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Global Warming Effects on Irrigation and Drainage Development

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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 in the private sector 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. At this regard, 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 gradually developed over the centuries, and many of the systems structures are nowadays aged or are deteriorating. In addition, agricultural 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, economical 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].

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 [3].

Irrigation and Drainage Systems Development

Development in irrigation

Over the last 40 years, the irrigation has been a major contributor to the growth of food and fiber supply for a global population that has more than doubled, from 3 to over 6 billion people. Global irrigated area increased by around 2% a year in the 1960s and 1970s, slowing down to around 1% in the 1980s, and lower still in the 1990s. Between 1965 and 1995 the world's irrigated land grew from 150 to 260 million ha. Nowadays it is increasing at a very slow rate because of the significant slowdown in new investments, combined with the loss of irrigated areas due to salinization and urban encroachment.

Notwithstanding these achievements, today the majority of agricultural land (1.1 billion ha) still has no water management system. In this context it is expected that 90% of the increase in food production will have to come from existing cultivated land and only 10% from conversion from other uses. In the rainfed areas with no water management systems some improvements can be achieved with water harvesting and watershed management. However, in no way can the cultivated area with no water management contribute significantly to the required increase in food production. For this reason, the share of irrigated and drained areas in food production will have to increase. This can be achieved either by installing irrigation or drainage facilities in the areas without a system or by improving and modernizing existing systems. The International Commission on Irrigation and Drainage (ICID) estimates that within the next 25 years this process may result in a shift of the contribution to the total food production to around 30% for the areas with no water management system, 50% for the areas with an irrigation system and 20% for the rainfed areas with a drainage system [4].

Development in drainage and land reclamation

Drainage and land reclamation are crucial instruments for achieving sustainable development of both irrigated and rainfed agriculture throughout the world. Figure 1 shows the expansion of the world's cultivated, irrigated and drained areas since the beginning of the nineteenth century [6]. Out of a total cultivated area of around 1,500 million ha, 1,100 million ha are agriculturally exploited without a water management system.

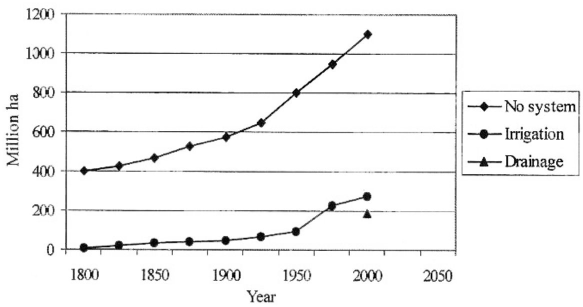

Figure 1: Expansion of world's cultivated area with no water management system and under irrigation and currently drained land [5].

However, methods such as water harvesting or soil treatment may be applied in some parts. These areas produce 45% of crop output. Irrigated land currently occupies more than 270 million ha and is responsible for 40% of crop output. Irrigation consumes about 70% of water withdrawn from the world's river systems. About 130 million ha of rainfed areas are equipped with drainage facilities and contribute to around 15% of crop output. Roughly 60 million ha of irrigated land are also provided with drainage systems [6].

Climate Change Scenarios

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" [7]. These scenarios can be classified into three groups:

Hypothetical scenarios;

Climate scenarios based on General Circulation Models (GCMs);

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 [8]. The scenarios of the second group have been widely utilized to reconstruct seasonal conditions of the change in temperature, precipitation and potential evapotraspiration at basin scale over the next century. GCMs are complex three-dimensional computer-based models of the 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 (CO2) concentration (the control run) and then to rerun the model with doubled (or sometimes quadrupled) CO2 (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 CO2 concentration through the perturbed run. However, current results are not sufficiently reliable.

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 should 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 a 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 [9].

The suitability and robustness of an infrastructure can be assessed either by running "what if scenarios" that incorporate alternative climates or through synthetic hydrology by translating apparent trends into enhanced persistence.

If climate change is really recognized as a major planning issue (first step), the second step in the process would consist of predicting the impacts of climate change on the region's irrigated or drained area. The third step involves the formulation of alternative plans, consisting of a system of structural and/or non-structural measures and hedging strategies that address, among other concerns, the projected consequences of climate change. Non-structural measures that might be considered include modification of management practices, regulatory and pricing policies. Evaluation of the alternatives, in the fourth step, would be based on the most likely conditions expected to exist in the future with and without the plan [10]. The final step in the process involves comparing the alternatives and selecting a recommended development plan. 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 cli- mate 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 [11,12].

Concluding Remarks

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, even implicit, that climatic conditions would not change in the future. Nowadays the disturbing news about global warming need to be locally verified in order to perform reliable analysis. Therefore, engineers and decision-makers need to systematically review planning principles, design criteria, operating rules, contingency plans and water management policies. 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.

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

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 is over the next fifty years 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.

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.

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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