Dietrich Borchardt · Janos J. Bogardi
Ralf B. Ibisch *Editors*

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ISBN 978-3-319-25069-4 ISBN 978-3-319-25071-7 (eBook)
DOI 10.1007/978-3-319-25071-7

Library of Congress Control Number: 2015953813

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Foreword

2015 was a pivotal year for water in development generally, and for Integrated Water Resources Management (IWRM) in particular. It started with the launch of the report “Global Risks 2015” at the World Economic Forum that identified “water crises” at the top global risk in terms of impacts (eighth in terms of likelihood). In September the UN General Assembly adopted the 17 Sustainable Development Goals (the SDGs), with 169 specific targets, to guide the world’s development agenda through 2030. One of the goals is to “Ensure availability and sustainable management of water and sanitation for all”, and one of the six targets to be achieved under this is “By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate”. And 2015 ended with a new global climate agreement at COP 21 in Paris in which the critical role of water for adaptation and resilience building is highlighted.

Hence the book “Integrated Water Resources Management: Concept, Research and Implementation” addresses the right topic at the right time.

As explained in the book IWRM has developed and matured since early thoughts the 1950s through the world conferences at Mar del Plata in 1977 and Dublin in 1992, and the World Summits in Rio in 1992, in Johannesburg in 2002 and Rio in 2012, to being adopted as a global target for sustainable development in 2015. Highlights on this journey have been the four “Dublin principles” in 1992, the adoption of IWRM in Agenda 21 in 1992, the target in the Implementation Plan from Johannesburg in 2002 for “all countries to develop IWRM and Water Efficiency Plans” to the UN report to Rio+20 in 2012 reporting that 80 % of all countries were making good progress, including IWRM in national policies and legislation, while half are in an “advanced state of implementation”. In a historical perspective this rapid advance of a development concept that cuts across sensitive political, cultural, economic, social and environmental dimensions is indeed remarkable.

But obviously there are questions and doubts. The IWRM concept lends itself to many interpretations, and therefore also doubts as to its apparent "success". Some critics, mainly academics, have seen IWRM as a set of principles—even brand—that does not provide a clear methodology to support actual problem solving, while most policy makers and practitioners view IWRM as a philosophy and process that provides an integrated approach to complex issues that need to be reconciled across sectors, across levels and across stakeholder interests, taking a problem-driven approach embedded in integrated thinking.

However, we have no choice. With the world having adopted the SDG target on IWRM we need to look forward, reconcile views and form alliances across civil society, public, private and academic actors towards a commonly agreed approach and set of actions that can be monitored.

So what is the main challenge and key way forward for IWRM?

At the World Water Forum in Korea in April 2015 IWRM was one of the key thematic areas and the subject of a high-level panel. The discussion up to, during and after the forum converged on a view that the implementation of IWRM invariably being a "messy, noisy process in which stakeholders are trialling solutions, negotiating choices and moving upwards and downwards between levels and sectors", picturing IWRM as a process in messy "bazaar", rather than religion in a "cathedral". This view is consistent with the "integration" in IWRM being a difficult combination of the horizontal integration between sectors and stakeholders at all levels, and the vertical integration from the local village or catchment level through basin and de-central administrative structures to the national and the regional levels. The future focus in IWRM implementation must take its point of departure in pragmatic solutions to actual problems, reconciling IWRM processes with pragmatic problem solving, from high-level policy and strategy development, through proper operating mechanisms to bridge strategy and problem solution, to monitoring of progress.

However, the world is changing and future IWRM implementation needs to adapt to new vectors such as climate change, demographic change, the water–energy–food security nexus and greening growth. The "water sector" may not be in the lead in many cases, rather, as has been recognized in the nexus debates, we need to think "beyond the water box" and include a much wider set of stakeholders and actors. The SDG on water is one of 17 goals, likely to galvanize revitalization of IWRM implementation; but most of the other 16 goals—e.g. on gender, health, food, energy, cities, ecosystems, oceans and so on—cannot be achieved without proper development and management of our scarce, vulnerable and variable water resources and we need to think and act across them. IWRM provides a vehicle for doing so.

