CHAPTER 3

MANAGEMENT OF WATER RESOURCES

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Today, water scarcity is an urgent issue expected to impose severe constraints on the Mediterranean region for its development and food security. According to the World Water Assessment Program of the UNESCO (WWAP, 2015), without significant global policy change, the world will only have 60% of the water it needs by 2030. The Mediterranean region is one of the most water-scarce areas in the world. The region holds only 3% of the world's freshwater resources but hosts more than 50% of the world's "water poor" populations, or around 180 million of the region's 460 million inhabitants (Châtel *et al.*, 2014). The entire region has a supply of renewable water resources of about 1,452 km^3, which is distributed in an extremely inhomogeneous way between the North (74%), the East (21%) and the South (5%) (Ferragina, 2010). However, water scarcity is expected to intensify further in this region that has already been made fragile due to population and economic growths, desertification and the needs for environmental protection. In addition, the rise in temperatures will impose further stress on the Mediterranean's finite water resources as this region is identified as one of the most prominent climate response hot-spots. Water scarcity can involve not only a lack of water but also poor water delivery infrastructure and poor water management. Some consider water scarcity as an absolute shortage of physical supply while others argue that it is generated by poverty, inequality and bad water management policies. Water resource availability in the Mediterranean has already been negatively affected and this is seriously jeopardising food security and the environment.

This chapter exposes the different components affecting the variability of water availability and therefore assesses the reasons behind wastages and losses of water and the possible solutions with the aim of ensuring a more sustainable food production and environment. It presents a holistic approach to water issues, analysing the current situation, based on the actual irrigated vs. rainfed areas, and then setting the general framework for required actions, the so-called "Water-Energy-Food Nexus". Within this triangle, this chapter explains the components that would greatly influence the overall improvement of the other components, the tools to be adapted for the achievement of higher efficiency at farm level vs. the whole ecosystem, the effects of climate change, emphasising the importance of the involvement of stakeholders and finally, the indispensable comprehensive management that can be achieved under a reliable water governance.

Water use in Agriculture: current situation, future scenarios and challenges

Agriculture is the largest water consumer in the Mediterranean (including northern and southern countries): it uses an average of 64% of water (varying from 50% up to 90% in some countries), followed by industry (including the energy sector and the tourism industry) (22%) and the domestic sector (14%) (GWP, 2010). By 2050, agriculture will need to produce 60% more food globally and 100% more in developing countries (Alexandratos and Bruinsma, 2012). In many of the low rainfall regions of the Middle East and Northern Africa, most of the exploitable water is already withdrawn, with 80% to 90% of it used in agriculture. So, rivers and aquifers are depleted beyond sustainable levels (FAO, 2011a). The agricultural sector will therefore need to increase crop productivity with respect to water in order to achieve food security. Producing more "crop per drop" will be one of the major challenges in the years to come.

Agriculture can be considered both a cause and victim of water scarcity. Of all sectors of the economy, agriculture is the most sensitive to water scarcity. Mediterranean countries increasingly rely on groundwater, which is a significant source of water across the region, to meet the rapid growth of the agricultural sector. The use of new technologies has led to groundwater extraction rates far in excess of recharge. The result has been a rapid depletion of aquifer reserves resulting in salt intrusion along coastal areas with consequent desertification. In addition, the dangerous pollution of aquifers by the leaching of agricultural chemicals has diminished the quality of groundwater and of rivers and streams fed by groundwater.

The water demand of the growing population, agriculture and industry put heavy pressure on the limited water supply of the Mediterranean region. Sustainable solutions are therefore required to meet the current and projected demand as well as to protect ecosystems. Integrated management of water resources with a holistic and inclusive approach requiring coordinated responses across the different sectors, is needed to ensure water and food security. Potential solutions to enhance water supplies include water harvesting with artificial groundwater recharge to increase water storage capacity and freshwater availability, wastewater reuse and solar energy desalination. In terms of trade, importing products requiring large amounts of water in their production ("virtual water"), constitutes a key element in helping to eliminate or at least soften water shortage and it is called to play a more important role to overcome water scarcity (Playán and Mateos, 2006).

Future water challenges in the Mediterranean call for innovative solutions with regards to the development of more sustainable water management strategies focusing on the conservation of this precious resource. Therefore, there is a need to balance water supply and demand with a focus on better management and conservation rather than only through the construction of infrastructures such as dams and water transfer systems. Since irrigated agriculture is the largest water consumer in the Mediterranean, significant water savings benefits could result from irrigating with reused or recycled wastewater. Water that is "wasted" is costly in terms of mobilisation and distribution; thus, these water savings would be a source of financial savings. With an average supply cost of 0.40 euro per m^3, almost 220 billion euros could be saved in 20 years (Hervieu et Thibault, 2009). To achieve food security while facing water shortages, it is necessary to implement a sustainable resource management. Indeed, food security is strongly dependent on effective trade policy, sustainable farming practices, water security, sustainable irrigation techniques and proper waste management (CIHEAM, 2015).

