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Opinion

Impacts of Climate Change on Food and Nutrition

Daniele De Wrachien*

Senior Professor, Department of Agricultural and Environmental Sciences, University of Milano, Past President EurAgEng, Italy

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***Corresponding author:** Daniele De Wrachien, Senior Professor, Department of Agricultural and Environmental Sciences, University of Milano, Past President EurAgEng, Italy

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Introduction

Irrigated agriculture is expected to play a major role in reaching the broader development objectives of achieving food security and improvements in the quality of life, while conserving the environment, in both the developed and developing countries. Especially as we are faced with the prospect of global population growth from almost 6 billion today to at least 8 billion by 2025 [1]. In this context, the prospects of increasing the gross cultivated area, in both the developed and developing countries, are limited by the dwindling number of economically attractive sites for new large-scale irrigation and drainage projects. Therefore, any increase in agricultural production will necessarily rely largely on a more accurate estimation of crop water requirements on the one hand, and on major improvements in the operation, management and performance of existing irrigation and drainage systems, on the other. The failing of present systems and the inability to sustainably exploit surface and ground water resources can be attributed essentially to poor planning, design, system management and development. Concerning agricultural development, most of the world's 270 million ha of irrigated land and 130 million ha of rainfed land with drainage facilities were developed on a step-by-step basis over the centuries. In many of the systems structures have aged or are deteriorating. Added to this, the systems have to withstand the pressures of changing needs, demands and social and economic evolution. Consequently, the infrastructure in most irrigated and drained areas needs to be renewed or even replaced and thus redesigned and rebuilt, in order to achieve improved sustainable production. This process depends on a number of common and well-coordinated factors, such as new and advanced technology, environmental protection, institutional strengthening, economic and financial assessment, research thrust and human resource development. Most of these factors are well known and linked to uncertainties associated with climate change, world market prices and international trade. These uncertainties call for continued attention and suitable action on many fronts, if productivity and flexibility in agricultural systems are to be improved [2].

Problems and Solutions

All the above factors and constraints compel decision makers to review the strengths and weaknesses of current trends in irrigation and drainage and rethink technology, institutional and financial patterns, research thrust and manpower policy so that service levels and system efficiency can be improved in a sustainable manner. To develop this process in a well-planned and controlled way the following aspects need to be adequately addressed:

a) Technology.

b) Institutional and financial aspects.

c) Research thrust.

d) Human resources and networking.

Technology in irrigation and drainage development is concerned with the planning, design and control of the systems, including water conveyance, regulation structures, water quality and environmental protection measures. It is also concerned with modernization procedures and methods for conjunctive use of surface and groundwater to minimize water use and reduce deep percolation. In this context, the process of determination of design parameters, selection of systems and materials, construction methods, operation and maintenance aspects has to proceed in a balanced way, in order to optimize designs and to take into account the interactions among land use, agricultural practices and the layout and characteristics of irrigation and drainage networks [3]. Institutional strengthening and proper financial assessment are essential tools for efficient planning, design and management of irrigation and drainage systems. Without a sound institutional framework, at the national or river basin levels, it will not be possible to promote and ensure sustainable water management for agriculture. Economic constraints are equally important. The cost of system improvement is normally substantial and governments, in an era of transition from state to a market economy, will not be able to continue financing irrigation and drainage activities, as they used to do. The new philosophy is based on the principle that the services must be paid for by those who benefit from them. Sustainable development, as defined earlier, should, therefore, meet two basic requirements, namely institutional strengthening and economic viability.