This book provides support for that way forward. As stated in the first chapter "translation into practical implementation has been demonstrated in the various studies in this book". By addressing 10 key topics of IWRM implementation in 28 chapters the book clearly identifies the duality between "philosophy" on the one hand and "methodology" on the other, it rightly emphasizes about the adaptive management in a changing world. It also makes a clear case of the role of research and the need for future research into methodologies for implementation under different settings that can support a pragmatic approach.

For the "IWRM community", but also for a lot of people outside it, this book is an important contribution to our continued journey towards achieving the post-2015 development agenda by moving the IWRM agenda forward.

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World Water Week in Stockholm
Chief Water Policy Adviser, DHI Group
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Acknowledgments

The results and findings presented in this book were generated within the framework of the BMBF funding measure on ‘Integrated Water Resources Management (IWRM)’. The funding by the German Ministry of Education and Research (BMBF) which has made the research and this publication possible is gratefully acknowledged. Further thanks go to the project management agencies in Jülich and Karlsruhe for their excellent support during the realisation of the projects.

The editors would like to thank the researchers who responded to our call and provided research results or reviews for this book on IWRM. We are grateful to the following experts who have volunteered their time and knowledge to peer-review the chapters of the book. In alphabetic order, our sincere thanks go to Amir AghaKouchak (University of California Irvine, USA), Andrew Allan (University of Dundee, UK), Sue Baggett (University of Dundee, UK), Francesco Bosello (Fondazione Eni Enrico Mattei, Italy), Stewart Burn (CSIRO Land and Water, Australia), Marie Campbell (University of Victoria, Canada), Steen Christensen (Aarhus University, Denmark), Murray Clamen (McGill University, Canada), Cornelia Claus (University of Tübingen, Germany), Damien Closson (Royal Military Academy, Belgium), Sue Cuddy (CSIRO Land and Water, Australia), Katherine Daniell (Australian National University, Australia), Ralf Dannowski (Leibniz-Zentrum für Agrarlandschaftsforschung - ZALF e.V., Germany), Bernd Diekkrüger (University of Bonn, Germany), Jörg Dietrich (Leibniz University of Hannover, Germany), Joachim Fettig (Hochschule Ostwestfalen-Lippe, Germany), Tom Franks (University of Bradford, UK), Carlo Giupponi (Università Ca' Foscari of Venice, Italy), Alireza Gohari (Iran University of Science and Technology, Iran), Geoffrey Gooch (University of Dundee, UK), Heinz Hoetzl (Karlsruher Institut für Technologie - KIT, Germany), Raymond Ison (Monash University, Australia), Alan Jenkins (Centre for Ecology & Hydrology, UK), Darko Joksimovic (Ryerson University, Canada), Manfred Lange (The Cyprus Institute, Cyprus), Daniele La Rosa (University of Catania, Italy), Jörg Londong (Bauhaus-Universität Weimar, Germany), Daniel Peter Loucks (Cornell University, USA), Francesco Mannocchi (University of Perugia, Italy), Douglas Maraun (GEOMAR Helmholtz-Zentrum für