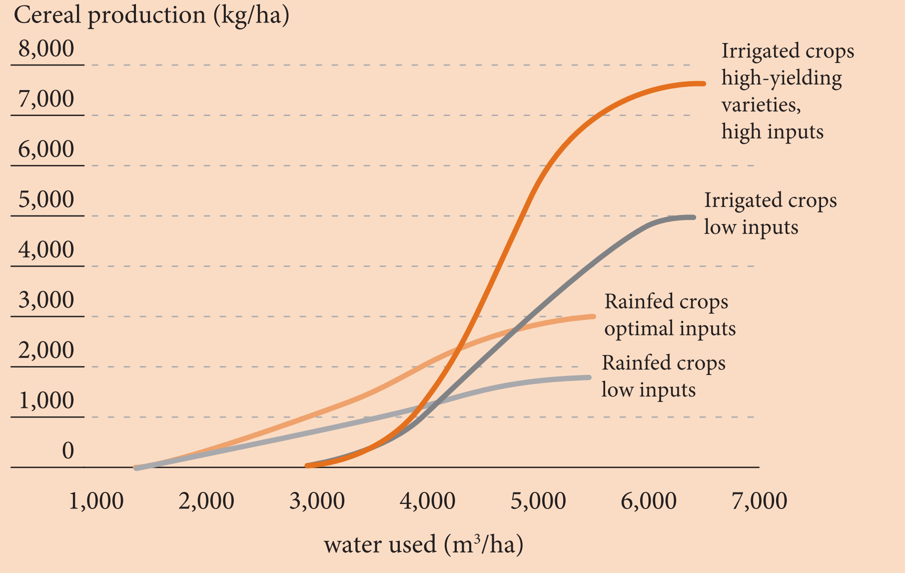
Agro-climatic suitability and yield gap (rainfed versus irrigated productions)

In 2000, about 25% of the global harvested areas were irrigated, with a cropping intensity (including fallow land) of 1.12 and over 50% of the world was suitable for rainfed agriculture, as reported by the MIRCA2000 (Portmann *et al.*, 2010). The major harvested crop in irrigated areas is rice with 1 million km^2 while wheat and maize crops are the largest harvested areas in rainfed lands with 1.5 and 1.2 million km^2, respectively (Portmann *et al.*, 2010).

The total area of rainfed agriculture differs spatially from 95% in Sub-Saharan Africa to 90% in Latin America, 75% in North Africa and the Near East, 65% and 60% for the East and South Asia, respectively (Wani *et al.*, 2009). Despite the irrigated agriculture area being much smaller than the rainfed area, it contributes to 40% of the total agriculture food production (FAO, 2002). According to the FAO (2002), the highest cereal yield that could be obtained from irrigation is more than the double the highest yield that can be obtained from rainfed agriculture. Even low-input irrigation is more productive than high input rainfed agriculture as shown in Figure 1.

Rainfall is one of the major constraints that could limit rainfed agriculture in semi-arid and dry sub-humid areas. Nevertheless, this constraint is not a result of the low precipitation but rather of its extreme variability with high intensities, few rain events, and poor spatial and temporal distribution of rainfall (Rockstrom *et al.*, 2010). Drought and land degradation are constraining the expansion or production increment of the agriculture system. This is also associated with the low efficiency in water use and lack of efficient policies to improve the situation in the short- and long-term. Inappropriate management of natural resources accompanied with farmers' lack of knowledge and lack of policy support and infrastructure including markets and credits, low investments in rainfed agriculture, planting traditional cultivars, low use of fertilisers and low rainwater use efficiency, pests and diseases and absence of integrated and compartmental approach for management are the main reasons for low on-farm yields and a large yield gap in rainfed agriculture (Wani *et al.*, 2009). The major constraints facing agriculture, especially the rainfed agriculture are summarised in Figure 2.

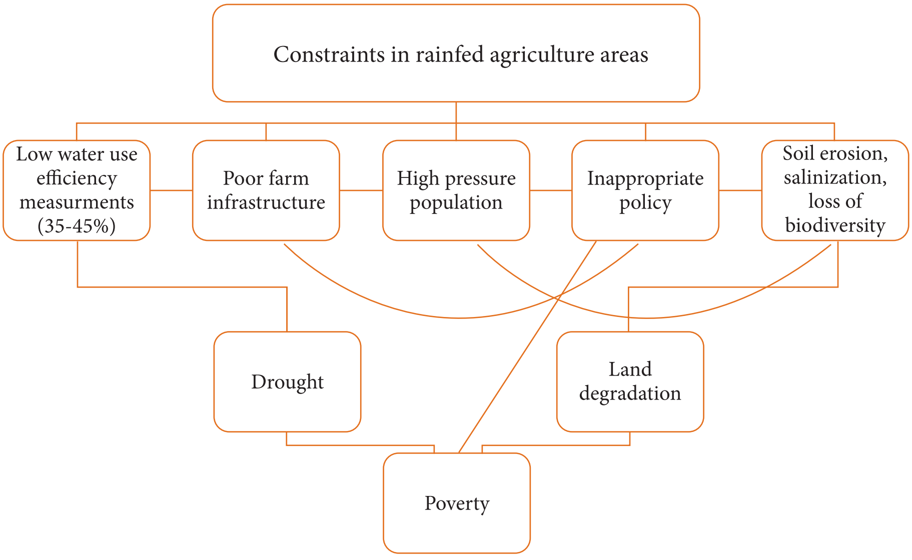
Figure 1 - Yields and water requirements of irrigated and rainfed agriculture



Source: FAO (2002).

