Climate Change and Mediterranean agriculture
Expected impacts, possible solutions and the way forward

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Climate and agriculture have been inherently linked since the very beginnings of our civilization. The increase of temperature, the melting of glaciers and favorable pedo-climatic and hydrological conditions enabled the establishment of the first human settlements and the starting of farming in the Fertile Crescent about 11,000 years ago. The successive increase of air temperature progressed toward the North and the West, with an approximate pace of 1 km per year, which had permitted the step-by-step expansion of agriculture into the areas of Peloponnese, Balkan and Apennine peninsulas, and the rest of Europe. Since that time, several cold and warm periods occurred at the global scale and the agriculture had to adapt to different agro-climatic, hydrological, soil and landscape conditions. Subsequently, it was possible to distinguish different climatic zones on the Earth and the Mediterranean as one of them (Köppen, 1936; Peel et al., 2007).

The Mediterranean type of climate doesn't extend only around the Mediterranean Sea but also to coastal California, central Chile, the Western Cape of South Africa and southern and southwestern Australia. This type of climate is characterized by mild and rainy winter seasons and dry summers and, therefore, a specific native vegetation (grasses, herbs, shrubs, evergreen and deciduous trees) and a typical cropping pattern including fruit trees (olives, citrus, grapes, figs and walnuts), winter-spring cereals (durum wheat and barley) and legumes (lentils, chickpeas, beans) and spring-summer, mainly irrigated, vegetables (tomato, potato, fennel, asparagus, eggplants, zucchini, etc.).

These crops are at the base of the Mediterranean diet which is the expression of healthy eating and living recognized also by UNESCO and inscribed in 2013 on the Representative List of the Intangible Cultural Heritage of Humanity. Accordingly, due to the peculiarities of the Mediterranean, agriculture is one of the main production sectors sustaining the socio-economic development of the region. However, the on-going climate change poses serious threats to sustainable agricultural production in the future.

The area around the Mediterranean Sea presents a transition zone between the temperate and rainy climate of continental Europe and the arid and hyper-arid climate of North Africa. This incites the interactions between the mid-latitude westerlies and tropical processes originated in the South which, associated with the limited availability of land and water resources, contribute to characterize the region as highly vulnerable to climate change (Giorgi, 2006; Giorgi and Lionello, 2008; IPCC, 2014). Therefore, the impact of climate change on the Mediterranean agricultural systems and the mitigation and adaption policies and measures are of great importance to the region in order to preserve limited natural resources and assure sustainable ecosystems functioning and resilient rural development.