Ozeanforschung Kiel, Germany), David Marlow (CSIRO Land and Water, Australia), Wolfram Mauser (Ludwig-Maximilians-Universität München, Germany), Karen Meijer (Deutsches Institut für Entwicklungspolitik - DIE, Germany), Frank Molkenthin (BTU Cottbus, Germany), Hans-Peter Nachtnebel (Universität für Bodenkultur Wien, Austria), Susanne Neubert (Humboldt-Universität zu Berlin, Germany), Stephen Nortcliff (University of Reading, UK), Lennart Olsson (Lund University, Sweden), Mario Parise (Università degli Studi di Bari, Italy), Angel Perni (Universidad de Murcia, Spain), Roger Pielke (University of Colorado, Boulder, USA), Joachim Quast (Leibniz-Zentrum für Agrarlandschaftsforschung - ZALF e.V., Germany), Brian Richter (The Nature Conservancy, USA), Henk Ritzema (Wageningen University, Netherlands), David Rosenberg (Utah State University, USA), Samuel Sandoval Solis (University of California, Davis, USA), Christian Schleyer (Helmholtz-Centre for Environmental Research - UFZ, Germany), Gerd Schmidt (Martin-Luther-Universität Halle-Wittenberg, Germany), Uwe Schneider (Hamburg University, Germany), Ana Serrano (University of Zaragoza, Spain), Christian Siebert (Helmholtz-Centre for Environmental Research - UFZ, Germany), Per Stålnacke (Norwegian Institute for Agricultural and Environmental Research, Norway), Christian Stamm (EAWAG, Switzerland), Eva Sternfeld (TU Berlin, Germany), Matthias Themeßl (TU Graz, Austria), Dominique Trévisan (French National Institute for Agricultural Research, France), Kristof Van Assche (University of Alberta, Canada), Nick van de Giesen (Delft University of Technology, Netherlands), Joost Vervoort (University of Oxford, UK), Martin Volk (Helmholtz-Centre for Environmental Research - UFZ, Germany), Frank Ward (New Mexico State University, USA), Dorothea Weingärtner (RWTH Aachen, Germany), Mark Wiering (Radboud University Nijmegen, Netherlands), Scott Wilson (USGS, USA), Nadine Wittmann (TU Berlin, Germany), Matthias Zessner (TU Wien, Austria).

The editors thank Dr. Stephan Klapp and Mrs. Ulrike Stricker-Komba of Springer Nature for their interest in highlighting the IWRM topic with this book and their highly constructive cooperation during the entire publishing process.

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Part I
Introduction

Chapter 1
Integrated Water Resources Management: Concept, Research and Implementation

Ralf B. Ibisch, Janos J. Bogardi and Dietrich Borchardt

Abstract This chapter reviews the concept, contemporary research efforts and the implementation of Integrated Water Resources Management (IWRM) which has evolved as the guiding water management paradigm over the last three decades. After analyzing the starting points and historical developments of the IWRM concept this chapter expands on relations with recently upcoming concepts emphasizing adaptive water management and the land-water-food-energy nexus. Although being practically adopted worldwide, IWRM is still a major research topic in water sciences and its implementation is a great challenge for many countries. We have selected fourteen comprehensive IWRM research projects with worldwide coverage for a meta-analysis of motivations, settings, approaches and implementation. Aiming to be an up-to-date interdisciplinary scientific reference, this chapter provides a comprehensive theoretical and empirical analysis of contemporary IWRM research, examples of science based implementations and a synthesis of the lessons learnt. The chapter concludes with some major future challenges, the solving of which will further strengthen the IWRM concept.

Keywords Sustainable development · IWRM · Adaptive management · Nexus approach · Global change

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D. Borchardt et al. (eds.), *Integrated Water Resources Management: Concept, Research and Implementation*, DOI 10.1007/978-3-319-25071-7_1

1.1 Origins and Development of the Integrated Water Resources Management (IWRM) Concept

Very few ideas and recommendations have been embraced in the “water world” as quickly, enthusiastically and universally as IWRM. Hardly any major international event with relevance to water and water management, and the associated declarations have missed to endorse IWRM as the way to tackle and to solve water problems irrespective of scale and scope. Probably the most prominent among these events was the World Summit on Sustainable Development held in Johannesburg in 2002. The Johannesburg Plan of Implementation (JPoI) (United Nations 2002) stipulates that within five years all countries should have IWRM and water efficiency plans. While this appeal triggered the compilation of national IWRM plans the implementation of this resolution was much less than universal. With this resolution the JPoI placed IWRM at the national level. Other models are also promoted however. The European Water Framework Directive (EC 2000/60/EC) defines the basin and “water body” scale as appropriate for water resources management whereas other sources promote small scale, stakeholder involved IWRM (Burton 2003).

