Support Water-Management Decision-Making Under Climate Change Conditions

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Novinka

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PREFACE

According to climate change assessments, less precipitations and higher temperatures can be expected in the Iberian Peninsula and other Mediterranean zones. Besides, an increment in droughts and other extreme events can be expected as well. Such climatic conditions require an effort to optimize irrigation technologies and to improve water management efficiency. There are currently available water-use and crop-growth simulation models, which can be combined to climate scenarios and weather generators in order to recommend, through many simulations, the most reliable irrigation management. The Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change and the National Plan for Adaptation to Climate Change recommend the use of such simulation tools in Spanish climate-change impact assessments. Those tools, however, have not been used yet to support irrigation decision-making in our country. In that sense, the EU-funded proposal AGRIDEMA, leaded by Spain, has been addressed to introduce such tools, connecting the tools "providers" from Universities and high-level research centres, with their "users", located in agricultural technological or applied-research centres. AGRIDEMA comprised courses and Pilot Applications of the tools. Local researchers knew in the AGRIDEMA courses how to access to GCM data and seasonal forecasts, they receive also basic knowledge on weather generators, statistical and dynamical downscaling; as well as on available crop models as DSSAT, WOFOST, CROPSYST, SWAP and others. About 20 pilot assessments have been conducted in several European countries during AGRIDEMA, applying the modelling tools in particular cases.

The AGRIDEMA results are commented, mentioning particularly the Pilot Assessments that were held in Spain and in the Mediterranean area. Furthermore, several "users" opinion regarding the available climate and crop-growth simulation tools are also pointed out. Those opinions can be used as important feedback by the tools "developers". An illustrative example on how modelling tools can help to manage Sugarbeet irrigation under present and future climate conditions in Spain is also shown. Several future research directions are pointed out, as followed from the shown example and the AGRIDEMA results. Those research directions agree with the actions recommended in the Spanish National Plan for Adaptation to Climate Change, as well as in the European and international guidelines. Stakeholder will adopt climate-change mitigation options only if they realize the reliability of such options on their specific cases. To achieve this, the "users" of the modelling tools must develop local demonstration proposals, aimed to model calibration and validation, etc. Particularly, some demonstration proposals should be aimed to recommend productive and efficient irrigation water managements under the adverse climate conditions that Spanish farmers will eventually face in the next years.

CONTENTS

Chapter 1

CLIMATE CHANGE, AGRICULTURE AND WATER RESOURCES IN THE MEDITERRANEAN REGION

The last IPCC (2007) report pointed out clearly the climate variability observed in the last decades, very probably due to the higher concentration of CO_2 and other gases emissions related to human activity. Particularly, the increment in the frequency of extreme event, as droughts and flooding, has been considered also as a climate-change consequence. Despite that temperature rising could be expected all over the world, rainfall changes are different according to the regions. Northern regions might expect increment in yearly rainfall, while total precipitation in other zones, as the Mediterranean regions, could be significantly lower during the second half of the 20 century (IPCC, 2007).

Climate change will bring important consequences to agriculture, perhaps the man activity most dependants on meteorological conditions. According to IPCC (2007), general yield changes, freezing-loosing reductions, increment in crop and livestock damages due to higher temperature and other adverse and positive changes can be expected in the future. Those consequences will be different according to the regions.

The IPCC Working Group II, aimed to assess Climate Change Impacts, Adaptation and Vulnerabilities on natural managed and human systems; reported significant changes on several physical and biological systems in Europe from 1970 to 2004. Most of those changes are consistent with the expected response to temperature rising and cannot explained by natural variability (IPCC, 2007). According to the IPCC Working Group II, Climate Change is expected to magnify regional differences in Europe's natural resources and assets. In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity (IPCC, 2007).

One of the main achievements of the IPCC (2007) fourth assessment is its confirmation, through new data and documentary proves, of many previsions that had been already made in the previous IPCC assessments. For instance, the IPCC (2001) report already pointed out the Climate-Change related risks on European and World agriculture.

Olesen and Bindi (2002) studied the climate change impact to European agriculture, considering several regions within Europe. According to them, Mediterranean agriculture will be the most affected, due to precipitation reduction in the zone, which will bring lesser water availability. Water scarcity, combined to higher transpiration rates due to temperature increments, will mean a challenge for irrigated agriculture in Southern Europe. Those conclusions agree with the IPCC (2007) last report. Despite rainfall changes are less confident than temperature rising at the global scale, many of the modelling assessments included in the IPCC (2007) report coincided in predicting less rainfall in the Mediterranean region.