Climate change and expected impacts

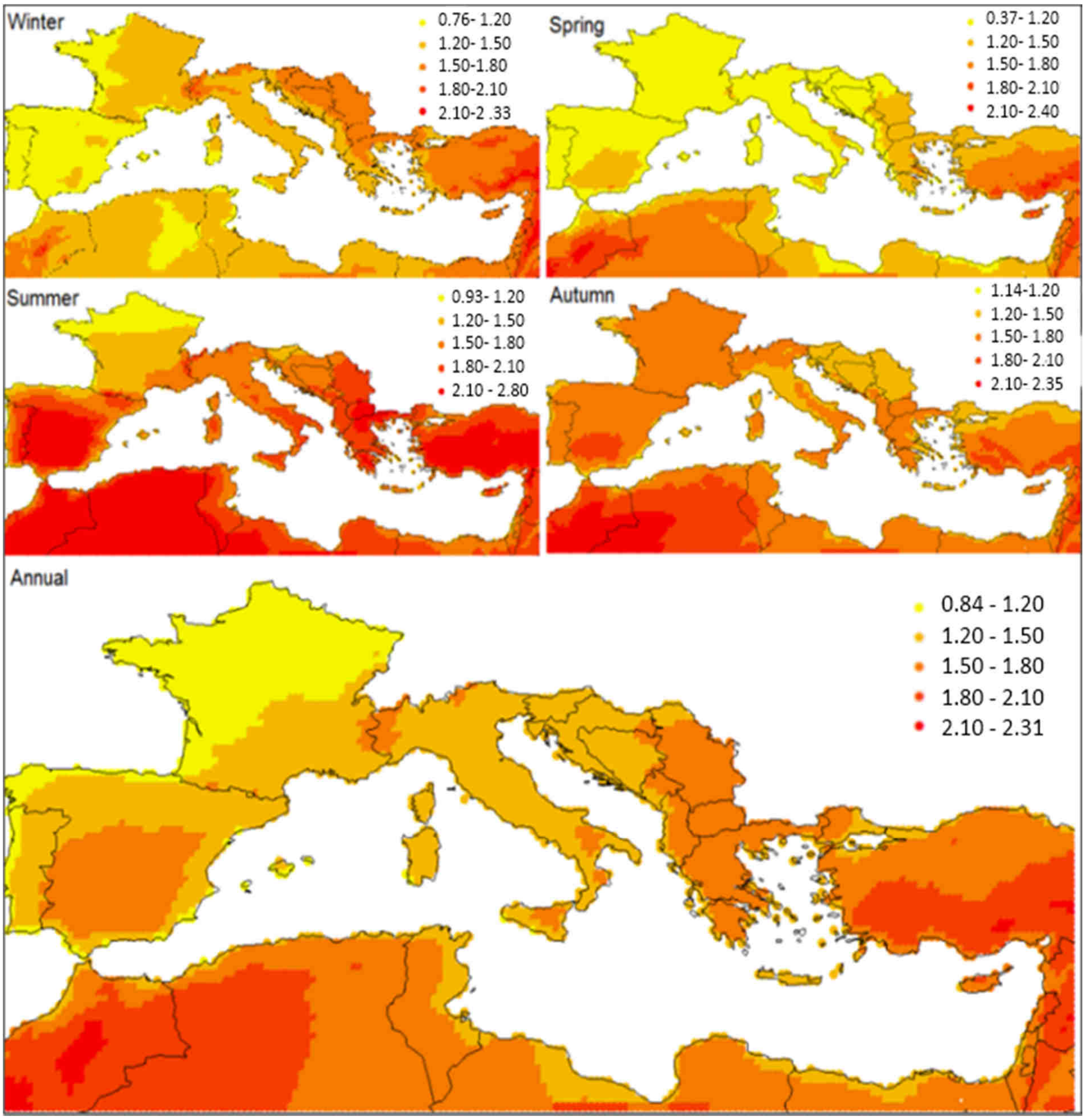
The impact of the climate change on the Mediterranean agriculture is already evident in many areas and especially in arid and semi-arid regions. Frequent droughts, flash floods, heat spells and spring frosts triggered the decline of agricultural production, further depletion of water resources, soil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

Several recent studies reported evidence of climate change in the last decades over the Mediterranean and tried to foresee the expected trend and its impact on Mediterranean agriculture in the future (Giorgi and Lionello, 2008; IPCC, 2014; Tanasijevic et al., 2014; Saadi et al., 2015).

One of the latest analyses, based on A1B SRES (Special Report on Emission Scenarios), indicated that air temperature would increase from 0.8°C to 2.3°C over a period of 50 years (2000-2050) (Tanasijevic et al., 2014; Saadi et al., 2015). The air temperature rise would be the greatest in some areas of North-West Africa, the Middle East, and in Southern Turkey (Fig. 1).

Seasonal patterns indicated that, in winter, the continental interior of South-eastern Europe and 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). It is expected that the evapotranspiration demand of the atmosphere will follow the temperature projections.

