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Climatic change effects on Mediterranean rainfed agriculture

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SUMMARY – The paper summarizes some aspects of the effects of climate change on Mediterranean agriculture. Differences between climate change and climate variability are stated. The role of CO_2 is established as promoter of greenhouse and global warming effects and concern is expressed on the effect that human activities have on the increase of CO_2 and other greenhouse gases. The positive and negative effects of the climate change on the Mediterranean rainfed agriculture are analyzed through the prediction of models and changing scenarios. Key questions for the assessment of vulnerability and adaptation of agriculture to climate change are discussed.

Key words: Climatic change, Mediterranean, rainfed agriculture.

RÉSUMÉ – *"Effets du changement climatique sur l'agriculture pluviale méditerranéenne". Cet article résume certains aspects des effets du changement climatique sur l'agriculture méditerranéenne. Les différences entre changement climatique et variabilité du climat sont indiquées. Le rôle du CO_2 y est défini comme facteur de déclenchement des effets de serre et du réchauffement global, et des inquiétudes sont exprimées quant à l'effet qu'ont les activités humaines sur l'augmentation du CO_2 et autres gaz à effet de serre. Les effets positifs et négatifs du changement climatique sur l'agriculture pluviale méditerranéenne sont analysés à travers la prédiction des modèles et des scénarios d'évolution. Des questions cruciales pour l'évaluation de la vulnérabilité et de l'adaptation de l'agriculture au changement climatique sont discutées.*

Mots-clés : *Changement climatique, Méditerranée, agriculture pluviale.*

Introduction

Climate changes measured in seasonal, interannual and decadal scales are key factors affecting human development. Societies, cultures and economies in the world's history have successfully developed by mastering their abilities to adapt to climatic conditions. Consequently, temperature or precipitation anomalies have often resulted in catastrophic consequences, particularly if such anomalies were not predicted. Although often public or media attention is focused on extreme events, climate variability can also have subtler consequences, but with significant economic impacts.

Countries are usually unprepared to cope with climatic anomalies in an effective way. Governments typically react to a climatic extreme event through "crisis management" rather than through the formulation and implementation of anticipatory measures commonly referred to as "risk management". A typical reason mentioned by decision makers for the lack of such risk management policies has been the lack of means to predict climate conditions (e.g., precipitation, temperature) with sufficient skill and lead-time. In selected regions of the world, this situation has changed dramatically due to recent advances in the capacity to predict climate anomalies linked to the onset and intensity of a warm or cold event as part of the El Niño/Southern Oscillation (ENSO) phenomenon. ENSO is the main source of interannual climate variability in many parts of the world.

Although the advances in climate prediction are a significant scientific achievement, there are still limitations in our ability to establish effective risk management policies or, in general, to take advantage of the improved forecasting capabilities. Since the early 1990s several International and National organizations started efforts to establish research projects around the world oriented to develop effective applications of climate forecasts.

Analyzing and improving land and water resource systems requires sound understanding of physical, chemical, physiological and climatic processes but also tools to evaluate their interactions. Effects of management strategies need to be assessed and quantified in terms of productivity and their impact on the resource base. High rainfall variability means that often even one lifetime of cropping experience can be insufficient to sample the underlying variability adequately. Cropping systems models are an obvious choice to address such issues and have many potential applications ranging from environmental issues and policy matters to farm optimization and variety adaptation. Generation of probabilistic information useful to systems managers (e.g. What if? When? How often?) can help to identify gaps in current knowledge. By simulating the production system, the state of the system at any point in time is known and alternative management options and their long-term impact on sustainability and productivity can be evaluated.

Climate change and climate variability

The climate system consists of a series of fluxes and transformations of energy (radiation, heat and momentum), as well as transports and changes in the state of matter (e.g., air, water and aerosols). Received solar radiation is the major energy source that powers the entire system. The flows and transports occur between and within the main components of the system: the atmosphere, oceans, land, biota and cryosphere (the domain of ice and snow). The system varies regularly due to the shape of the earth's orbit, its angle, and daily rotation, but also irregularly because the atmosphere and the oceans are both fluids subject to internal movements associated with random turbulence, as energy is transported and transformed through the climate system. These latter variations result in climate extremes.