The direct impact of the agro-climatic suitability on the yield produced from rainfed agriculture as well as the key role of water resources management for both rainfed and irrigated areas is apparent. Different ways and methods for the classification of systems are based on one or more criteria such as rainfall, temperature, major agriculture systems, differences in ecological characteristics, etc. The FAO Water Report No. 41 emphasises the need for "smart" realistic options in order to reduce and close the yield gaps in both small- and large-scale cropping systems worldwide. To make progress in this direction the following steps should be taken into account: definitions and techniques to measure and model yield at different levels (actual, attainable, potential) and different scales in space (field, farm, region, global) and time (short and long term); identification of the causes of gaps between yield levels; management options to reduce the gaps where feasible; policies to favour the adoption of gap-closing technologies.

Figure 2 - Constraints in rainfed agriculture areas



Source: Rockstrom *et al.* (2007); Wani *et al.* (2009).

Certain strategies and plans should be conducted to reduce the total number of the world's poor especially with the increasing population pressure. A study (Rockstrom *et al.*, 2010) analysed the yield gaps in rainfed agriculture, that is, the gap between the actual yields compared to the potential ones under better farm management for major grains for some selected African, Asian, and Middle East countries. Experience in Mediterranean countries showed that government's organisation alone cannot scale out improved production system technologies to reduce the yield gap and reduce food loss and waste, but it is indispensable in facilitating actions among stakeholders including the public sector, civil societies, and the private sector through: the creation of a policy and institutional enabling environment; the creation of a favourable investment climate; the strengthening of technology transfer and dissemination through public-private partnership; awareness raising and advocacy; the development of partnerships and alliances; support to innovative products and processes; capacity development at the supply chain and institutional levels; and the enhancing of research funding for high-yielding, water-efficient, and multi-diseases tolerant crops development programmes.

Irrigation efficiency along the distribution chain and water productivity

The use of "efficiency" in the analysis and evaluation of any system is a key indicator in understanding how each system helps reduce wastage on its own scale; but this might not apply to the overall system. In the agricultural sector, water use efficiency is far from being satisfactory. The term "efficiency" is often used in the case of irrigation systems and is commonly applied to each irrigation sub-system: storage, conveyance, off- and on-farm distribution, and on-farm application sub-systems (Pereira *et al.*, 2012). The concept of "water supply efficiency" or "irrigation efficiency" defines the difference between water withdrawn and the physical losses resulting from leakage from pipes and open channels as well as on-farm wastage through inappropriate water applications for the crops. For example, among the 23 countries of the Mediterranean, an estimated 25% of water is lost in urban networks and 20% from irrigation canals (FAO, 2012). Some authors prefer the use of the term "water productivity", the output of goods and services in physical or monetary terms per unit of water consumed, rather than the often confusing irrigation efficiency or water use efficiency (Rijsberman, 2006). Molden (2010) states that under optimistic assumptions, three-quarters of the additional food demand could be met by improving water productivity on existing irrigated lands. Experts estimate that developing countries use twice the amount of water per irrigated hectare than industrialised countries do, despite the fact that their crop yield is three times lower due to ineffective irrigation methods, inefficiencies, evaporation rates, etc. (GWP, 2010).

Water productivity can be improved mainly by an adequate agronomy and better cultivars. Since the main factors affecting efficiency from this perspective are actually the climate-soil-crop combination, this improvement should therefore be based on the suitable selection of each component. As for the engineering aspect, the modernisation and rehabilitation of water delivery and farm irrigation infrastructure can include the adoption of adequate technology and on-farm management practices. In most of the modernisation projects aiming at increasing irrigation efficiency, the consequences averred to be controversial: farmers switched to more profitable crops with higher water demands (Fernández García *et al.*, 2014). The use of technology alone, without the improvement of water management at basin and farm levels cannot solve water shortage issues. Improving water productivity will therefore require an understanding of the biophysical as well as the socioeconomic local environments crossing scales between field, farm and basin (Molden *et al.*, 2010).

The "chain of efficiency" approach proposed by some authors provides another way of examining this issue. This chain includes the following steps: conveyance efficiency and farm efficiency, application efficiency, consumptive efficiency and transpiration efficiency, assimilation efficiency, biomass efficiency and yield efficiency. This approach helps to analyse and assess the extent of the overall improvement in water use efficiency in terms of improvements in each step. In addition, the enhancement of water efficiency requires smart policies that include managers and farmers. The progress in technology has undoubtedly led to gains in water productivity. However, a knowledge-exchange system is needed to help farmers, water users associations and resource managers to identify the scope for further improvements, so that they can share greater responsibility across the entire water supply chain (Levidow *et al.*, 2014). Smart water management is necessary to combat scarcity and to help the agricultural sector adapt to the uncertain future.

Efficiency of on-farm irrigation systems

The efficiency of an irrigation system can be calculated at reservoir (storage efficiency), distribution system (conveyance efficiency), farm (on-farm water application efficiency) and plant (water use efficiency) levels. However, the overall irrigation efficiency can be expressed as the ratio of water volume used by the plant to the volume extracted from the source.