Figure 1
Spatial pattern of the mean annual and seasonal temperature difference (°C) between 2050 and 2000

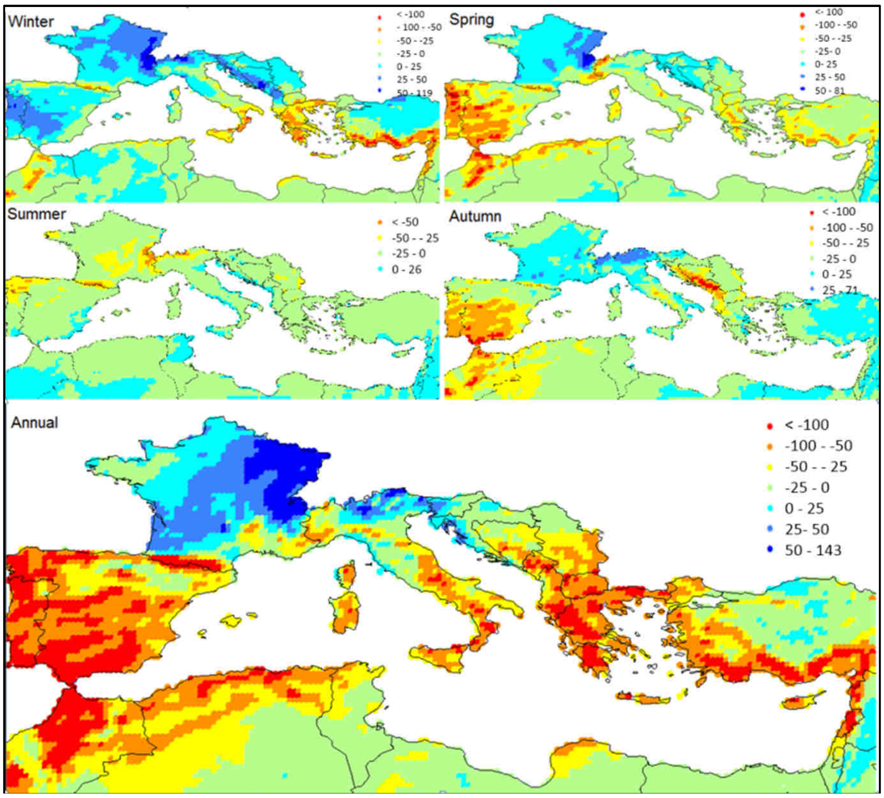


Source: Saadi et al., 2015

For the same time span (2000-2050), the average annual precipitation could have a decreasing trend of around 6% for the whole region, while the expected range of variation at country level would be between -21% (for Cyprus) and +1% (for France and Slovenia). The spatial pattern of annual precipitation indicated an increase over most of France and the Alps, while a decrease could be observed in almost all other regions (Fig. 2). There is a marked contrast between winter and summer patterns of precipitation change. 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 (Tanasijevic et al., 2014; Saadi et al., 2015). Hence, a climatic water balance, estimated as a difference between precipitation and reference evapotranspiration, could be lower and less favorable in the future than nowadays.

Spatial and temporal variation of precipitation pattern, air temperature increase and higher atmospheric CO_2 concentration are three major interconnected parameters that would influence agricultural production in the future. Accordingly, new cultivation scenarios will be designed including the shifting of agro-ecological zones northward and towards higher elevations, and modified land and water availability. On one side, 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, the increase of air temperature will extend the overall period suitable for cultivation and permit, in some areas, more than one crop in the same year. Nevertheless, the duration of optimum temperature range for obtaining maximum yield could be compromised in many regions. Additional impact on agricultural production will be due to altered biological cycles of weeds and pests, and new weeds/pests and crop diseases (Fig. 3).