In 1990 the International Commission on Irrigation and Drainage (ICID) made an urgent appeal to the World Bank to respond to the need for promoting research and development in irrigation and drainage, both in the developed and developing countries. Insufficient research, application of research findings and access to new and advanced technology in the sector were seen as some of the main reasons for the problems plaguing the sector: poor water use efficiency, environmental degradation, high costs and lack of responsiveness to beneficiaries. Since then, many technology research programs have been launched by different scientific, financial and professional institutions. Their mission has been to enhance the standard of irrigation and drainage research and development, at worldwide level, with a view to improving technology and management so as enhance system performance, food security and sustainability of the irrigation and drainage environment. Successful technology and research activities in irrigation and drainage development depend on the number and quality of human resources (professional-and-research-related people) involved. They use their know-how and skill to solve priority problems and adapt available techniques to local situations. Moreover, these experts will have to assist national and international agricultural and irrigation and drainage institutions to improve training in water related topics, as well as scientific organizations to identify subjects that warrant further analysis and investigation.

Climate Change Scenarios

Over the past centuries, the Earth's climate has been changing due to a number of natural processes, such as gradual variation in solar radiation, meteorite impacts and, more importantly, sudden volcanic eruptions in which solid matter, aerosols and gases are ejected into the atmosphere. Ecosystems have adapted continuously to these natural changes in climate, and flora and fauna have evolved in response to the gradual modifications to their physical surroundings or have become extinct. Human beings have also been affected by and have adapted to changes in local climate, which, in general terms, have occurred very slowly. Over the past century, however, human activities have begun to affect the global climate. These effects are due not only to population growth, but also to the introduction of technologies developed to improve the standard of living. Human-induced changes have taken place much more rapidly than natural changes. The scale of current climate forcing is unprecedented and can be attributed to greenhouse gas emissions, deforestation, urbanization, and changing land use and agricultural practices. The increase in greenhouse gas emissions into the atmosphere is responsible for the increased air temperature, and this, in turn, induces changes in the different components making up the hydrological cycle such as evapotranspiration rate, intensity and frequency of precipitation, river flows, soil moisture and groundwater recharge. Mankind will certainly respond to these changing conditions by taking adaptive measures such as changing patterns in land use. However, it is difficult to predict what adaptive measures will be chosen, and their socio-economic consequences [4,5].

Concerning global patterns, the following considerations can be drawn from analysis of the hydrologic and meteorological time series available:

a) Average global temperature rose by 0.6 °C during the 20th century [6].

b) 1990's was the warmest decade and 1998 the warmest year since 1861 [7].

c) The extent of snow cover has decreased by 10% since the late 1960s [8].

d) Average global sea level rose between 0.1-0.2 metres during the 20th century [9].

e) precipitation increased by 0.5 to 1% per decade in the 20th century over the mid and high latitudes of the northern hemisphere and by between 0.2 and 0.3% per decade over the tropics (10° N to 10° S) [10].

f) precipitation decreased over much of the northern sub-tropical (10° N to 30° N) land areas during the 20th century by about 0.3% per decade [11].

g) The frequency of heavy rain events increased by 2 to 4% in the mid and high latitudes of the northern hemisphere in the second half of the 20th century. This could be the result of changes in atmospheric moisture, thunderstorm activity, large-scale storm activity, etc. [12].

h) Over the 20th century land areas experiencing severe drought and wetness have increased [12].

i) Some regions of Africa and Asia recorded an increase in the frequency and intensity of drought in the last decade [13].

j) CO_2 concentration has increased by 31% since 1750 [14].

k) 75% of CO_2 emissions is produced by fossil fuel burning, the remaining 25% by land use change especially deforestation [14].

l) Methane CH_4 has increased by 151% since 1750 and continues to increase. Fossil fuel burning, livestock, rice cultivation and landfills are responsible for emissions [15].

m) Nitrous Oxide (N_2O) has increased by 17% since 1750 and continues to increase. This gas is produced by agriculture, soil, cattle feed lots and the chemical industry [16].

n) The Stratospheric Ozone (O_3) layer has been depleting since 1979 [16].