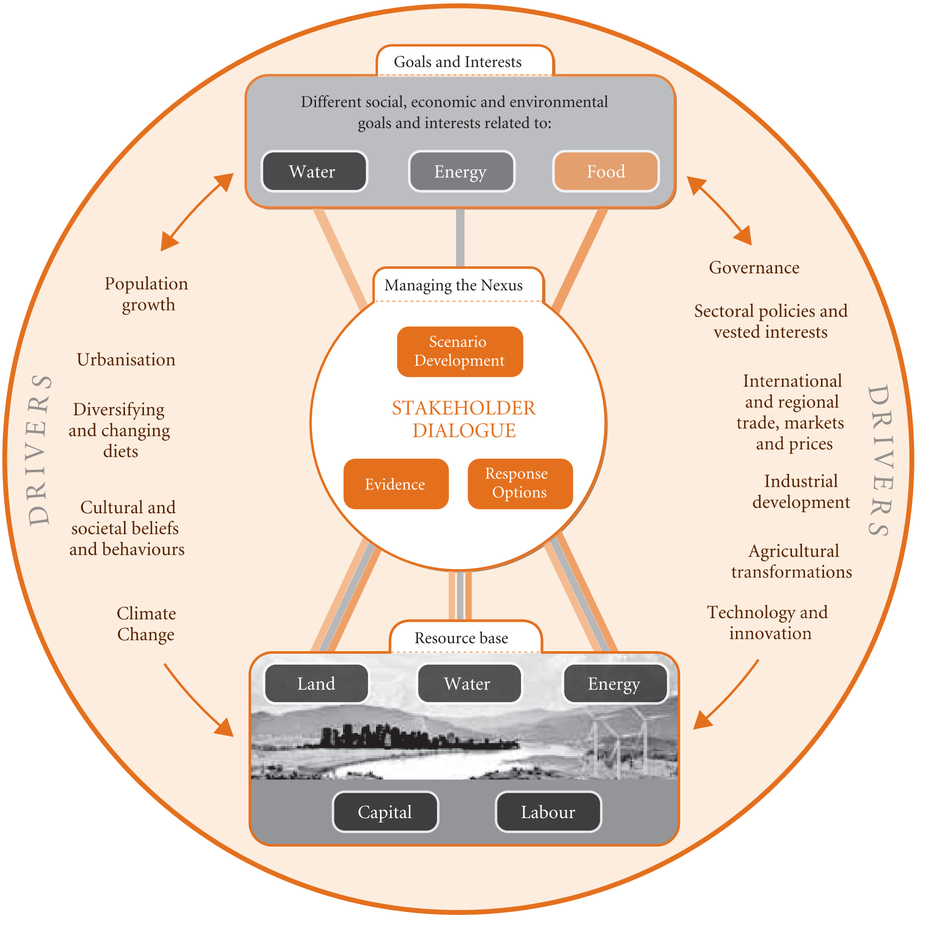
On-farm irrigation systems can be classified depending on their application method: trickle, sprinkler and surface. Pressurised water distribution systems have considerable advantages with respect to the traditional open channels as they can: 1) reduce greatly the water losses during transportation; 2) overcome the topographic constraints; 3) avoid the uncontrolled water withdrawals with the possibility to establish water fees based on water consumed; and 4) ensure great flexibility to farmers in managing their irrigation practices according to their needs (Lamaddalena and Sagardoy, 2000). Regardless of the irrigation method used, in order to be efficient, the system has to apply the desired volume of water in the right place with minimal wastage possible.

Water-Energy-Food Nexus

Water, energy and food systems are inextricably interconnected. Water is needed to produce agricultural goods in the fields and along the entire agro-food supply chain. It is also needed for almost all forms of energy generation, which, in turn, requires the production and transport of water and food, e.g. groundwater and surface water pumping, as well as wastewater treatment. The relationships and trade-offs within this triangle of resources are known as the "water-energy-food nexus" and any significant waste or inefficient strategy, would affect the whole system. These three systems intertwine and therefore any decision-making and actions related to one system impacts one or both of the other systems. Nexus policymaking is about designing resilient strategies in ways that take account of the connections between food, water and energy systems (WWF and SABMiller, 2014). It offers a holistic vision of sustainability that recognises and tries to strike balance between the different goals, interests and needs of the population and the environment. The framework of this approach is summarised in Figure 3.

While agriculture accounts for 70% of total global freshwater withdrawals, the food sector currently accounts for only 30% of the world's total energy consumption but produces over 20% of global greenhouse gas emissions. In addition, around one-third of the produced food, and the energy embedded in it, is lost or wasted (FAO, 2011b). This situation is expected to worsen in the near future as 60% more food will need to be produced in order to feed the world population in 2050 (FAO, 2014b). Climate change is also likely to exacerbate pressure on resources and therefore contribute to the vulnerability of the correlated systems and widening the waste gap within the triangle. To face these challenges, it is vital to plan future development by integrating all aspects to ensure that the three sectors (water, energy and food) are not considered in isolation, but in a way that each can contribute to the resilience of the others (WWF and SABMiller, 2014). Ensuring the reliability and efficiency of the system as a whole (that is, saving resources and reducing losses) by improving each of its essential components requires significant and sustained efforts at all levels. Another issue identified by the scientific community is the contradictory demands of the different components of the Nexus (CIHEAM, 2015).

Figure 3 - The FAO approach to the Water-Energy-Food Nexus



Source: FAO (2014b).