Climate is defined as the prevalent pattern of the weather observed over a prolonged period of time. Climate variables (e.g., temperature, precipitation, wind speed) can be time-averaged on a daily, monthly, yearly or longer basis. Associated with the average states of climate variables are indications of their oscillations or variations about their mean values. The term *climate change* refers to an overall alteration of mean climate conditions, whereas *climate variability* refers to fluctuations about the mean. The changing climate will bring changes in climate variability, and may already be doing so.

Through burning fossil fuels and eradication of forests, human activity has caused the carbon dioxide (CO_2) concentration of the atmosphere to increase by some 25% since the industrial revolution, and that increase continues. Measurements made on Mauna Loa in Hawaii since 1956 reveal the recent CO_2 trend.

CO_2 plays an important role in inhibiting the escape of the heat radiated by the earth. The sun beams short-wave radiation to the earth, which sends long-wave radiation back to space. Greenhouse gases in the earth's atmosphere (carbon dioxide, water vapor, methane, nitrous oxide and the chlorofluorocarbons) absorb the outgoing radiation, thereby holding heat near our planet. This process occurs naturally: without the natural greenhouse effect, our planet would be near freezing. Instead, this process warms the earth to its current mean temperature of about 15 ^{o}C.

The concern now is that human activities are causing the natural greenhouse effect to be augmented, leading to significant changes in the temperature and related changes in the entire climate system. Has global warming actually begun? When we look at the Earth's global average temperature over the last century, we find that temperatures have risen about 0.5 ^{o}C. The decade of the 1990s is the warmest on record. While it is difficult to prove conclusively that rising CO_2 is causing the earth to warm, scientists believe that the two trends – increasing carbon dioxide and increasing temperatures – are likely to be linked.

Because the earth's climate system is too large to allow controlled experiments, scientists have been employing mathematical models, known as global climate models (GCMs), to assess the processes known to occur and their possible interactions. The results of such models are used to forecast the trend of climate over the coming decades. Their results are still tentative and should not be accepted uncritically. However, we should examine the implications of their predictions, while continuing to look for the emerging empirical evidence of changing climate.

At least ten GCMs have been developed by atmospheric scientists in various research groups and have been used to project the effects of greenhouse gas increases. Results from these simulations show a mean global warming in the range of 1.5 to 4.5 ºC by the end of the next century. When the effects of sulfate aerosols are included in the projections, the best estimate for 2100 is a temperature increase in the range of 1.0 to 3.5 ºC. These projections are somewhat cooler since sulfate aerosols from industrial pollution tend to cool the earth's atmosphere. Global climate models also predict an increase in mean global precipitation ranging from about 5 to 15%.

GCMs further predict that:

(i) The high latitudes are likely to experience greater warming than the global mean warming, especially in winter.

(ii) The hydrological cycle is likely to intensify, bringing more floods and more droughts.

(iii) Sea-level rise is one of the major impacts projected under global warming. Global factors such as the rate of warming, expansion of sea water, and melting of ice sheets and glaciers all contribute to this effect. However, local conditions such as coastal land subsidence or isostatic uplift should also be taken into account in considering the extent of sea-level changes and their regional impacts.

Beyond what is clear however lie great uncertainties: How much warming will occur, when and at what rate, and according to what geographical and seasonal pattern? What will be the consequences for agricultural productivity in different countries and regions? Will some areas benefit while other areas suffer, and who might the winners and losers be? And there are the practical questions: What can be done to mitigate these changes? And to the extent that such damages may be unavoidable, what can be done to adapt our practices so as to minimize or even overcome them? Upon our ability to answer these and other questions related to the environment may rest the welfare of our national agriculture in the coming century.

Seasonal climate prediction in the Mediterranean

Atmospheric scientists can now predict some of the medium-term (one or two seasons ahead) features of our climate with a reasonable level of skill. While the Mediterranean region is not expected to achieve a high level of seasonal forecast skill in the foreseeable future, research does suggest that there is some seasonal forecast skill. The skill at least for the western Mediterranean may be focused on the latter part of the rainy season (March-April) providing very specific opportunities for incorporation into agricultural strategies. However, the very large interannual and decadal climate variability that is now know to exist in the region requires itself careful evaluation in the context of agricultural management. Thus the climate context for the project is highly variable and requires careful management, together with a modest amount of seasonal forecast skill. The appropriate adoption of climate information and forecasting technologies should permit farmers to reduce the uncertain effects of climate and weather on their production. In addition, the efficient use of inputs (e.g. fertilizers) and water could be further improved.

