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# **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 characterised 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 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. 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 utilisation 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.

The book is divided in four parts. Part I focuses on strategies for regulating and managing water resources and follows the multidisciplinary approach adopted by researchers of the WaterStrategyMan (WSM) project. Part II of the book studies sustainable use of water on

Mediterranean islands, by addressing conflicting demands under varying hydrological and socio-economic conditions through the use of a stakeholder-participatory approach to integrated and sustainable water management. In particular, it provides the reader with results from the MEDIS project. Part III of the book focuses on a number of economic issues that emerge to be 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. Part IV of the book focuses on the co-evolutionary approach to adaptive integrated water management and is based on research of the Aquadapt project. The book concludes with a chapter that integrates the results of the different projects and approaches and derives the lessons to be learnt for sustainable and integrated water management from the interdisciplinary effort that takes place in the framework of the ARID cluster. In particular, it harmonises the results, identifies common themes and conclusions, and discusses the policy implications for sustainable and integrated water management in water deficient regions. Below we give a more detailed description of content of each part of the book and attempt to highlight the commonalities between the four different parts of the book.

Chapters 2, 3 and 4 compose Part I 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, Prof. Bernard Barraqué, Prof. Christos Karavitis and Ms. Pipina Katsiardi, descriptively present the range of existing circumstances in a number of case studies, carried out by the WaterStrategyMan project Consortium<sup>1</sup>. This chapter provides an overview of the selected regions, presenting information relating to their geographical, hydrological and water use characteristics. Fifteen regions were selected from six countries. These include Greece (regions: Attica, Thessaly and the Cyclades Islands),

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<sup>1</sup> The Consortium consists of the National Technical University of Athens, Greece, the Ruhr-University Bochum, Germany, ProGEA S.r.l., Italy, the Office International de l'Eau, France, the Hebrew University of Jerusalem, Israel, the Water Development Department, Cyprus, INSULA (International Scientific

Italy (Belice basin and Emilia-Romagna), Spain (Doñana and the Canary Islands), Portugal (Algarve, Sado and Guadiana), Cyprus (Akrotiri, Germasogeia and Kokkinochoria), and Israel (Tel Aviv and Arava). The authors construct region-specific summary matrixes of descriptive indices related to the prevailing natural conditions and infrastructure, economic and social system, and decision-making processes. These matrices are very useful for the implementation of the Water Framework Directive as they provide summary information for the regions where the Directive is to be implemented. This information can be used for the identification of the region-specific management strategy that will potentially support the implementation of the Directive.

In chapter 3, Prof. Ezio Todini, Prof. Andreas Schumann and Prof. 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 formalised 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. The WSM DSS is currently being applied to river basins and regions in Greece, Italy, Cyprus, Portugal, Israel and Spain, aiming to

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Council for Island Development), Spain, Aeoliki Ltd, Cyprus, and the Faculdade de Engenharia da Universidade do Porto, Portugal.

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 4 by Prof. Rodrigo Maia is intended to complete chapters 2 and 3 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 located in the southern stretch of the country and covers a total area of 3837 km<sup>2</sup>. 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 exist conflict between different uses of water resources, especially between the tourism sector and agriculture, 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 (i) structural opinions for supply enhancement including dam construction, network enhancements, desalination, new boreholes for groundwater abstraction and reduction of network losses; (ii) demand management options comprising of water re-use and improvement in irrigation methods; and (iii) 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: (i) one reflecting the dominant water management paradigm in the region and (ii) another reflecting a new, shifting, paradigm. The main goal of both water management options and strategies is to achieve 95% coverage for domestic use and a minimum of 80% coverage of irrigation demand, while adhering to a maximum use of 80% 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 II 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 5, by Antonia Donta, Manfred Lange and the MEDIS consortium<sup>2</sup> presents water management in Mediterranean islands and in particular it identifies relevant pressures and recommends the appropriate policy and management options to accommodate/face these pressures. The authors argue that “water” is a realm of study dominated by natural scientists and engineers, although integrated water resources management, concerns equally natural, social and economic aspects. One method that not only enables such an integrated approach by combining the natural and socio-economic aspects also allowing a stakeholder involvement is the implementation of indicators. Such indicators facilitate the characterisation of an integrated picture of water management conditions and the existing situation, as well as making a comparison between different situations and catchments possible. By using indicators and following the Driving forces-Pressures-State-Impacts-Responses approach, the driving forces and pressures of both the natural environment, i.e. pressures exerted by natural phenomena, and the socio-economic one, i.e. conditioned by anthropogenic activities, can be considered. This chapter intends to show how this approach is being carried out in the MEDIS-project and conducted on the islands of Corsica, Crete, Cyprus, Majorca and Sicily. The aim is to define recommendations for equitable and sustainable water management on Mediterranean islands, which include physical data such as climatic, hydrological but also agricultural and socio-economic data

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<sup>2</sup> The MEDIS consortium consists of the following Institutions: Centre for Environmental Research, University of Muenster, Germany; Institute of Geoinformatics, University of Muenster, Germany; Institute of Geophysics University of Muenster, Germany; Centre of Ecology and Hydrology, National Environment Research Council, UK; Department of Political and Social Sciences, University of Cyprus, Cyprus; Institute of Electronic Structure and Laser, Foundation for Research and Technology, Hellas, Greece; NAGREF, Subtropical Plants and Olive Tree Institute, Greece; Regional Governor of Crete, Water Resources Management Department, Greece; Dipartimento di Costruzioni e Tecnologie Avanzate, University of Messina, Italy; Système Physique de l'Environnement – URA CNRS 2053, Université de Corse,

as well as stakeholder demands and experiences. These recommendations contribute directly to the implementation of the Water Framework Directive (WFD) on the Mediterranean basin.

