

1. Water management in arid and semi-arid regions: interdisciplinary perspectives – an introduction

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Water deficiency in many arid and semi-arid regions in Southern Europe is becoming a major constraint for economic welfare and sustainable regional development. These water-deficient regions are characterized by high spatial and temporal imbalances of water demand and supply, seasonal water uses, inadequate water resources and poor institutional water management. Appropriate strategies and guidelines for water management are necessary for the formulation and implementation of integrated sustainable management of water resources.

The recently adopted Water Framework Directive (WFD) clearly demonstrates the EU's intention to respond to this challenge through an integrated multi-objective approach for water management. There is a clear need to develop and evaluate strategies for integrated water resources management (IWRM) in Southern European water-deficient regions through multi-perspective approaches that take into account economic, technical, social, institutional and environmental constraints. In particular, there is a pronounced need to learn to cope with rapid social changes, efforts for economic development and escalating water demands in a continuously changing environment.

The aim of this book is to present the culmination of results from the ARID Cluster of projects, which examine water scarcity and demand in arid and semi-arid regions, as well as participatory and adaptive approaches for appropriate management strategies. Experience and lessons learned are derived from various case studies, which examine competing water use patterns, comparing governance structures and how these have evolved in response to scarcity, and structural and non-structural instruments to address water deficiency.

The ARID Cluster is supported by the European Commission under the Fifth Framework Programme and is contributing to the implementation of the Key Action 'Sustainable Management and Quality of Water' within

the Energy, Environment and Sustainable Development programme. The ARID Cluster project was initiated in 2001 and will be completed in 2006. The ARID Cluster brings together three distinct, yet related research projects dealing with water management in arid and semi-arid regions. In particular, its purpose and objectives amount to bringing together the results of three cross-disciplinary approaches to sustainable and integrated water management, so as to develop effective and efficient policy recommendations that can feed directly into the water management decision-making processes.

These are the Aquadapt project, focusing on a co-evolutionary approach to adaptive, integrated management under changing utilization conditions; the MEDIS project, addressing conflicting demands and varying hydrological conditions for the sustainable use of water on Mediterranean islands; and the WaterStrategyMan project, which seeks to develop strategies for regulating and managing water resources and demand in water-deficient regions. The nature of the work undertaken in the three projects has evolved primarily through the use of case studies, thus providing important insights into the issues of water scarcity under different socio-economic and environmental conditions. The purpose of the ARID project is to identify and evaluate common issues and challenges that exist across the three projects and to determine the means by which these can be addressed most efficiently. Finally, one of the underlying objectives of ARID is to examine what policy implications these results may have for the implementation of the Water Framework Directive.

Chapters 2 and 3 compose Part II of the book, which focuses on strategies for regulating and managing water resources and presents some of the main results of the WaterStrategyMan project of the ARID Cluster.

In Chapter 2, Professor Ezio Todini, Professor Andreas Schumann and Professor Dionysis Assimacopoulos present the WaterStrategyMan Decision Support System, aiming to define an appropriate methodology for supporting decision-makers in the sustainable and integrated water resource planning in arid and semi-arid regions. In the context of the EU Water Framework Directive, the systematic evaluation of water management interventions should be performed for a long time horizon, simulating long-run accumulative effects and anticipating potential future changes and uncertainties. Selected methodologies and indicators should assist decision-makers in identifying the appropriate policy and management instruments in relation to regional economic growth and environmental sustainability. Multidisciplinary information is needed for the analysis of water management strategies and plans, and the evaluation of their effects, taking into account economic, hydrologic and environmental interrelationships. This objective was accomplished through the development of a procedure based

on the simulation of alternative water availability and demand scenarios and the evaluation of the effect of alternative water management options and instruments. The procedure was formalized in a prototype decision support system (WSM DSS), designed to simulate the impacts of different water management options and strategies, integrating the economic principles of the Water Framework Directive 2000/60/EC. Since 2004, the WSM DSS is being applied to river basins and regions in Greece, Italy, Cyprus, Portugal, Israel and Spain, aiming to assist in the formulation of alternative water management strategies following the principles of integrated water resources management (IWRM). The chapter ends with some concluding remarks on potential further application and future developments and extensions of the system.