Figure 2
Spatial pattern of the mean annual and seasonal precipitation differences (mm) between 2050 and 2000



Source: Saadi et al., 2015

At a larger regional scale, a set of complementary issues should be considered including the land use change, sea level rise, salinization, loss of coastal areas, population growth and migration, availability of resources (land, water and energy), market integrations and fluctuations, food (in)security, political/social/economic stability, changes in diets/habits and progress in implementation of innovations (plant breeding and genetics, irrigation and crop production technologies and agronomic management practices). Very likely, these effects will be redistributed in a different way at the global and regional level, with economically advanced regions more capable of adapting to changes as opposed to the areas characterized by scarce economic and natural resources, as the Southern parts of the Mediterranean. For example, the World Bank (2014) reported that the sea level rise will cause the displacement of about 3.8 million people living in the Nile Delta and other coastal areas of the Mediterranean questioning the survival of cities like Alexandria, Algiers, Benghazi, etc.

In fact, the impact of climate change on agricultural production could be negative for most areas of the Mediterranean with a large variability and reduction of yield (Olesen et al., 2007). 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 (Giannakopoulos et al., 2009; 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 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) are expected to decrease, for winter-spring and spring-summer crops, by 4 to 8% over the whole Mediterranean region (Saadi et al., 2015). Hence, the average net irrigation requirements (NIR) would decrease or remain steady. So, the air temperature increase could have a dominant role on the shortening of the growing season rather than on the increase of crop water requirements. The impact of precipitation decrease would be limited only to the perennial and autumn-winter crops because most of spring-summer agricultural production in the Mediterranean is already characterized by very low rainfall. Thus, a slight increase of CWR and irrigation inputs could be expected for perennial crops like olive trees (Tanasijevic et al., 2014).

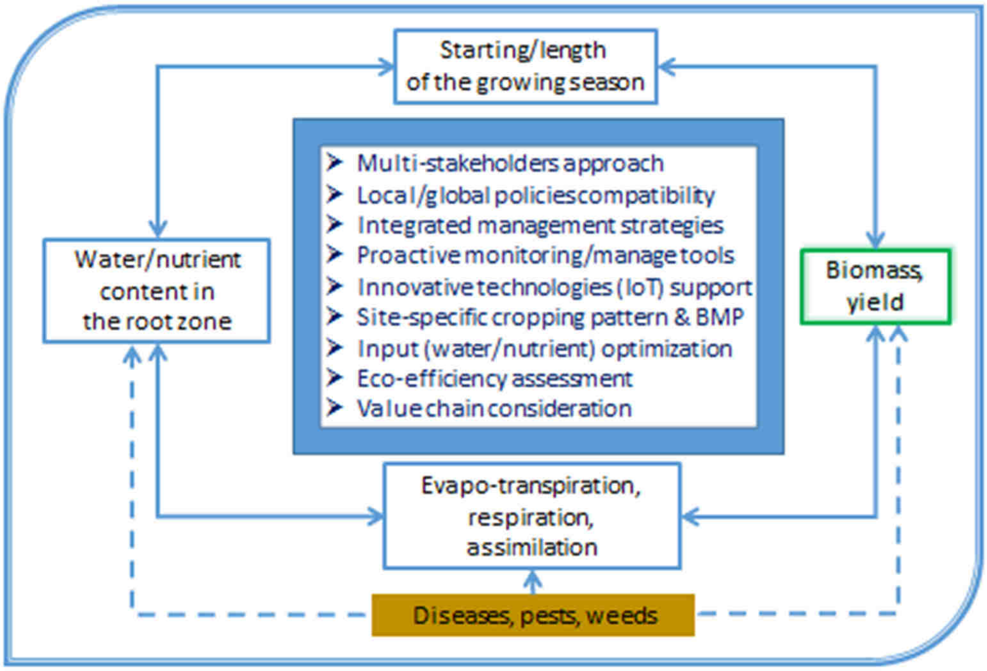
Most of rain fed cropping systems could be negatively affected by climate change due to the expected increase in water deficit (i.e. difference between evapotranspiration and precipitation), and overall reduction of water availability for agriculture. The latter is due to projected increase of water demand by other sectors (Milano et al., 2012; Boehlert et al., 2015). Overall, climate change could likely intensify the problems of water scarcity and land degradation, and affect negatively the sustainability of agricultural production in the region.