With the introduction of technology and mechanisation, the modernisation of agricultural practices has helped to increase yields and food security. In return, however, energy use for irrigation, which depends on the type of water distribution systems, on-farm irrigation systems and the source of water, has increased significantly. The Spanish experience is a good example. Since 2002, the Spanish government has developed a National Irrigation Plan and an Emergency Plan for the Modernisation of Irrigation systems with the aim of saving 3,000 m^3 of water per year in an effort to improve the conveyance efficiency. As a result, water use for irrigation per unit of irrigated area has been reduced by 21% from 1950 to 2007. However, the energy consumption has increased by 657% over the same period involving higher energy costs for farmers (Fernández García *et al.*, 2014). That is, the irrigation communities are now paying four times the cost of water in energy costs. Another example is the over exploitation of groundwater, which provides close to half of total consumptive irrigation water use for food production. Groundwater is generally more energy intensive than surface water, so that up to 40% of total energy use in some countries is used for pumping groundwater (Hoff, 2011).

Consequently, water, food and energy resources are linked through shared risks and opportunities and the collaboration between the three systems is crucial. The alternative competition to control resources serves the resilience capacity of the water-energy-food nexus (WWF and SABMiller, 2014). A coherent approach, on the contrary, highlights the interdependence of water, energy and food security and the natural resources that support that security. This approach identifies mutually beneficial responses and provides an informed and transparent framework for determining trade-offs and synergies that meet demand without compromising sustainability (Hoff, 2011). For the Water, Energy and Food Security Nexus, the resource limitations in all sectors require a shift towards resource use efficiency, demand management and more sustainable consumption patterns, thus saving by reducing wastage on all fronts. Policymakers need to adopt smart strategies to enhance the nexus considering the opportunities and synergies of all systems (Zahner, 2014; CIHEAM, 2015):
– Solar pumping solutions can reduce carbon footprints of irrigation systems;
– Precision irrigation generally improves energy productivity (but may not save much water);
– Intensification in rainfed agriculture that can reduce the demand for irrigation and associated blue water and energy inputs;
– Reduction of food wastage;
– Increased deployment of renewable energy technologies and increased efficiency through improvements in food production, processing and distribution;
– Changes in lifestyles and consumption patterns can also reduce pressure on water, energy and food;
– Increased investments in research and innovation for water and food security and nutrition, with due attention to neglected areas;
– Considering that the interactions between water, energy and food systems should incorporate full life-cycle assessments in terms of the mutual interaction between the three components of the full nexus;
– Resources policies and regulations should be more based on the scientific knowledge related to the use of resources and the natural or man-induced impacts.

New approaches and tools to improve water management

Agriculture's impact on water resources involves complex trade-offs between economic, social and environmental demands under a wide range of institutional structures. As a major consumer of water, agriculture has a significant impact on the resource quality and the water it uses is considerably wasted. The major challenge is to ensure that water resources used by agriculture are best allocated among competing demands to efficiently produce food and fibre, minimise the pollution it causes and support ecosystems, while meeting social aspirations under different property right arrangements and institutional systems and structures (OECD, 2006). Actually, irrigation systems perform way below their potential because of poor network maintenance and operation, inadequate irrigation and agronomic techniques and poor governance structure.

Many Mediterranean countries have embarked on reforming their water sector to face the increasing stress (Thivet and Fernandez, 2012). For decades, most of the national strategies favoured the supply-side, determined by the scientific and technological progress and dominated by investments and efforts to develop infrastructures and increase water storage and conveyance. They disregarded the large potential of saving water at the different scales of the chain. The focus has gradually been shifting towards sustainability, that is, the wise and responsible use of natural resources and safeguarding the rights of future generations (Ferragina, 2010). Supply-side strategies paved the way to demand management strategies with the primary objectives to rationalise and control water use, reduce waste and increase use efficiency and equity in view of limited supplies. How can we improve water management? Answering this question would require a supply management strategy, involving highly selective development and exploitation of new conventional and non-conventional water supplies, coupled with a vigorous demand management involving comprehensive reforms and actions to optimise the use of the existing supplies (Thivet and Fernandez, 2012). This alternative path adopts a mixture of tools to address technical, economic, institutional and behavioural dimensions of water management and thus achieving a greater efficiency in agriculture.

On the technical side, irrigation efficiency is determined by management, and good management requires comprehensive data collection and integration, sophisticated analytical tools and other "soft" sophisticated technologies. Thus, it is necessary to improve and use the existing technologies more effectively (precision agriculture, weather stations infrastructures, pumping efficiency, reliable system for evapotranspiration measurements, conservation tillage etc.) and/or adopt new irrigation practices (remote sensing data sources, weather forecasting, Decision Support Systems [DSS], plant-based data sensor systems, combinations of long-term management practices, statistically explicit analytical tools, etc.) (Neea, 2015). Since these technologies can only be used successfully if appropriate skills for their use have been integrated, their development must include capacity building through training of the people concerned.

From an economic point of view, improving water resource management requires recognising how the overall water sector is linked to the national economy (FAO, 2015), i.e. understanding how alternative economic policy instruments influence water use across different sectors at various scales. To this aim, fundamental changes in the institutional arrangements and regulations, improvements in the performance of water users and their organisation are all equally important. Irrigation institutions need to adopt a service-oriented approach and improve their performance in economic and environmental terms. Irrigation-sector institutions need to link their central task of providing irrigation services to agricultural production and to integrate their water demands and uses with other users at basin level. An enhanced appreciation of the water cascades and flows across landscapes and the circulation of groundwater within aquifers will lead to informed decisions on the use and reuse of agricultural water. This entails applying improved administrative principles and techniques and promoting the participation of water users (Kijne, 2003).