Chapter 3 by Professor Rodrigo Maia is intended to supplement Chapter 2 by demonstrating the development and evaluation of alternative water management scenarios through the application of the DSS on the Ribeiras do Algarve River Basin, which is located in the Algarve region, Portugal. This river basin is situated in the southern stretch of the country and covers a total area of 3837 km². The climate in the basin is Mediterranean, characterized by rainy winters and dry summers, as well as precipitation with varying spatial and temporal distributions. Currently this region is the most popular tourist destination in mainland Portugal, where there exists conflict between different uses of water resources, especially between the tourism sector and agriculture, as well as infrastructure deficiencies, poor groundwater quality, high losses in secondary water supply networks and inadequate irrigation methods. The application of the DSS tool takes place in two phases. In the first phase, stakeholders' opinions are analysed to formulate appropriate water management responses. These include: (1) structural opinions for supply enhancement including dam construction, network enhancements, desalination, new boreholes for groundwater abstraction and reduction of network losses; (2) demand management options comprising of water reuse and improvement in irrigation methods; and (3) socio-economic measures, addressing domestic and irrigation water price adjustments. The second phase involves the formulation of strategies using the available options. In particular, two different strategies were considered: (1) one reflecting the dominant water management paradigm in the region; and (2) another reflecting a new, shifting, paradigm. The main goal of both water management options and strategies is to achieve 95 per cent coverage for domestic use and a minimum of 80 per cent coverage of irrigation demand, while adhering to a maximum use of 80 per cent of aquifer recharge. The chapter concludes with a description of a strategy that could be able to achieve economic sustainability, as required by the cost recovery principle of the Water Framework Directive.

Part III of the book focuses on sustainable use of water on Mediterranean islands and addresses the conflicting water resources demands under varying hydrological and socio-economic conditions. The results presented in this part of the book derive from research efforts of the MEDIS project of the ARID Cluster, which uses a stakeholder participatory approach to integrated and sustainable water resources management.

Chapter 4, by Manfred Lange, Antonia Alkistis Donta and the MEDIS consortium, focuses on climate change and vulnerabilities to drought on Mediterranean islands. The vulnerability of a system depends on its sensitivity to external changes and on its adaptive capacity that will reduce the impacts of those changes on the system. Assuming that sensitivities to droughts of arid and semi-arid regions are relatively stable, the vulnerability of a given region to water scarcity results from the impact of changes in water availability not to be compensated by adaptation. Reducing vulnerability to droughts therefore requires effective adaptation strategies. In devising such strategies, a number of aspects or dimensions need to be considered: the physical and environmental dimension, the economic and regulatory dimension and the social, institutional and political dimension. These aspects will have to be considered holistically, which requires an interdisciplinary research design. In this chapter, the authors briefly review some of the concepts of integrated assessments of climate change. This provides the basis for looking at issues affecting present adaptability to water scarcity in arid and semi-arid regions related to the three aforementioned dimensions. Moreover they discuss briefly how global change might affect some of the adaptabilities and suggest various strategies to enhance adaptive capacity, with regards to islands in the Mediterranean.

In Chapter 5, Kostas Chartzoulakis and Maria Bertaki focus on water use in agriculture in Mediterranean islands. They argue that sustainable water resources management in the major Mediterranean islands (Cyprus, Crete, Sicily, Corsica and Mallorca) is closely related with water use in agriculture, which uses more than 50 per cent of available water resources. This percentage ranges from 55 in Corsica up to 82 per cent in Crete. It is also the sector least efficient in water use, since irrigation efficiency is less than 55 per cent. The demand for irrigation water is high in all islands even though only a small percentage of agricultural land is irrigated, ranging from 8.8 in Mallorca up to 33.4 per cent in Crete. In all islands, water for agriculture comes mainly from groundwater sources, while only in Corsica is surface water the sole source of irrigation water. Treated wastewater, although it is a valuable irrigation water resource, makes a very low contribution to irrigation (1 and 7 per cent in Cyprus and Mallorca respectively). Among the crops dominating in Mediterranean islands, citrus, fodder and

open-field vegetables are the high water-demanding crops, while olives are the less water-demanding crop. Modern irrigation systems have been widely used the last few decades in all islands. Localized (drip or mini-sprayer) irrigation systems are mainly used for tree crops and vegetables, while sprinkler irrigation is dominant for fodder crops and some vegetables. The growing water demand in Mediterranean islands makes the rational use of irrigation water extremely important for agricultural development to be sustainable and for the environment to be conserved. To meet these goals, aspects related to water management in agriculture are discussed in this chapter, with emphasis on irrigation application, soil and plant management practices, water pricing, reuse of treated wastewater, farmers' participation in water management, and capacity building.

Part IV of the book is composed of Chapters 6 and 7 and focuses on a number of economic issues that emerge as vital for efficient water resources allocation and the optimal implementation of the Water Framework Directive. This section has a strong economic focus and derives from the research of a group of economists in the ARID Cluster.

In Chapter 6, Katia Karousakis and Phoebe Koundouri present a typology of economic instruments and methods for efficient water resources management in arid and semi-arid regions. In particular, this chapter provides the economic perspective to implementing integrated water resources management, and describes the valuation techniques and economic instruments that have been developed and are available to help price water efficiently, and allocate it to its highest-valued user as required by the EU Water Framework Directive.

