rates of the specified year.
PrimarySchoolEnrollment	UNESCO Institute for Statistics	Annual % net	Total number of students enrolled in primary education, expressed as a percentage of the total population.

VARIABLES	Source	Unit	Definition
GDPpercapita	World Bank national accounts data, and OECD National Accounts data files.	Current US$	GDP per capita is gross domestic product divided by midyear population. GDP at purchasers prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.
sq_GDPpc	Own elaboration based on: World Bank national accounts data, and OECD National Accounts data files.	GDP per capita squared (current US$)	
Domestic_use_index	Own elaboration based on following sources: FAO AQUASTAT	Adimensional	Two-way index as described in Lawrence et al. 2003
RatioIndustrialwatereff	Own elaboration based on following sources: -FAO AQUASTAT		Ratio between: - Industry (including construction), value added (% of GDP)

VARIABLES	Source	Unit	Definition
	- World Bank national accounts data, and OECD National Accounts data files.		- Annual freshwater withdrawals devoted to industry as a % of total freshwater withdrawal.
RatioAgriculturalwatereff	Own elaboration based on following sources: - FAO AQUASTAT - World Bank national accounts data, and OECD National Accounts data files.		Ratio between: - Agriculture, forestry, and fishing, value added (% of GDP) - Annual freshwater withdrawals devoted to agriculture as a % of total freshwater withdrawal.
Agr_waterefficiency	Own elaboration based on following sources: - FAOSTAT - FAO AQUASTAT		Ratio between: -Cereal yield (kg per hectare) -Annual freshwater withdrawals devoted to agriculture as a % of total freshwater withdrawal.
Precipitation_log	UN Environment Statistics Database	Million cubic meters (in logs)	Total volume of atmospheric wet precipitation (rain, snow, hail, dew, etc.) falling on the territory of the country over one year, in millions of cubic meters.

VARIABLES	Source	Unit	Definition
TWW_Reuse	FAO AQUASTAT	km3/year or 10^9m3/year	Treated municipal wastewater (primary, secondary, tertiary effluents) directly used, i.e. with no or little prior dilution with freshwater during most of the year.
Water stress	-FAO AQUASTAT	%	Freshwater withdrawals as a percentage of total renewable water resources
General Determinants of Economic Growth			
Gross_fixed_cap	World Bank national accounts data, and OECD National Accounts data files.	(% GDP)	Gross fixed capital formation (% of GDP)
Popgrowth_plus0.05	World Bank	Annual rate + 0.05	Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.
SecondarySchoolEnrollment	UNESCO Institute for Statistics	% of total population	School enrollment, secondary (% gross)

VARIABLES	Source	Unit	Definition
TerciaryEnrollment	UNESCO Institute for Statistics	% of total population	School enrollment, tertiary (% gross)
InitialGDP_5yearavg	Own creation based on data from World Bank national accounts data and OECD National Accounts data files.	Current US$	5-year averages. Since we have data from 2000 to 2015, we take the following periods for the average: 2000-2004, 2005-2009, 2010-2015

9 Annex II. Recent trends (2000-2015) of the Prevalence of Undernourishment and the Average Dietary Energy Supply Adequacy.