Possible solutions: mitigation and adaption policies and measures

A concerted regional action plan and additional funding are needed to face the impact of climate change in the Mediterranean region. The mitigation and adaptation measures should be discussed and identified through a comprehensive multi-stakeholders campaign with the aim of assuring the acceptance and compatibility of local, regional and global policies and actions (Fig. 3). The implementation of the solutions on the ground should be promoted following a priority ranking and expected positive impact of interventions. However, the type of actions and implementation methodology could change in time and space in respect to the specific conditions of the site and its vulnerability state.

Figure 3

Main eco-physiological aspects of climate change impact and a set of concerted mitigation and (in the center) adaptation policies and measures (IoT – Internet of Things; BMP – Best Management Practices)



The mitigation and adaptation actions are often complementary and should focus on the integrated management strategies, demonstration actions and on-ground implementation of the best practices based on the conservation and more efficient use of natural resources in agriculture and in other sectors. In the agricultural sector, particular attention should be reserved to the combined effects of temperature increase, rainfall variability, CO_2 increase and possible management solutions including the change of cropping pattern, genetic improvements and latest agronomic and technological achievements (CGIAR, 2012).

Hence, the continuous monitoring of weather and hydrological variables, water and carbon balance represent the preconditions and priority for interventions and research. Equally so, the proactive management tools (e.g. early warning systems and water/nutrient management decision support systems considering the weather forecasting data) and measures are of primary importance to attenuate negative impacts of extreme weather events and various abiotic stresses.

The success of such measures is based on the interactive use of certified innovative technological solutions (i.e. Internet of Things), and the selection of the site-specific and resource-optimized management practices and varieties able to respond to adverse environmental conditions and to increase/stabilize yields and water productivity in the future (Fig. 3). The aim should be to promote resilient and efficient farming systems able to adapt to climate change while decreasing pollution and impacts on the environment and getting the benefits of climate change (Ewert, 2012).

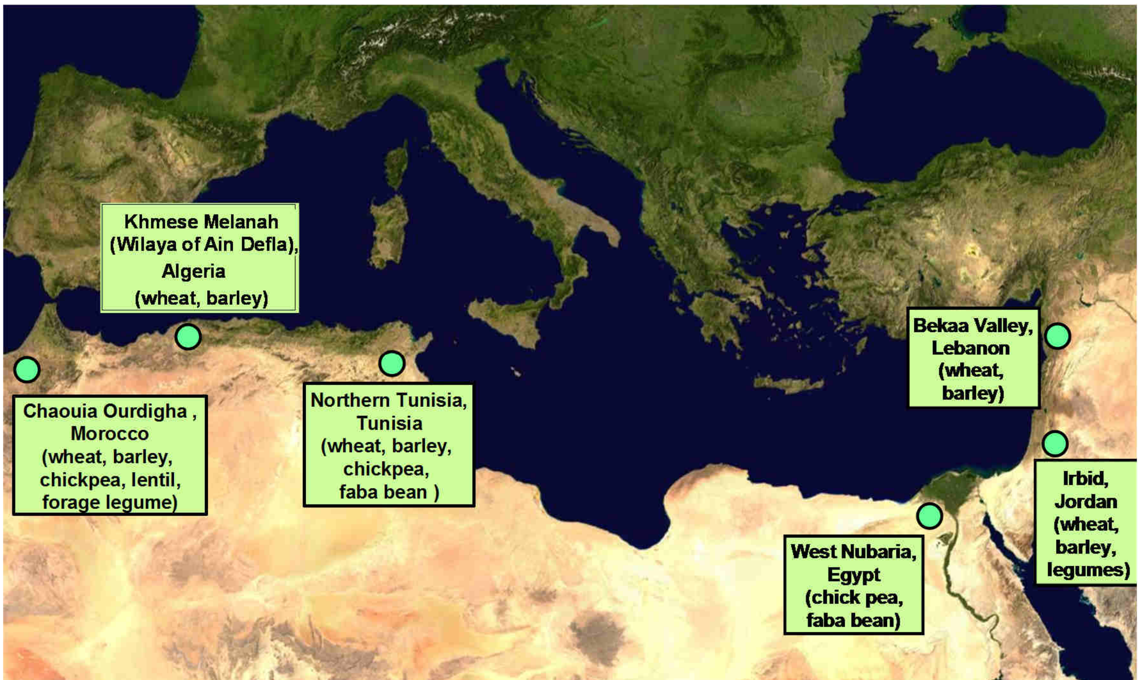
This means a full recognition of the eco-efficiency concept which is suitable to monitor progress in agricultural systems and to evaluate the adoption of eco-innovative technologies and practices that can contribute to environmental protection or to a more efficient use of natural resources. Eco-efficiency embraces both ecological and economic aspects of agricultural production.