Several regional studies are looking at the benefits of climate information and seasonal climate forecasts for different farm types and cropping systems in both northern and southern Mediterranean countries. The work focuses on improving timing of production and efficiency of irrigation water use. The regional studies focus on optimizing traditional production systems since they are the current basis of agricultural production in the Mediterranean, but the research also has benefits for large-scale commercial systems.

Future global change scenarios

Climate change scenarios are the essential first step in any real assessment of the impacts of climate change. Climate change scenarios are defined as plausible combinations of climatic conditions that may be used to test possible impacts and to evaluate responses to them. Scenarios may be used to determine how vulnerable a sector is to climate change, to identify thresholds at which impacts become negative or severe, and to compare the relative vulnerability among sectors in the same region or among similar sectors in different regions.

While there is scientific consensus that increased atmospheric concentrations of greenhouse gases will likely raise global temperatures, with associated increases in global precipitation and sea level, there is no consensus on how fast and how much the climate may change, on how regional climates may change, nor on how climate variability may change. To cope with these uncertainties, climate scenarios of different types have been developed for regional impact analysis. It is still difficult, if not impossible, to associate probabilities with any particular scenario of climate change, due to uncertainties in future emissions of radiatively active trace gases and in the response of the climate system to those emissions. Thus, impact studies based on climate change scenarios do not make actual predictions; rather, they are useful in defining for critical biophysical and socioeconomic systems directions of change, relative magnitudes of change, and critical potential thresholds of climate-sensitive processes. By conducting climate change impact analyses, researchers and resource managers are conducting "practice" exercises, which help to engender flexibility in the systems responses to potentially changing conditions in the future.

Climate is not the only factor that will be changing as the twenty-first century unfolds. Population growth and changing economic and technological conditions are likely to affect world society and the environment even more than changes in climate. It is important to take such changes into account in climate change impact analyses: first, because climate change will occur not in the present but in the future, and second, because such changes may affect the sensitivity of agriculture (or other sectors) to climate change. However, predicting population growth rates and future economic conditions is equally if not more uncertain than predicting the future climate. Therefore future scenarios need to be designed carefully to address a range of possible conditions. A useful approach is to contrast "optimistic" and "pessimistic" views of the future. In the optimistic scenario, population growth rates are low, economic growth rates and incomes rise, environmental pollution decreases and land degradation abates. In the pessimistic scenario, population growth rates are high, economic growth rates and incomes are low, environmental pollution increases, and land degradation accelerates. A scenario of no change (i.e., present conditions) should also be included. The differential effects of climate change on current conditions, and on these two alternative scenarios of the future may then be evaluated.

CO_2 and greenhouse gas emission scenarios are needed, especially for agriculture because of the need to estimate crop responses to the CO_2 fertilization effect, as well as projections of sea-level rise. Socioeconomic factors often considered in future scenarios include population, income, productivity and technology levels. Environmental factors may include stratospheric and tropospheric ozone levels and changes in land use. Institutions and legal structures may change as well, but these are very hard to predict.

Vulnerability and adaptation of agriculture to climate change

Background

Agriculture and water resources are projected to have major impacts under global warming. Global factors such as the rate of warming, degradation of land (erosion and salinization), water quality and population increase all contribute to this effect. Projections of these often require full impact assessments of their own, or could be included as interactive components within an integrated assessment framework.

While agriculture is a complex sector, the system is still dependent on climate, because heat, light and water are the main drivers of crop growth. Plant diseases and pest infestations, as well as the supply of and demand for irrigation water are also dependent on climate.