Chapter 6 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/dimensions need to be considered: the physical/environmental dimension, the economical/regulatory dimension and the social/institutional/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 7, 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

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France; Dep. De Ingenieria del Terreno, Universitat Polytecnica de Catalunya; Balearic Island University Spain; for further details, please see: <http://www.uni-muenster.de/Umweltforschung/medis/index.html>



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 surface water is the sole source of irrigation water. Treated wastewater, although it is a valuable irrigation water resource, its contribution to irrigation is very low (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 olive is the less water-demanding crop. Modern irrigation systems have been widely used the last few decades in all islands. Localized (drip or mini-sprayers) 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 make the rational use of irrigation water extremely important for agricultural development to be sustainable and for the environment to be served. To meet these goals, aspects related to water management in agriculture are discussed in this chapter, with emphasis to irrigation application, soil and plant management practices, water pricing, reuse of treated wastewater, farmers participation in water management and capacity building.

Part III of the book is composed of chapters 8, 9 and 10 and focuses on a number of economic issues that emerge to be 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 8, 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 9 by Marita Laukkanen and Phoebe Koundouri, present an analytical attempt to approximating the behavior of economic agents in groundwater extraction under two possible scenarios, namely co-ordination and no co-ordination between the agents. This is a formalized experiment to investigate the potential of organizing irrigated agricultural regions in irrigation divisions; i.e. 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 impact 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.

Chapter 10 by Phoebe Koundouri, focuses on another tool which administrators and researchers in the field of the implementation of the WDF need to master. In a competitive economy, the socially efficient level of investment is attained by investing in projects where the net present value (NPV), determined by discounting costs and benefits at the social discount rate (SDR) over the time horizon, is greater than zero. It follows that the level of the SDR is critical in determining whether an individual public investment or policy will pass a CBA test. A common critique of discounting is that it militates against solutions to long-run environmental problems. The question arises: What is the appropriate procedure for such long time horizons? A recently proposed solution to this problem is to use a discount rate, which declines with time, according to some predetermined trajectory, this raising the weight attached to the welfare of future generations. It is immediately obvious that using a declining discount rate (DDR) would make an important contribution towards meeting the goal of sustainable development. So, what formal justifications exist for using a DDR and what is the optimal trajectory of the

decline? This chapter provides a brief non-technical review of recent contributions addressing these two issues in different ways. The author ties together the different approaches --- some deterministic, others based on uncertainty, some based upon intergenerational equity, others on considerations of efficiency --- and illustrates through a case-study on investment in flood defenses the effects of using DDRs in public policy. This work has important implications for the implementation of the EU Water Framework Directive and should be integrated in the economic aspects of such an implementation at the local, regional, country and EU level.

Part IV of the book introduces the co-evolutionary approach to adaptive integrated water management. In particular, chapter 11 and 12 of the book present some of the main results from the research conducted by the AQUADAPT project, which is the project that investigates the potential of such an evolutionary approach to integrated water management.

In particular, in chapter 11 Antonio Aledo Tur Guadalupe and Ortiz Noguera focus on socio-cultural determinants of water utilisation and they have three specific objectives. The first objective is to understand 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, France: Hérault watershed (Survey conducted by BRGM<sup>1</sup>), Slovenia: Kras plateau (Survey conducted by ZRC-SAZU-School of Water Sciences), Spain: Marina Baixa region (Survey conducted by Alicante University), and UK: Nene catchment (Survey conducted by Cranfield University). The chapter has been structured into the following points: first, 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; second, an explanation of the undertaken methodology; third, the comparative analysis of

the basic frequencies gathered in the survey; fourth to show the results from the Profile Analysis; and finally, to offer some general conclusions on a shared culture of water in Europe.

Chapter 12 by Andreu Bonet, Juan Bellot, Denise Eisenhut, Juan Peña, Juan Rafael Sánchez, and Julio César Tejada, investigates evidence of landscape change, water usage, management system and governance co-dynamic 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 processional 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 adaptive capacity that maintains the long-term sustainability of a socio-natural system. The literature pertaining to the concepts resilience and adaptive capacity recognises that resilience refers to the potential of a natural or social system to reorganise or restructure. The problem in this study is that there has been a history of both inter-basin and intra-basin water transfers (viz. 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, as well as 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.

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.