The Life Cycle Assessment methodology is applied to evaluate the envrionmental performance of agricultural systems while the economic performance is measured using the total value added due to the use of resources and adopted management practices. Eco-efficiency should be applied at different levels of analysis and consider either the whole value chain of agricultural and food production or its specific components. The adoption of such approach supports the stakeholders and policy makers in analyzing the agricultural systems and identifying the best mitigation/adaptation options of mutual interests and for more eco-efficient agricultural production (Todorovic et al., 2016).

An example of the implementation of the climate change adaptation measures in the Mediterranean agriculture is the ACLIMAS project (www.aclimas.eu) funded by the Sustainable Water Integrated Management (SWIM) programme of the European Union and coordinated by the CIHEAM – Bari.

The project consortium was composed of 15 partners from 10 countries and the project lasted from December 2011 to December 2015. The activities were carried out in 6 Mediterranean countries (Morocco, Algeria, Tunisia, Egypt, Jordan and Lebanon) and focused on demonstration, on-field implementation and dissemination of the research results of previous EC-funded projects and other initiatives (Fig. 4). The overall objective was to bring a durable improvement of the agricultural water management, stabilization of yield and a broader socio-economic development of target areas in the context of adaptation to climate change, increasing water scarcity, and desertification risks. ACLIMAS pursued a holistic multidisciplinary border-crossing approach that integrates a set of locally-tailored adaptation measures (technical, agronomic and genetic) with socio-economic and environmental aspects of water management in Mediterranean agriculture.

Figure 4
The ACLIMAS project target areas and main crops



Source: www.aclimas.eu

The ACLIMAS project focused on cereals (durum wheat and barley) and legumes (chickpea and faba bean) since they are strategic and complementary crops in the Mediterranean (Fig. 4). The adoption of varieties resistant to abiotic stresses and adequate management practices (i.e. timing and density of sowing, minimum tillage, residue cover, crop rotation, water harvesting, and optimization of irrigation/nutrient inputs) demonstrated the potential for yield increase between 10 and 30% and water productivity rising up to 50%.

Other direct outcomes of the project were: a) setup and technical upgrade of 6 demonstration stations; b) 3 years of testing of more than 60 combinations of genotypes and water management practices (Fig. 5), c) on-ground implementation of the best management practices over a surface area of more than 320 ha with the involvement of about 110 farmers, d) 35 training courses with more than 890 participants; e) 68 field days with more than 2270 participants; f) 6 seminars with about 400 participants, guidelines (in Arabic, English and French), 24 brochures, more than 250 minutes of video material, etc.