Besides long-term climate-change effects, its related climate variability and the increment in extreme-events frequency (IPCC, 2007) can mean important constraints to agriculture. The higher mean temperature of 2003 summer is a good example of that. Such warm summer brought many agricultural loosing, particularly in France (Seguin et al., 2004).

The European Commission is aware about the Climate Change risks that can be expected in Europe. The European Environmental Agency released a Technical Report aimed to point out the vulnerability and adaptation to Climate Change in Europe (EEA, 2006). The report indicates that Southern Europe, the Mediterranean and central European regions are the most vulnerable to Climate Change. Considering vulnerabilities by issues, the EEA (2006) technical report considered that Climate Change and increased CO_2 atmospheric concentration could bring a beneficial impact on Northern European agriculture, through longer growing season and increasing plan productivity. However, in the South and parts of Eastern Europe the impacts are likely to be negative (EEA, 2006). The EEA (2006) report gives special attention to water resources availability in Southern Europe as one of the most important Climate-Change expected risks. The report remarks the importance of adopting concrete measures and policies on National and EU Adaptation plans to Climate Change, although it is a relative new issue.

Due to the importance of water resources management under Climate Change conditions, the European Environmental Agency released recently a Technical Report addressed to this issue (EEA, 2007). Two main impacts are recognized in the report: Flooding risks in Northern and Central Europe, as well as water scarcity in Southern countries. According to EEA (2007), several adaptation measures have been taken regarding flooding, but few have been addressed to water scarcity. Furthermore, three priorities are pointed out in the EEA (2007) report. The top priority for adaptation in the water sector should be to reduce the vulnerabilities of people and societies to shifts in hydro-meteorological trends, increased climate variability and extreme events. A second priority is to protect and restore ecosystems that provide water resources services. The third priority should be to close the gap between water supply and demand by enhancing actions that reduce demands (EEA, 2007). The report also recognize the need of research on climate-change impacts in water sector, as well as the interactions among European, national and local decision-making levels.

Besides the EEA (2006) and (2007) reports, the European Commission is preparing a "Green Book" regarding Climate Change to be released late 2007. The first draft (EC, 2007) of such "Green Book" identifies also the Mediterranean region as the most risky zone within Europe, due to the combination of temperature rising with precipitation reductions. Concerning the future of European agriculture, the Green Book points out that Climate Change would be one of several challenges, as world-trade globalisation and rural population decrement. Furthermore, the Common Agricultural Policy and several other EU policies and directives can effectively influence in climate-change adaptation issues, as water use efficiency and pollution risks (EC, 2007).

1.1 The Spanish Climate-Change Adaptation Plan

Additionally to the EU concerns, the Spanish government and the National institutions are also ready to introduce Climate-Change adaptation actions, taking into account that Spain is one of the most risky countries within Europe. The huge assessment comprised in the Preliminary Evaluation of Climate Change effects in Spain (Moreno, 2005), including the risks of Spanish agriculture (Minguez et al., 2005), has been an important guidelines to develop Climate-change adaptation strategies at the country level.

In general, the Minguez et al. (2005) assessments agree with the IPCC (2007) and the EEA (2006) reports. They all point out that the increase in CO_2 concentration and air temperature, as well as changes in seasonal rainfall, would have counteracting and non-uniform effects. The positive effect of CO_2 on photosynthetic rates can be compensated by greater temperatures and less precipitation. They also agree that while milder winter temperatures will allow higher crop growth rates if water is sufficiently available, higher summer temperatures can increase evaporative demand and hence irrigation requirements. As highlighted in all the above-cited reports, Minguez et al. (2005) indicated that he expected increase in extreme weather years will difficult crop management and will require more analysis of agricultural systems sustainability.

Minguez et al. (2005) also pointed out that crop simulation models using climate data from Regional Climate Models are nowadays the most efficient tools for impact analysis, as they are able to quantify the non-linear effects of climate change. Furthermore, they indicate the need of identifying regions with different impacts in order to recommend the corresponding adaptation measures.

According to Minguez et al. (2005), short term adaptation strategies can rely on simple management practices such as changes in sowing dates and cultivars. Nevertheless, in the long term, adaptation of cropping systems to future climate conditions is required. Implications on vegetable crops, fruit orchards, olive groves and vineyards should specifically addressed to assess adaptation at minimum cost (Minguez et al., 2005).