Participatory Irrigation Management (PIM) is a key term in the toolbox of current approaches to improve the performance of water resources management in the countries that are to cope with the issue of water scarcity, or problems associated with global and climate change in the foreseeable future (Regner *et al.*, 2006). PIM is an approach for irrigation sector reform with the potential to improve the sustainability of irrigation systems. It needs systematic public awareness campaigns, capacity building programmes, consultations and involvement of all stakeholders.

Participatory Irrigation Management

The growing concern on the need for PIM approaches is due to their advantages:

– Reducing financial and budgetary difficulties of government;

– Improving irrigation management efficiency;

– Better and timely Operations and Maintenance (O&M of irrigation infrastructure);

– Changing farmer's attitude of over dependence on external assistance;

– Positive experience on new institutional arrangements that can be extended to other areas;

– Promoting community activities;

– Facilitating collection of water fees.

The devolution of management responsibility over irrigation systems or parts thereof requires:

– A firm policy decision to transfer a meaningful level of responsibility over the management of irrigation systems to water users;

– A legal framework for the establishment and the empowerment of independent Water Users Associations (WUAs);

– The ability of WUAs to manage the irrigation system or sub-system serving them;

– The ability of public irrigation agencies to 1) provide technical and institutional support to WUAs and 2) oversee the performance of WUAs;

– Economically viable irrigated agriculture (to be independent and self-managed, WUAs must be financially autonomous and viable).

Source: Lamaddalena and Khadra (2012); APO (2002).

The implementation and sustainability of all the above require the recognition of the economic value of water along with the acceptance of the notion of opportunity cost and attention to cost recovery, though with concern for affordability and access right. Water tariffs are a fundamental tool for creating incentives to save and allocate water in an efficient way. Above all, in the agricultural sector, appropriate water tariffs could serve to promote more efficient use of water, reduce the burden on the taxpayer and give incentive to farmers to introduce water-saving irrigation systems and to recover the service cost. Pricing policy is often influenced by two conflicting goals: efficiency and equity. However, the apparent trade-off between the two can be overcome by a differentiation of water price according to place, consumption and type of allotments (Ferragina, 2010).

Since prevailing attitudes can either impede or drive innovation and its adoption, interventions to influence expectations and support are also important. To this aim, intensive and persistent public information programmes to raise awareness on the merits of the proposed strategies and the enforcement of implementation tools are of utmost importance.

Climate Change Impacts and adaptation measures (best practices)

Most Mediterranean countries, particularly the arid and semi-arid ones, are chronically water-stressed. Population growth, urbanisation, development progress and climate change will all exacerbate this stress and result in enormous pressure on limited water and land resources. To this end, the horizons of research should be widened to cover the major issues of Mediterranean agriculture, among which those related to the impacts of climate change on water resources and agricultural production. Recent analyses based on the A1B scenario of the Special Report on Emission Scenarios (SRES) indicated that the raise of air temperature would be the highest in some areas of Northern Africa and the Middle East, and in Southern Turkey (see Figure 4). In winter, the continental interior of South Eastern Europe and the Eastern Mediterranean would warm more rapidly than elsewhere. Differently, in summer, the Western Mediterranean would warm more than the other parts (Saadi *et al.*, 2015).

For the same time span (2000-2050), the average annual precipitation could have a decreasing trend of around 6% for the whole region. Most of Europe could get wetter in the winter season with the exception of Greece, Southern Italy and Turkey. In summer, an overall decrease of precipitation could be expected in the Euro-Mediterranean area, while an increase is foreseen in some areas of Northern Africa and the Middle East (Saadi *et al.*, 2015). Hence, a climatic water deficit, estimated as a difference between precipitation and reference evapotranspiration, could increase and be less favourable in the future than nowadays.

The shifting of agro-ecological zones will be one of the primary impacts of climate change that will interact with the land and water availability and agricultural productivity under new conditions. On the one hand, higher air temperature will decrease the growing cycle of plant species, anticipate sowing/planting dates, increase respiration rates, reduce period of yield formation, lessen biomass production and yield and, very likely, decrease yield quality (i.e. lower protein level of grains). On the other hand, the increase of air temperature will extend the overall period suitable for cultivation and permit, in some areas, for more than one cropping in the same year. The impact of climate change on agricultural production could be negative for most areas of the Mediterranean with a large variability and reduction of yield (Olesen *et al.*, 2011). No changes or slight increase in yield are expected for autumn and winter crops, while, for spring-summer crops, a remarkable decrease of yield is predicted due to temperature increase and shortening of the growing season (Saadi *et al.*, 2015). The possible increase in water shortage and in frequency and intensity of extreme weather events may cause higher yield variability and a reduction of suitable areas for traditional crops (Ferrara *et al.*, 2010). As a consequence of air temperature increase and the shortening of the growing season, the average crop water requirements (CWR) over the whole Mediterranean region are expected to decrease for winter-spring and spring-summer crops by 4 to 8% (Saadi *et al.*, 2015). Hence, a slight increase of CWR and irrigation inputs could be expected for perennial crops like olive trees.