Current scientific research is focused on the enhanced greenhouse effect as the most likely cause of climate change in the short-term. Until recently, forecasts of anthropogenic climate change have been unreliable, so that scenarios of future climatic conditions have been developed to provide quantitative assessments of the hydrologic consequences in some regions and/or river basins. Scenarios are "Internally-consistent pictures of a plausible future climate" [17]. These scenarios can be classified into three groups:

A. Hypothetical scenarios.

B. Climate scenarios based on general circulation models (GCMs).

C. Scenarios based on reconstruction of warm periods in the past (paleo-climatic reconstruction).

The plethora of literature on this topic has been recently summarized by the Intergovernmental Panel on Climate Change [18]. The scenarios of the second group have been widely utilized to reconstruct seasonal conditions of the change in temperature, precipitation and potential evapotranspiration at basin scale over the next century. GCMs are complex three-dimensional computer-based models of atmospheric circulation, which provide details of changes in regional climates for any part of the Earth. Until recently, the standard approach has been to run the model with a nominal "pre-industrial" atmospheric carbon dioxide (CO_2) concentration (the control run) and then to rerun the model with doubled (or sometimes quadrupled) CO_2 (the perturbed run). This approach is known as "the equilibrium response prediction". The more recent and advanced GCMs are, nowadays, able to take into account the gradual increase in the CO_2 concentration through the perturbed run. However, current results are not sufficiently reliable.

Climate Change and Irrigation Requirements

Agriculture is a human activity that is intimately associated with climate. It is well known that the broad patterns of agricultural growth over long time scales can be explained by a combination of climatic, ecological and economic factors. Modern agriculture has progressed by weakening the downside risk of these factors through irrigation, the use of pesticides and fertilizers, the substitution of human labour with energy intensive devices, and the manipulation of genetic resources. A major concern in the understanding of the impacts of climate change is the extent to which world agriculture will be affected. Thus, in the long-term, climate change is an additional problem that agriculture has to face in meeting global and national food requirements. This recognition has prompted recent advances in the coupling of global vegetation and climate models. In the last decade, global vegetation models have been developed that include parameterizations of physiological processes such as photosynthesis, respiration, transpiration and soil water intake [19]. These tools have been coupled with GCMs and applied to both paleoclimatic and future scenarios [20,21]. The use of physiological parameterizations allows these models to include the direct effects of changing CO_2 levels on primary productivity and competition, along with the crop water requirements. In the next step the estimated crop water demands could serve as input to agro-economic models which compute the irrigation water requirements (IR), defined as the amount of water that must be applied to the crop by irrigation in order to achieve optimal crop growth.

Estimates of long-term average climate change have been taken from two different GCMs:

a. The Max Planck Institute for Meteorology (MPI-ECHAM4), Germany.

b. The Hadley Centre for Climate Prediction and Research (HCCPR-CM3), United Kingdom. The following climatic conditions have been computed:

i. Present-day long-term average climatic conditions, i.e. The climate normal 1961-1990 (baseline climate) [22].

ii. Future long-term average climatic conditions of the 2020s and 2070s (climatic change) [23].

Planning and Design of Irrigation and Drainage Systems Under Climate Change

Uncertainties as to how the climate will change and how irrigation and drainage systems will have to adapt to these changes, are challenges that planners and designers will have to cope with. In view of these uncertainties, planners and designers need guidance as to when the prospect of climate change should be embodied and factored into the planning and design process . An initial question is whether, based on GCM results or other analyses, there is reason to expect that a region's climate is likely to change significantly during the life of a system. If significant climate change is thought to be likely, the next question is whether there is a basis for forming an expectation about the likelihood and nature of the change and its impacts on the infrastructures [24]. The planning and design process needs to be sufficiently flexible to incorporate consideration of and responses to many possible climate impacts. Introducing the potential impacts of and appropriate responses to climate change in planning and design of irrigation systems can be both expensive and time consuming. The main factors that might influence the worth of incorporating climate change into the analysis are the level of planning (local, national, international), the reliability of GCMs, the hydrologic conditions, the time horizon of the plan or life of the project [25].

