Climate Change Management

Walter Leal Filho *Editor*

Climate Change and the Sustainable Use of Water Resources

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Preface

Climate change is and will continue to be one of the central issues in the world's agenda. The 16th Conference of Parties (COP-15) of the UN Framework Convention on Climate Change held in Cancun, Mexico, in December 2010 has reiterated how much still needs to be done in order to tackle the various challenges climate change and its various ramifications pose to mankind.

This book, prepared as a follow-up to the third online climate conference CLIMATE 2010/KLIMA 2010, held on 1–7 November 2010, focuses on *Climate Change and the Sustainable Management of Water Resources*. There are two key arguments for the choice of this particular topic:

- First, it is widely believed that climate change has a serious impact on global water supplies and may worsen water scarcity–a problem which threatens a large part of the world already today. Under present conditions, approximately 1.2 billion people—especially in developing countries—have no access to drinking water. In order to address this problem, the United Nations has set the goal of increasing access to a further 600 million people by 2015, i.e. better access to drinking water for around 100 million people per year between 2010 and 2015.
- Second, there is a pressing need to use the presently available water resources, which are very scarce in some areas, more sustainably. Even though in parts of Africa, Latin America and the Middle East water resources are already scarce, the proportion of water wasted partly to leaks but also due to the lack of adequate systems to retain, recycle and reuse water is considerably high. Urgent action is needed to address this issue to keep up the UN targets.

The thematic focus of this book, which is also prepared in the context of the Interreg IVB (North Sea) project North Sea Skills Integration and New Technologies (SKINT), will allow in-depth discussions and support the search for global and regional solutions for the impacts climate change has on water supplies and will address the need to promote sustainable water use across the world.

Part I contains a set of papers on geochemical and physical impacts of climate change on water supplies, as well as on aspects of modelling, forecasting and software applications. Part II includes papers on the socioeconomic aspects of climate change in relation to water supplies and use, whereas Part III presents papers on the links between climate change, policy-making and sustainable water use. Part IV presents a number of projects and initiatives, which focus on addressing the links between climate change and sustainable water use, including educational and awareness-raising initiatives.

I want to thank all authors for sharing their knowledge and their experiences, as well as Mrs Marika Rudzite-Grike for the editorial support provided. Thanks are also due to the ICCIP Team (Franziska Mannke, Natalie Fischer, Kathrin Rath and Johanna Vogt) and Olaf Gramkow for contributing to Climate 2010 and to this book project.

It is hoped that this book, which is Volume 3 of the "Climate Change Management Series", initiated as part of the "International Climate Change Information Programme" (ICCIP), will be useful and allow a better understanding of the problems, barriers, challenges, opportunities and possibilities related to the promotion of the sustainable use of water resources worldwide.

Summer 2011 Walter Leal Filho

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Part I

Chapter 1
Climate Change Impacts on Green Water Fluxes in the Eastern Mediterranean

Ibrahim M. Oroud

Abstract The present paper is part of the Glowa Jordan River project, which has been focusing on climate change impacts on environmental, economic and social issues within the lower Jordan river riparian states. The eastern Mediterranean is characterized by scarce and erratic precipitation with relatively cool, wet winters and dry hot summers. Water is the biggest growth-limiting factor. The present paper discusses the use of climate gradient as a tool to examine the impact of climate change on precipitation partitioning over field crops. The present experiment is carried out using a multi-layer, multi-year model with a daily time step. Six years of daily data for five locations, with average annual precipitation ranging from 170 to 580 mm, were used in this investigation. Results show that the ratio of soil evaporation (BE) to annual precipitation (P) during the growing season depends strongly on precipitation regime and amount, ranging from $\sim$15 to 20% when P > 600 mm to $\sim$60% when annual P < 200 mm. A decrease of 10% in precipitation along with a temperature rise of 2°C increases bare surface evaporation, on average, by $\sim$10% compared to average current conditions. The implications of this would be a tangible reduction in blue and green water fluxes, leading to compulsory land use shift and further water stress in the region.