Minguez et al. (2005) summarizes that one of the main constraints of Spanish agriculture will be related to water availability for summer-crops agriculture, due to the expected rainfall decrement combined with the temperature rising, particularly in the summer. Furthermore, drought frequency and intensity will be higher in the near future, since it has been observed already from the last 30 years (IPCC, 2007). Along with the IPCC (2007) and the EEA (2006) and (2007) reports, Minguez et al. (2005) point out that weather variability could be the most critical issue in the coming years. The stability and sustainability of Spanish agroecosystems is affected by interannual and seasonal variations in rainfall, water availability for irrigation, the greater or smaller frequency of frost in springtime and the storms that have especial impact on the fruit and vegetable sector. Furthermore, Minguez et al. (2005) indicated also that improving water management efficiency should be a priority.

Minguez et al. (2005) pointed out particularly the influence of the CAP in crop sequences of both dry farming and in irrigation systems. Crop choices are not always the best in agronomic terms, especially in relation to climate and soil, so the sustainability of these agricultural systems is questionable. The progressive reduction of EU subsidies is beginning to affect management decisions, as can be seen in the restructuring and changing geographic distributions of olive groves and vineyards. Therefore, CAP and other European and national policies should be taken into account.

Following the conclusions of the Preliminary Evaluation of Climate Change effects in Spain (Moreno, 2005), the Spanish Climate-Change Office has prepared the National Plan for Adaptation to Climate Change (PNACC, 2006). The Plan comprises action guidelines for the hydraulic resources, the agricultural sector and several other sectors that can be potentially affected by Climate Change.

The PNACC (2006) includes also a Workplan and a Timetable. The first task is to develop Spanish-based Climate-Change scenarios that can be used further for impact assessments at each involved sector. Developing such regional data base was defined as a priority in the EEA (2006) report. The first version of the Spanish Climate-Change scenarios has been already provided by the National Institute of Meteorology (Brunet et al., 2007). Furthermore, due to its extreme importance, assessing Climate-Change effects on the hydraulic resources in Spain is the second commitment included in the PNACC (2006).

Regarding crop agriculture, the PNACC comprises the following guidelines:

- Mapping climate change effects on Spanish agricultural zones.
- Developing crop models to simulate radiation interception, water and nitrogen balances and yields.
- Evaluating irrigation demands according to different scenarios.
- Providing general recommendations for short-term agricultural management under climate change conditions.
- Identifying long term adaptation strategies, particularly in fruits, olives and vineyards.

1.2 Climate Change and Spanish Irrigated Agriculture: The Challenge

Irrigation is largely the main water user in most countries. Worldwide agricultural production in irrigated area is, in average, more than twice the production in rainfed zones, despite that irrigated area is lesser than 25% of the total agricultural area. The increment of world population and their feeding needs point toward an efficient agriculture and therefore irrigation is an absolute need. Irrigated agricultural land means approximately 350 million ha in the world. Irrigated areas are responsible for approximately 40% of the global food production (Smedema et al., 2000).

According to EUROSTAT data, irrigated area comprised 14 807 980 ha in the EU-25 during 2003. It meant 9.5% of the total EU agricultural area. The irrigated area corresponding to the EU Mediterranean countries (i.e. Spain, Italy, France and Greece) is more than 80% of the total EU-25 irrigated area. Particularly, Spanish irrigated area is 30% of the total EU-25 area, which makes Spain as the country with the largest irrigated area in the EU. Irrigated area is about 20% of the total cropped area in Spain, which means more than twice the average EU ratio. Despite their location corresponds to the temperate climate area, solar radiation rates in Mediterranean countries are relatively high. This radiation conditions could lead to higher crop transpiration rates and hence suitable agricultural productions. However, water availability constraints in Mediterranean agriculture are higher than those found in other places of the world. Therefore, rainfed production in those countries of common crops is usually lower than that found, for instance, in Northern Europe.

Table 1: Relevant crops in Spain, according to reported rainfed, irrigated and total cropped area (MAPA, 2004)

Crop	*Rainfed (ha)*	*Irrigated (ha)*	*Total*	*% of Total*	*% Irrigated*
Barley	2807592	303281	3110873	21.3	9.7
Olives	2056532	383050	2439582	16.7	15.7
Wheat	2024930	195711	2220641	15.2	8.8
Vineyards	1009407	163390	1172797	8.0	13.9
Fruits	987169	271201	1258370	7.6	28.3
Sunflower	699105	87727	786832	5.4	11.1
Maize	96872	464569	561441	3.8	82.7
Oats	462888	33439	496327	3.4	6.7
Vegetables	28897	396866	425763	2.9	93.2
Alfalfa	49441	191239	240680	1.6	79.5
Rye	104789	3283	108072	0.7	3.0
Potato	28466	72635	101101	0.7	71.8
Sugarbeet	17101	82733	99834	0.7	82.9

Table 1 shows the most relevant crops in Spain, according to the Ministry of Agriculture report (MAPA, 2004). Table 1 shows also the total cropped area, as well as the corresponding rainfed and irrigated area. Moreover, the Table depicts the percent of each crop area, regarding the total agricultural area; as well as the percent of irrigated area of each crop, respecting the total crop area. As can be seen in the Table, rainfed cereals as Barley and wheat are the most important crops in Spain, although olives and vineyards represent an important cropped area as well. Maize shows the largest irrigation area, followed by vegetables and olives. Irrigated cereals mean also an important percent of the total Spanish irrigated area. Vegetables, Sugarbeet, Maize, Alfalfa and Potatoes are mainly irrigated crops in Spain, since more than 70% of their cropped area is under irrigation.