Figure 5
Demonstration fields of ACLIMAS project at the Maru station of NCARE
(National Center of Agricultural Research and Extension) in Irbid (Jordan) where the performance of durum wheat varieties had been tested considering different sowing time, density and water and Nitrogen inputs

Photo credit: M. Todorovic (CIHEAM – Bari)

The main target groups and beneficiaries of ACLIMAS project were rural societies (i.e. farmers, growers and local breeders), farmers' associations and local governmental extension services (i.e. policy makers and agricultural advisors) and governmental research institutions. ACLIMAS has directly involved more than 3500 local stakeholders with a realistic possibility to produce a multiplier effect not only due to replication in the future but also due to extension of the initiative to other communities and stakeholders in the areas of interest.

The way forward

The universal agreement on climate change, signed last December in Paris, committed countries to adopt the initiatives keeping the global temperature rise below 2°C, the threshold above which the impact of climate change could be significant. However, the translation of the Paris Agreement into practices is not sufficiently elaborated and it will represent one of the major challenges in the years to come.

The Agreement is particularly important for the Mediterranean region, one of the major climate change hotspots worldwide, and its agriculture, a priority sector for intervention and socio-economic development. The relationship between climate change, natural resources, agricultural production and food security is very complex and needs a consideration of both bio-physical, social, economic, technical, political and anthropogenic factors and their interactions at different scales and in different directions. Hence, the multi-stakeholders' dialogue remains one of the main concerns together with the no-regret actions which can be justified independently of the expected climate change impact (e.g. dissemination/communication on a more efficient use of water, land and nutrients, drought/flood risk management, etc.).

Special attention should be given to the coastal areas and marginal Mediterranean lands to safeguard natural resources against the physical impacts of climate change causing the depletion and impoverishment of land and water resources, modification of ecosystems, dwindling of biodiversity and numerous collateral effects including poverty and migration of population. The research efforts should address the selection of appropriate indicators for assessing the system-wide eco-efficiency performance and possible improvements, the integration of existing tools and assessment methods in a coherent modelling and management environment, and the analysis and characterisation of existing production systems. Subsequently, the eco-efficiency concept should be extended to the whole value chain of agricultural production, conservation, transport and consumption. Certainly, the next Conference of Parties (COP22), scheduled for November 2016 in Marrakesh, will present an excellent opportunity to activate new funds for the implementation of the research achievements and innovative mitigation and adaptation programs on the ground.

Climate change has been recognized as one of the key topics of CIHEAM since the end of last Century (Lacirignola, 2000). In 2010, during the 8th Meeting of the Ministers of Agriculture, Food and Fisheries of the Member States, the CIHEAM recognized officially the climate change issue as one of its priorities. The translation of the regional and national policies into consistent on-ground implementation measures is of paramount importance for the Mediterranean region. The overall objective is to promote resilient and efficient farming systems able to adapt to climate change while reducing the wastes, pollution and degradation of natural resources and getting the benefits of climate change. The CIHEAM represents one of the main actors on the road of conceptualisation, adoption and on-ground implementation of the policies and management solutions for the climate change resilient Mediterranean agricultural systems (CIHEAM, 2015).

Henceforth, the CIHEAM on-going repositioning process aims to advance the strategic policy of the Organization within an innovative framework and the Strategic Agenda 2025 recognizing the Organization's mission around 4 pillars of development (Protect the Planet, Food Security and Nutrition, Inclusive Development and Crises and Resilience), divided into 15 thematic priorities. "Climate change solutions" in agriculture is one of the thematic priorities aiming to foster further adoption of adaptation and mitigation policies and their implementation on the ground. The Agenda pursues a set of fundamental values (Holistic vision of development, Multilateral approach, Bottom-up collaboration and Problem-solving -oriented initiatives) and embraces the multi-functional and complementary development tools including: a) education and training, b) research and innovation, c) networks and open knowledge platform, d) projects and technical assistance, e) policy dialogue and partnership.

Definitely, the adoption of such comprehensive and integrated platform represents the keystone of the institutional setting for the future and on the road to the development of resilient Mediterranean agricultural systems and society. In this context, COP22 will represent an unrepeatable occasion to extend the CIHEAM Strategic Agenda visibility to other international and regional climate change actors.

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