Keywords Climate change · Mediterranean · Soil moisture partitioning · Rain-fed field crops

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Introduction

Rain-fed field crops are widely grown in western Asia and North Africa. Being located in a transitional zone, this area experiences limited amounts of precipitation with substantial interannual and within season variability. For instance, a 30-year record of precipitation in a station located in this area shows that the average, lowest and highest annual precipitation there were 340, 123 and 639 mm, respectively, with a coefficient of variation of precipitation exceeding 30% in many locations. Precipitation in the eastern Mediterranean exhibits strong spatial gradients both latitudinally and across elevation contour lines. This is clearly depicted in the geographic distribution of water resources, floral composition and dominant agricultural practices.

General circulation models and long-term regional meteorological observations suggest strongly that the eastern Mediterranean will experience a warming trend along with a reduction in annual precipitation during the twenty-first century. This climate change is expected to adversely affect soil moisture availability at different depths, with subsequent impacts on the evapotranspiration regime and biomass production. One of the objectives of this paper is to demonstrate the impact of climate gradient on soil moisture partitioning when planted with a field crop, wheat for instance. The use of climate gradient, or space-for-time approach, provides an assessment of what to expect following a change in climate.

The objective of the present investigation is to examine how soil moisture regime within the active root zone of a wheat crop is influenced by the amount of precipitation and its temporal distribution, and how it is partitioned via direct evaporation and transpiration along a climate gradient. A multi-year, multi-layer simulation model was used. Six years of daily meteorological data for five stations representing the high precipitation zone in Jordan were used in this investigation.

Study Area and Data Quality

The study area represents a semi-dry Mediterranean climate regime with "average" Koppen climate classification of Csa and Csb. The study area is located in the mountainous areas of Jordan, with average annual precipitation ranging from 170 mm to about 550 mm (Fig. 1).

Precipitation falls in the cold season, October/November, and ceases around the end of March/early April. Figure 2 shows the annual course of precipitation in two locations. Annual potential evaporation (PE) in the study area is around 1,000 mm, with the index of aridity ranging from 1.5 in a small mountainous enclave to about 4 in the drier mountainous regions. Six years of continuous daily meteorological data (precipitation, maximum and minimum air temperatures, sunshine hours, cloud cover, wind speed, and ambient vapour pressure) covering the period 1996/1997–2001/2002 were obtained from the Department of Meteorology, Jordan.