Irrigated agriculture in Spain and most of the Mediterranean area was introduced since ancient times and it has been improved through the long farmer' experience. Crops yields under irrigation are indeed quite high. However, irrigation techniques have been kept in the same way for centuries in many Mediterranean countries. Inefficient flooding irrigation systems, for instance, is still the most commonly found in many areas of Spain (Neira et al., 2005) and other Mediterranean countries.

Irrigation is expensive, but assures the farmer productions and keeps rural population in the countryside. It has been shown that farm profitability in Europe is lower than that reported in industrial or technical business. If farming is not profitable then existing farmers will cease their activities, and young people may not be attracted into agriculture. This will mean the long-term decline of the industry and of rural areas. Actually, one of the most important constraints that face European countryside is its continuous depopulation. Most farms are small businesses, often family-run. They are an important local employer in many rural regions and major players in the rural world. Farmers play a positive role in the maintenance of the countryside and the environment by working for secure and profitable futures for themselves and their families. Therefore, to keep good living standards in the European countryside is an important concern of EU authorities, as well as national governs.

A quite large irrigation modernisation is being conducted in Spain (Beceiro, 2003), aimed to replace flooding by sprinkler and other more-efficient techniques with governmental aids. The Spanish program aimed to introduce new engineering irrigation infrastructures in the national agriculture, *Plan Nacional de Regadíos* (MAPA, 2005), is carried out by the Spanish Ministry of Agriculture. The program has been recently revised and its goals comprised not only to increment irrigated areas, but to significantly improve water savings and to avoid groundwater pollution. This kind of effort is in accordance with the Lisbon Strategy and the goals of the EU Commission of Agriculture, addressed to improve farmer's income, to make more competitive their agricultural production and to meet the EU environmental requirements (EU, 2005; Fischer, 2005).

Irrigation modernisations efforts have been made in non-European Mediterranean countries also, as Egypt. However, there is still a big difference in irrigated agricultural production between European and non-European Mediterranean countries. As can be seen in Figure 1, shown below, rainfed crop production, as wheat, is similar in all the compared countries. However, the yields of a usually irrigated crop, as maize, are much larger in European countries than in non-European Mediterranean countries. The above information is a national average; therefore it includes also non-irrigated maize, as well as irrigated wheat. Nevertheless, the figure depicts clearly the mean yields at each country. Maize yields of the European and non-European Mediterranean countries show a considerable difference. This could be mainly due to the large new engineering irrigation infrastructures, which have been available in European Mediterranean countries since the last 20 years.

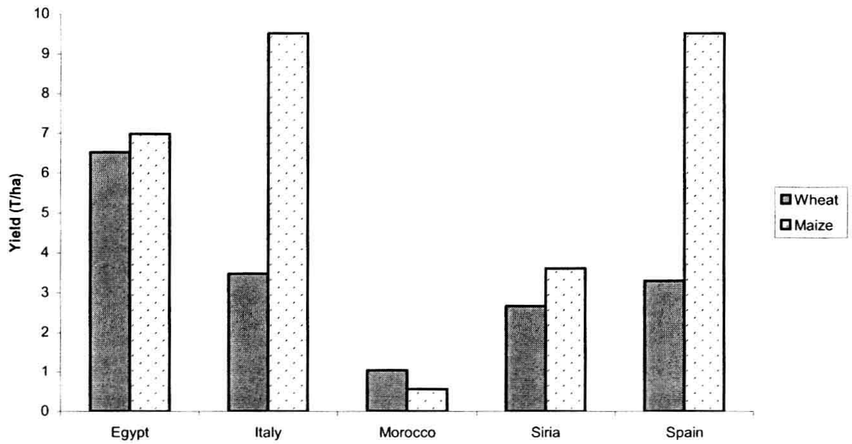

Figure 1: Average yields in 2004 in several Mediterranean countries, according to FAOSTAT data.