Strategic Action Plan

The above-described themes and principles tackle the root cause of the major problems encountered in irrigation and drainage system development. To be effective, they have to be translated into actions through the formulation of programs that take into account the actual conditions of the environment where they are expected to be implemented. These programs would have to include:

A. Adoption of a comprehensive approach that considers land and water use and management and the environment in an integrated manner.

B. Promotion of regional co-operation to ensure that the concerns of all parties are translated into sound decisions.

C. Recognition of the relationships between different land uses and availability of water resources (quantity and quality).

D. Encouragement of broad-based participation, including governments, professional and research institutions and non-governmental organizations.

E. Endorsement of phased programs of action at the international (river basin), national, regional and local levels.

This regional approach makes up and outlines the body of the ICID Strategic Action Program, a crucial procedure for implementing priority actions at national and local levels. The objectives of the Strategic Action Plan are to (ICID, 2015) [26]:

Goal 1: Enable higher crop productivity with less water and energy.

Goal 2: Be a catalyst for change in policies and practices.

Goal 3: Facilitate exchange of information, knowledge and technology.

Goal 4: Enable cross disciplinary and inter-sectoral engagement.

Goal 5: Encourage research and support development of tools to extend innovation into field practices.

Goal 6: Facilitate capacity development.

Priority selection would have to follow the five-step planning and design procedure listed below:

a. Ensure optimization of interventions, in order to concentrate resources on significant problems.

b. Pay due attention to both technical and non-technical aspects (human resources development, legal and institutional aspects, environmental impacts).

c. Avoid duplication and overlap.

d. Emphasize adaptive and cost-effective solutions through adaptation and/or improvement of existing technology to specific tasks.

e. Select topics for investigation and research that are likely to achieve the greatest benefit, considering return on investment, response time, probability of success and impact on agricultural production.

This integrated approach is expected to produce significant benefits in environmental and economic terms, a more sustainable use of land and water resources in irrigated agriculture and higher yields and incomes.

Concluding Remarks

a) Despite the enormous advances in our ability to understand, interpret and ultimately manage the natural world we have reached the 21st century in awesome ignorance of what is likely to unfold in terms of both the natural changes and the human activities that affect the environment and the responses of the Earth to those stimuli. One certain fact is that the planet will be subjected to pressures hitherto unprecedented in its recent evolutionary history.

b) Most of the world's irrigation and drainage facilities were developed on a step-by-step basis over the centuries and were designed for a long life (50 years or more), on the assumption that climatic conditions would not change in the future. This will not be so in the years to come, due to global warming and the greenhouse effect. Therefore, engineers and decision-makers need to systematically review planning principles, design criteria, operating rules, contingency plans and water management policies.

c) An integrated approach to food production and irrigation and drainage systems development is needed , so as to maximize water application , reduce deep percolation and intercept , isolate and recycle low-quality water effluents.

d) Possible impacts of climate variability that may affect planning principles and design criteria include changes in temperature, precipitation and runoff patterns, sea level rise, flooding of coastal irrigated and rainfed lands.

e) Uncertainties as to how the climate will change and how irrigation and drainage systems will have to adapt to these changes are issues that water authorities are compelled to cope with. The challenge is to identify short-term strategies to face long-term uncertainties. The question is not what the best course for a project over the next fifty years is or more, but rather, what is the best direction for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course.

f) The planning and design process needs to be sufficiently flexible to incorporate consideration of and responses to many possible climate impacts. The main factors that will influence the worth of incorporating climate change into the process are the level of planning, the reliability of the forecasting models, the hydrological conditions and the time horizon of the plan or the life of the project.

g) The development of a comprehensive approach that integrates all these factors into irrigation and drainage project selection, requires further research of the processes governing climate changes, the impacts of increased atmospheric carbon dioxide on vegetation and runoff, the effect of climate variables on water demand for irrigation and the impacts of climate on infrastructure performance.

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