Chapter 7 by Marita Laukkanen and Phoebe Koundouri presents an analytical attempt to approximate the behaviour of economic agents in groundwater extraction under two possible scenarios, namely coordination and no coordination between the agents. This is a formalized experiment to investigate the potential of organizing irrigated agricultural regions in irrigation divisions; that is, to investigate whether social welfare can increase from implementing irrigation divisions in a water basin. This is an economic policy that could prove efficient in the implementation of the WFD. In particular, the authors analyse a game with N farmers that extract groundwater from a common aquifer of small storage capacity. Their aim is to compare the socially optimal, myopic and feedback extraction strategies, the latter arising from competitive interaction between extracting agents. The main extension to existing literature is that the authors consider heterogeneous farmers, facing uncertainty deriving from stochastic rainfall. The farmers differ in terms of their choice of irrigation technology, which results in different farmer-specific impacts on the aquifer recharge rate. The implications of the different strategies on extraction rates, groundwater table levels

and welfare attained, are illustrated via simulations based on data from the Kiti aquifer in Cyprus.

Part V of the book introduces the co-evolutionary approach to adaptive, integrated water management. Chapters 8 and 9 of the book present some of the main results from the research conducted by the Aquadapt project, which investigates the potential of such an evolutionary approach to integrated water management.

In particular, in Chapter 8 Tur et al. focus on socio-cultural determinants of water utilization and they have three specific objectives. The first objective is to understand the political, socio-cultural, economic and technological determinants of collective and individual water consumption. The second objective is to investigate the attitudes of consumers towards water as a communal resource, as a social right and as a commodity. The third objective is to understand the linkages and the differences between four case studies to determine the scope of local, regional and international integrated water management challenges. These objectives are investigated in four selected areas of study, namely, the Hérault watershed in France (survey conducted by BRGM), the Kras plateau in Slovenia (survey conducted by ZRC-SAZU-School of Water Sciences), the Marina Baixa region in Spain (survey conducted by Alicante University), and the Nene catchment in the UK (survey conducted by Cranfield University). The chapter has been structured around the following points: firstly, the description of the socio-economic features of the four catchments that will allow us to contextualize the results obtained and to infer from the data to the social use of water; secondly, an explanation of the undertaken methodology; thirdly, the comparative analysis of the basic frequencies gathered in the survey; fourthly, to show the results from the profile analysis; and finally, to offer some general conclusions on a shared culture of water in Europe.

Chapter 9 by Andreu Bonet, Juan Bellot, Denise Eisenhuth, Juan Peña, Juan Rafael Sánchez and Julio César Tejada, investigates evidence of landscape change, water usage, management system and governance co-dynamics in South-Eastern Spain. The authors argue that the identification of the co-dynamic processes between landscape, water usage, management system and governance is crucial to determine the causes of structural change in a socio-natural system of semi-arid Spain. A clearer understanding of the co-dynamic processes that can occur in socio-natural systems could help to further illuminate the rapid and unforeseen changes that are inherent to the environmental, socio-economic and governance contexts within which water supply and demand patterns develop. The professional logic is that if co-dynamic processes cause structural change in socio-natural systems, then structural change could offer the key through

which to identify the characteristics of both the type of resilience and the adaptive capacity that maintain the long-term sustainability of a socio-natural system. The literature pertaining to the concepts of resilience and adaptive capacity recognizes that resilience refers to the potential of a natural or social system to reorganize or restructure. The problem in this study is that there has been a history of both inter-basin and intra-basin water transfers (that is, engineering resilience) introduced to stabilize the hydrological system. While engineering resilience maintains the global stability of the hydrological system, it could have ultimately locked out the desired type of co-dynamic processes and structural change that can lead to the creation and testing of alternative water sourcing and usage practices. The result of continued and increasing engineering resilience to maintain stability of the hydrological system diminishes both the adaptive capacity of other ecological systems, and social adaptive capacity. In this chapter the characteristics of the type of resilience the authors are interested in locating provides a socio-natural system with the potential to adapt or reorganize in a desirable way following disturbance-driven change that is caused by significant and regular water transfers. Therefore the ultimate challenge is to locate the reciprocal co-dynamic processes that promote the type of structural change that increases the ecological as well as the social resilience and adaptive capacity of the water-using communities in the Marina Baja. The aim then is to analyse structural change in both the natural as well as the social system and the nature of the reciprocal co-dynamic processes that promote either ecological and social adaptive capacity.

In Part VI the final chapter of the book brings together the common themes, issues and problems that have been identified throughout the research conducted in the ARID Cluster in a manner which enables conclusions and policy recommendations to be drawn that can feed into the Water Framework Directive.