Furthermore, Figure 2 depicts the absolute difference in Maize yields (in T/ha) and production (in BT) between Spain and Egypt from 1990 to 2004, following the same FAOSTAT (2005) data. Despite total Egyptian production is higher than that of Spain, the Spanish yields are not only higher than the corresponding Egyptian yields, but their yield differences have been linearly incremented during the last 15 years.

The yield differences between Spain and the European Mediterranean countries as compared to Non-European Mediterranean countries can be due to many reasons, but indeed the new engineering irrigation infrastructures that has been introduced in the European Mediterranean countries, as Spain, during the last 20 years (MAPA, 2005) has a notable influence in this yearly yield increment.

Despite the infrastructures investments in Spain and other European countries, irrigation is still very expensive at the world scale. Water could be not enough under the future-enhanced droughts conditions, particularly considering third-world population rise. However, irrigation must not only been kept, but also enlarged in order to feed the foreseen world population. This contradiction has been pointed out as important concern during the 19th Congress of the International Commission on Irrigation and Drainage (ICID), held in Beijing recently. The ICI Congress focused on the theme of "Use of Water and Land for Food Security and Environmental Sustainability" and they pointed out that: the key to increase future food production lies in expansion of irrigated and drained lands where potential exists; in better water and land management in existing irrigated and drained areas; and in increase in water use efficiency and land productivity, in the Beijing ICID declaration.

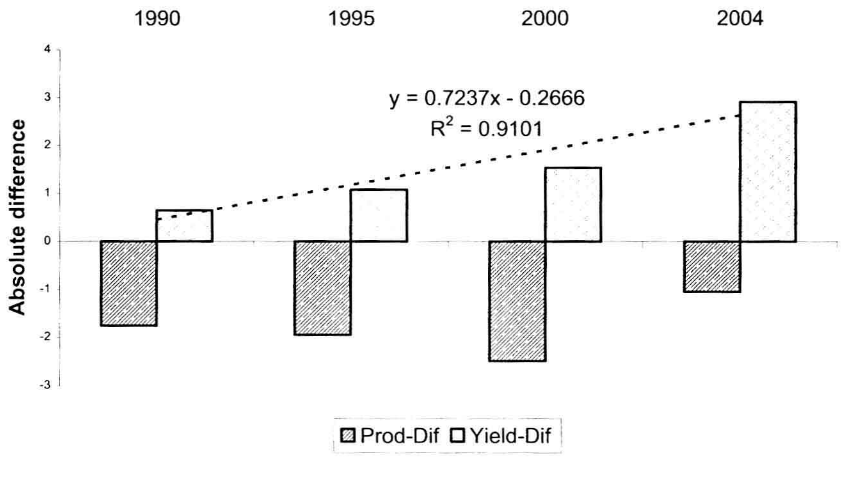

Figure 2: Absolute differences between Egyptian and Spanish Maize productions (in BT) and yields (in T/ha).

Climate change will impose a new challenge to Spanish and Mediterranean irrigation areas. Improving irrigation efficiency is an imperative, although it has been recognized that much water can still be saved in Spanish irrigation systems (Playan and Mateos, 2005). Some climate-change impact assessments have estimated that CO_2 rising will significantly reduce the crop water requirements

(Guereña et al., 2001; Villalobos and Fereres, 2004). However, such positive "fertilizing effect" of CO_2 rising seems to have been overestimated according to the FACE results (Craft-Brandner and Salvucci, 2004; Aisnworth and Long., 2005). Hence, Spanish irrigated agriculture might be affordable in the future only by reducing the water consumes. Furthermore, the globalisation of the world market and the "cost recovering principle" included in the EU Water Framework Directive (2000/60/EC) would lead to prices reductions in the future, while incrementing water costs.

Several examples can be pointed out on the challenge that climate change, combined with WFD and other future policies, could bring to the affordability of irrigated agriculture in Spain. Perhaps the most updated situation concerns Sugarbeet cropping. The EU Commission of Agriculture has proposed a reform to current EU sugar production conditions, which has been strongly rejected by Spanish sugar-beet farmers and producers, as well as those from other countries. The reform implies a substantial reduction of current EU prices. Sugar-beet is mainly an irrigated crop in Spain and other Mediterranean countries; hence the production costs are relatively high due to irrigation. Farmers who use groundwater to irrigate sugar beet are the ones facing the highest problem, due to the increment of oil costs. Furthermore, drought conditions, as that found during 2005 in Spain, can be strengthen in the near future, due to global change. Therefore, farmers need to reduce irrigation costs while cropping Sugarbeet under these new prices and climate conditions. They need help in order to find a reliable irrigation management. This is particularly important in those farms where irrigation modernisation or any irrigation investment in new technologies is expected, due to the amortization of the investment costs.