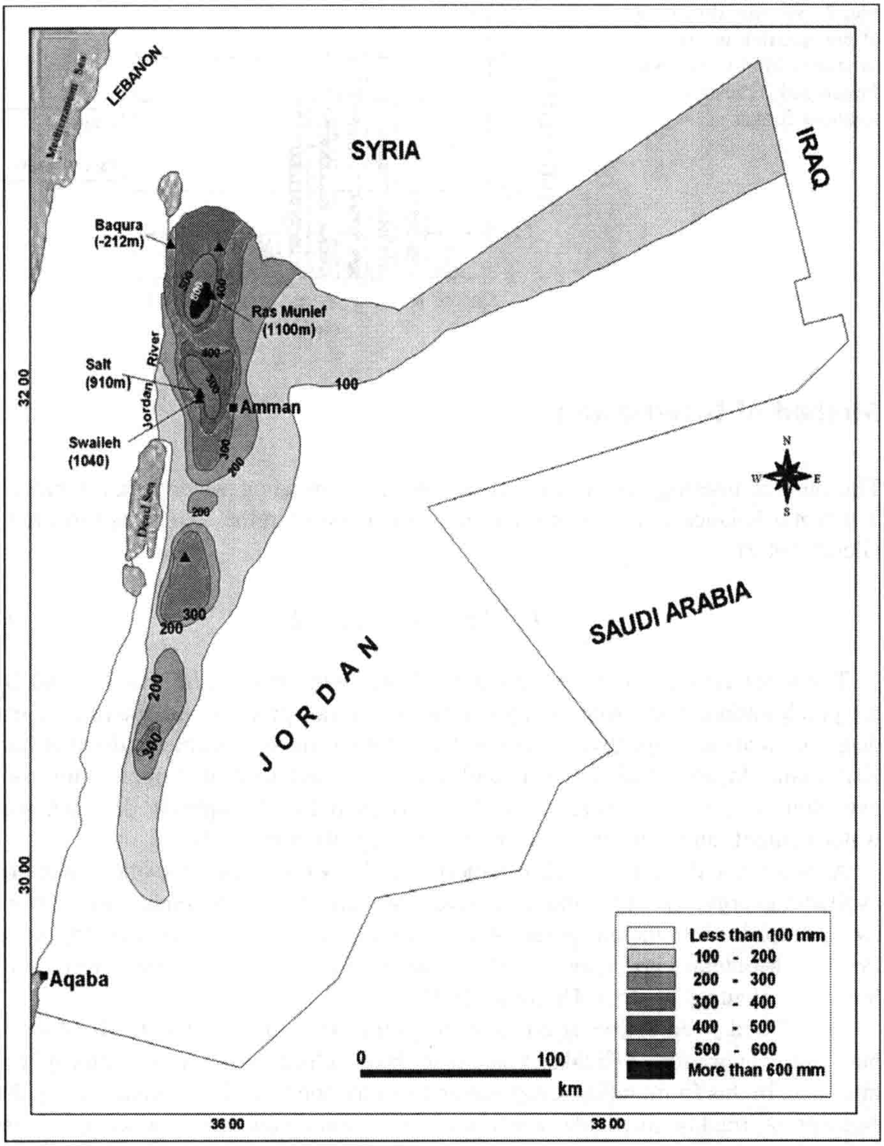

Fig. 1 Location of stations along with elevation (m) and average annual precipitation (mm)

This period covers several growing seasons with wet, average and dry years for the five stations used in the investigation. The selected stations provide good-quality meteorological data with elements being observed on an hourly or three-hourly basis. The data set was quite continuous with few gaps in certain elements which were estimated from neighbouring stations using linear regression, and were checked for consistency.

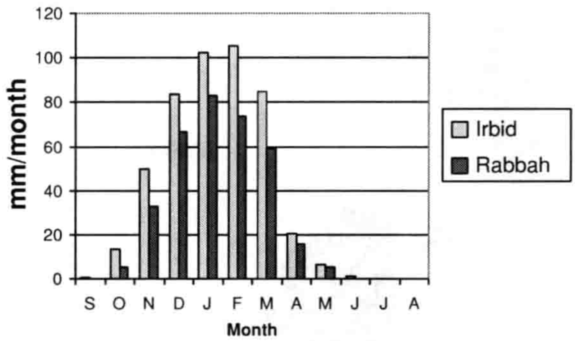

Fig. 2 Monthly distribution of precipitation in two locations, Irbid in northern Jordan and Rabbah in southern Jordan

Method of Investigation

The present investigation is carried out using a cascading water balance model. The water balance of a soil column may be expressed in the following form (e.g. Gleick 1987):

$$\frac{\delta S}{\delta t} = P - BE - A_T - R_O - D_p \tag{1}$$

The first term represents soil moisture change with time; P, BE, A_T, R_O, and D_p are precipitation, bare surface evaporation, actual transpiration, surface runoff, and deep percolation, respectively. In this formulation the soil profile is divided into four equal layers, 0.25 m each, and thus it is assumed that maximum root extension is 1 m. Soil evaporation is determined by atmospheric demand, soil water content, and soil hydraulic properties (e.g. Ritchie 1972).

Atmospheric demand, or PE, is a thermal index which represents the amount of available energy, radiative and advective, that can be used to convert water from its liquid phase into vapour phase. A widely used expression to calculate PE is the Penman–Monteith expression, in which radiative and advective terms were combined to calculate PE (e.g. Dingman 2002).

Actual soil evaporation is either energy-limited or moisture-limited. Most of bare soil evaporation (*BE*) takes place from layers close to the surface-atmosphere interface. In this formulation, evaporation from the top layer is calculated using the concept of readily available water such that soil evaporation proceeds at its potential rate when skin layer moisture (ω) exceeds atmospheric demands:

$$BE = \tau P_E, \quad \tau P_E \leq \omega, \quad 0 \leq \omega \leq 4 \text{ mm} \tag{2}$$

When skin moisture content does not meet evaporative demands, then direct evaporation is proportional to moisture content of the upper layer,

$$BE = \tau\omega + \tau(P_E - \omega)\left(\frac{\theta_i - \theta_h}{\theta_f - \theta_h}\right)^{1.8}, \quad \tau PE > \omega \tag{3}$$