Figure 4 - Spatial pattern of the mean annual and seasonal temperature difference (°C) between 2050 and 2000

Source: Saadi *et al.* (2015)

Most rainfed cropping systems could be negatively affected by climate change due to expected lowering of climatic water balance and overall reduction of water availability for agriculture. The latter is due to projected increase of water demand by other sectors. Overall, climate change could likely intensify the problems of water scarcity and sustainable agricultural production in the region.

The mitigation and adaptation measures to climate change should focus on conservation and more efficient use of natural resources in agriculture and other sectors. Particular attention should be reserved for the combined effects of temperature rise, rainfall variability, CO_2 increase and genetic and technological improvements (CGIAR, 2012). Hence, water and carbon balance of modern agro-ecological systems should be among the priorities for research. Equally so, the adaptation to extreme weather events and various abiotic stresses are of primary importance for agricultural production and food security. For arid and semi-arid Mediterranean lands, it is essential to select management practices and exploit varieties able to respond to adverse environmental conditions and to increase/stabilise yields and water productivity in the future. ACLIMAS (Adaptation to Climate Change of Mediterranean Agricultural Systems) is one of the projects pursuing this approach.

The ACLIMAS project

ACLIMAS is a demonstration project funded by the EC Sustainable Water Integrated Management (SWIM) programme. The consortium is composed of 15 partners from 10 countries and coordinated by the CIHEAM-Bari. The project started in January 2012 and was completed in December 2015.

The activities were conducted in six Mediterranean countries (Morocco, Algeria, Tunisia, Egypt, Jordan and Lebanon) with the objective of bringing a sustainable improvement of agricultural water management, stabilisation of yield and broader socio-economic development of target areas in the context of adaptation to climate change, increasing water scarcity and desertification risks. ACLIMAS focuses on cereals and legumes since they are strategic and complementary crops in the Mediterranean. The adoption of varieties resistant to abiotic stresses and adequate management practices (timing and density of sowing, minimum tillage, residue cover, crop rotation, water harvesting, irrigation/nutrient inputs, etc.) demonstrated the potential for yield increase between 10% and 30% and water productivity rise up to 50%.

The main target groups and beneficiaries of ACLIMAS are rural societies (farmers, growers and local breeders), farmer associations and local governmental extension services (policy makers and agricultural advisors) and governmental research institutions. ACLIMAS has involved directly more than 3,500 local stakeholders with a realistic possibility to produce a multiplier effect not only due to replication but also due to extension of the initiative to other communities and stakeholders.

Source: ACLIMAS (www.aclimas.eu/index-fr.html).

The translation of research findings into policy making and on-ground implementation is of paramount importance to promote appropriate and efficient farming systems able to adapt to climate change while reducing pollution and impacts on the environment and getting the benefits of this change (Ewert, 2012). This could be achieved through an appropriate institutional setting and further funding of the initiatives that focus on the demonstration units (see Figure 5) and on-farm implementation activities based on the locally tailored best management practices, modern monitoring-early warning systems and decision-making tools.

The relationship between climate change, natural resources, agricultural production and food security is very complex and requires the consideration of both bio-physical, social, economic, technical, political and anthropogenic (management) factors and their interactions at different scales and directions (from local to global level and vice versa). Particular attention should be given to the integrated coastal zone management and resilience of Mediterranean marginal lands. The efforts should focus on the effective implementation of innovative technological/management solutions and their economic and environmental impacts. Research should address the selection of appropriate indicators for the assessment of system-wide eco-efficiency improvements, the integration of existing tools and assessment methods in a coherent modelling environment, and the analysis and characterisation of existing water structures and management policies. Hence, the eco-efficiency approach should be extended to the whole chain of food production, conservation, transport and consumption.

Figure 5 - Conservation agriculture practices applied at ACLIMAS demonstration field in Bekaa Valley (Lebanon) (left) and demonstration field in CIHEAM-Bari (Italy) (right)

Source: M.T. Abi Saab, LARI (Lebanon) and R. Albrizio, CNR-ISAFOM (Italy).

Water Governance

Water governance represents a relatively recent topic of focus within the water community worldwide (UNESCO, 2015). It comprises all social, political, economic and administrative organisations and institutions, as well as their relationships to the development and management of water resource at different levels of society (GWP, 2003). It is more about the way in which decisions are made than about the decisions themselves.

While the social dimension points to the equitable use of water resources and the economic one draws attention to the efficient use of water and the role of water in overall economic growth, the political dimension is mainly directed at granting water stakeholders and citizens at large equal democratic opportunities to influence and monitor political processes and outcomes, thus emphasising a certain water equity for socially, economically and politically disadvantaged groups (Hamdy, 2012).

Water governance is needed for 1) managing an increasing demand; 2) ensuring an equitable, reliable and sustainable access to water; 3) overcoming shortcomings in accountability and transparency; 4) accomplishing the water sector reform process towards decentralisation and other aspects of integrated water resource management; 5) redefining water rights; and 6) mainstreaming gender issues (Hamdy, 2012; Scarlett, 2012).