The effects of climate change on agriculture are likely to vary between different regions and different scales (global, regional and local). As a result, it is most important that impact assessments be undertaken for as many different locations as possible and for different sizes of study region, focusing not only on final production, but on other indicators of vulnerability of the agricultural sector. This will only be useful, however, if the methods of assessment are broadly compatible, enabling the generation of sets of results that can be compared and integrated into a wider picture. The purpose of this chapter is to provide guidance toward a set of approaches that will enable progress toward this objective.

Why is climate change of concern in agriculture?

World food production varies by several per cent from year to year, largely as a result of weather conditions such as the inter-annual climatic variability in the Mediterranean and Sahel regions. But agriculture in some regions is more sensitive than in others. Typically, sensitivity to weather is greatest firstly in developing countries, where technological buffering to droughts and floods is less advanced, and secondly in those regions where the main physical factors affecting production (soils, terrain and climate) are less suited to farming. A key task facing those concerned with conducting climate impact assessments is to identify those regions likely to be most vulnerable to climate change, so that impacts can be avoided (or at least reduced) through implementation of appropriate measures of adaptation.

Key questions for V/A assessments in agriculture

With the national policy maker in mind the key questions are likely to be:

(i) Will climate change significantly affect domestic agricultural production?

(ii) Will climate change cause food shortages and lead to an increase in hunger?

(iii) Will climate change threaten exports?

(iv) Will climate change affect key government policies such as agricultural pricing, support, research and development?

(v) Will climate change increase food prices to consumers?

(vi) Will climate change, acting through agriculture, place greater stress on natural resources or contribute to environmental degradation (e.g., through land-use change, soil degradation, changes in water supply and water quality, pesticide use, etc.)?

The nature of the assessment is likely to be shaped by key questions in the minds of the user(s). These may not be clearly articulated, particularly if relatively little is known (prior to the assessment) about the possible effects of climate change, and a pilot survey of literature (see below) may be needed to clarify them. For the national policy maker the primary questions are likely to include:

(i) What components of the farming system are particularly vulnerable, and may thus require special attention?

(ii) Can the water/irrigation systems meet the stress of changes in water supply/demand?

(iii) What policies and programmes exist to protect populations from hunger/financial distress and how will they operate under climate change?

(iv) Is the agricultural research/extension system capable of providing adaptation advice to farmers? What technological options should be investigated? Does the country have access to potentially useful options developed in other countries?

(v) Should domestic agricultural policies be reformed?

(vi) Are the natural resource management programmes adequate?

(vii) If domestic production is threatened, will the country be able to import food, and (if so) at what cost?

The last of these questions is of special significance to the impact assessor because it provides a guide to the types of farming, the regions and the communities that may deserve to be the focus of study.

A survey of previous studies

Several hundred impact studies have now been completed of impacts of climate change on agriculture, and these can provide an indication both of the types and magnitude of climate change likely to be most important. A survey of such studies can provide an approximate and initial indication of the types of impact to expect and, thus, the likely methods of analysis that will be most effective. The survey is important because different methods of impact assessment will yield information on some, but probably not all, types of impact. For example, analysis of large-area shifts of cropping zones will require broad-scale use of simple agro-climatic indices, whilst analysis of yields can best be achieved through use of process-based crop growth models. Effects on income and employment can only be assessed using economic and social forms of analysis.

Climate variability is emerging as an important issue to be considered in the impact studies, especially when evaluating associated risks of spatial agricultural production. Recent studies consider explicitly the impact of climatic variability in addition to climate change in the evaluations of crop responses. In regions where current inter-annual climate variability is a mayor factor determining agricultural output, there is an additional challenge for projecting climate change impacts on crop patterns.

Conclusions

There has been remarkable progress in the science of climate and climate prediction in the last few decades. While this progress will continue, it is necessary to mainstream the climate variable into the development planning and implementation processes. This requires an understanding of how climate variability impacts society in a country, region or community.

To advance the understanding of vulnerability and adaptation of agriculture to climate change and variability requires a continuing strengthening of research capacities, interdisciplinary communication and international cooperation. Successful sustainable development strategies must embody the elements of adaptation and mitigation to climate variations.

Global change will alter agricultural production in many areas, with potentially serious consequences at local and regional levels. Many of the world’s poorest people – particularly those living in subtropical and tropical areas – are most at risk of increased hunger.

Further scientific information and datasets

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