Over the last 25 years, some common trends can now be identified in water governance:
– Significant decentralisation of some functions and establishment of effective participatory structures and processes;
– Efforts towards the effective application of the concept of "Integrated Water Resources Management";
– Enhanced recognition of the fact that bottom-up and inclusive decision-making is key to effective water policies;
– Strengthening of information tools and flows about deficiencies, failures and poor practices of water sectors.

Table 1 - Key co-ordination gaps in water policy and possible responses

Administrative gap	Geographical mismatch between hydrological and administrative boundaries. This can be at the origin of resource and supply gaps. => Need for instruments to reach effective size and appropriate scale.
Information gap	Asymmetries of information (quantity, quality, type) between different stakeholders involved in water policy, either voluntary or involuntary. => Need for instruments for communicating and sharing information.
Policy gap	Sectoral fragmentation of water-related tasks across ministries and agencies. =>Need for mechanisms to create multidimensional/systemic approaches and to exercise political leadership and commitment.
Capacity gap	Insufficient scientific, technical, infrastructural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.), as well as relevant strategies. => Need for instruments to build local capacity.
Funding gap	Unstable or insufficient revenues undermining effective implementation of water responsibilities at sub-national level, cross-sectoral policies and investments requested. =>Need for shared financing mechanisms.
Objective gap	Different rationales creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems reducing the political will to engage substantially in organising the water sector). => Need for instruments to align objectives.
Accountability gap	Difficulty ensuring transparency of practices across different constituencies, mainly due to insufficient user commitment, lack of concern, awareness and participation. => Need for institutional quality instruments. => Need for instruments to strengthen the integrity framework at the local level. => Need for instruments to enhance citizen involvement.

Source: Adapted from C. Charbit and M. Michalun, "Mind the Gaps: Managing Mutual Dependence in Relations Among Levels of Government", *OECD Working Papers on Public Governance*, 14, 2009.

However, regardless of the institutional setting, water availability or degree of decentralisation of the different countries (OECD, 2015), several gaps (see Table 1) which hinder the governance process and further delay the implementation as well as the design of water policy still exist. The needs for improvement can be identified.

In the Mediterranean countries, the issue of water governance is given a low political priority, creating bottlenecks such as: 1) the lack of appropriate institutional and legislative provisions with weak planning and operational management, fragmentation and imbalance between and across centralised and decentralised levels, democratic deficits and an overall lack of awareness and participatory culture and 2) the deficiencies in implementation and/or operational tools, poor infrastructure, lack of data, reliable information, capacitated personnel and financial resources (7th World Water Forum, 2015). Nevertheless, Mediterranean countries offered, throughout the years, a large experience of progress in water governance. In fact, the national and regional schemes reinforced the capabilities of water managers at all levels, while the recent transboundary negotiations and continuous cooperation efforts keep moving the Mediterranean from water sharing to benefit sharing. Additionally, great willingness and ability to find and implement solutions to the water challenges has been shown by the Mediterranean societies, through a variety of stakeholders (CIHEAM, 2015).

Conclusion

Ensuring water security is the basis to guarantee food security around the globe and, in particular, in the Mediterranean basin as water and food security are intrinsically linked. The Mediterranean region faces context-specific challenges associated with water scarcity, producing enough food for a growing population, increasing competition for water between people and sectors, increasing degradation of water resources and ecosystems, and the lack of fair and transparent allocation mechanisms that recognise and protect the interests and rights of all users, especially the most vulnerable and marginalised. In addition, climate change is expected to exacerbate the unbalance between water demand and water availability.

As a consequence, water saving in the Mediterranean became a necessity. It has been perceived that the reduction of water losses along the distribution chain (from crops to conveyance infrastructures) along with the reuse of alternative water resources may greatly help to balance demand and supply. However, solving the water issue cannot be restricted only to physical saving in terms of volumes. Energy consumption should be taken into account together with management activities and appropriate governance models. Policy-makers need to adopt smart strategies to plan and implement successful water security and food security policy. This policy should be differentiated between the scales at which water saving should be achieved, thus allowing the achievement of adequate environmental protection measures.

Major challenges were highlighted along this chapter in order to draw some water policy recommendations. The starting point of such a policy would necessarily rely on the identification of the administrative, political, informative, social and technical gaps based on which actions can be designed. Identifying these gaps requires the involvement of all the water stakeholders to ensure the success of the process.

Therefore, a people-centred approach should be adopted at all levels with the aim of transforming the management of water resources into a participatory discipline, which can be reflected in a wider decision making process. In addition, before implementing any policy, it is crucial to ensure the coherence between water and food security-related strategies and plans. Sustainability must be considered as a permanent goal at all levels. Technically, aiming at a sustainable modernisation of irrigation systems does not mean the installation of the latest technologies, but increasing the resilience of irrigation systems and adopting optimal solutions for the territory and the operators, which basically starts by achieving equal access to water and by prioritising the most vulnerable and isolated users. At this point, building capacities to create the acceptability and operation of water management systems through investment in water education is essential. The awareness generated through this process will allow a better and faster adaptation of the stakeholders and a wiser, better-informed opinion that takes into account the environmental benefit as a sustainability and success indicator of any decision taken.

Finally, it is important to highlight that targeting zero hunger cannot be achieved only by improving productivity without a substantial reduction of food wastage. Hence, addressing the issue of food production becomes a matter of geographical allocation as a main pillar of food security.

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