Clearly there are substantial uncertainties, if not outright differences in the interpretation of what IWRM is supposed to be. When did the concept of IWRM emerge and what were its original attributes? Report No. 7. of the EU funded NeWater Project (2005) claims that IWRM is a “Dublin-Rio” principle by referring to the respective water conference and UN Conference on Environment and Development, which both took place in 1992. This report also mentions the UN Conference in Mar del Plata 1977 as an origin and refers to UN efforts to introduce IWRM as early as the 1950s. Irrespective of these historical traces it is fair to identify the emergence of IWRM when it began occurring in laws, official government guidelines, or similar administrative documents as instructions for administration and technical services for the implementation of water resources management in a new “integrated” way. One comprehensive example of these guidelines is the Derde Nota Waterhuishouding “Water vor nu en later” (Water for Now and Later) issued by The Netherlands government (Rijkswaterstaat 1989). It is obvious that the political will and the concept of IWRM predate the Dublin Conference (Bogardi 1990). This conclusion does not aim to mitigate the significance of major international events which endorsed and scaled up IWRM. If we assume that IWRM implementation began in the late 1980s this should enable us to look back on almost three decades of experience. Yet conferences continue to issue appeals to use IWRM rather than being able to showcase many encouraging experiences and improvements gained through the application of IWRM. In this context it is worth mentioning the critical evaluation of IWRM (Biswas 2004, 2008) highlighting the meager accomplishments in applying IWRM worldwide. More than a decade after this review IWRM still looks like a cherished birthday cake, none of the guests daring to cut and savor.

The above-mentioned enthusiasm—at least verbally—for IWRM is accompanied by fairly broad interpretations (see review by Martínez-Santos et al. 2014). This might be acceptable as far as a concept or philosophy is concerned. However this "plurality" (in order to just avoid calling it "cacophony") could become a real handicap if IWRM were considered a method to be encapsulated in practical guidelines and manuals for implementation in practice.

This basically unresolved duality of IWRM being interpreted either as a philosophy, or a methodology (tool) can be seen as the main reason for its popularity and frequent endorsement, whereby being simultaneously hampered in becoming a day to day tool in water related institutions.

One core dilemma already highlighted by Bogardi (1990) is the question of what is to be integrated? This question has been reoccurring in the debate ever since (Biswas 2004; Molle 2008; Hering and Ingold 2012). There is an inherent contradiction. Integration should be as comprehensive as possible. Thus it provides an excellent concept for sketching the complexity of the problem and for drawing intricate flow charts displaying complex feedback loops and other interconnectedness. In the meantime engineering, applied science and administrative actions have been and are focusing on the main (actionable) components of a problem to be solved. No doubt this frequently implies simplification rather than expanding the integration.

By reviewing the early definitions of IWRM the different aims and aspirations of the different protagonists can be analyzed. It is worth juxtaposing some of the most prominent definitions of IWRM in order to trace the above-mentioned duality and highlight the diverging interpretations.

The Derde Nota Waterhuishouding (Rijkswaterstaat 1989) defines IWRM as

> Interrelated water resources policy making and management by government agencies responsible for the strategical and management tasks, executed on the basis of the systems concept under consideration of the internal functional relationships between quality and quantity aspects of both surface- and groundwater, as well as the external interactions between the water resources management and management of other fields like environmental protection, regional planning, nature conservation etc.

This definition is a clear example of a political/administrative guideline with clear limitations and degrees of consideration of what and how to be integrated. With the reference to systems concept even a hint of methodological prescription is given. Clearly this definition was formulated with IWRM as a practical tool in mind.

While NeWater calls IWRM a "Dublin-Rio principle" the four Dublin principles (the outcome of the Dublin Conference 1992) do not use explicitly the term "IWRM". Rather Principle 2

> Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels

refers to a participatory approach involving all stakeholders at all levels. Thus it calls for a kind of vertical integration in the sociopolitical sphere rather than emphasizing the need for the topical (horizontal) integration. It is a substantial addendum (or difference) compared to the definition by Rijkswaterstaat (1989).

Within the promulgation of the new water law of the Republic of South Africa in the late 1990s the Department of Water Affairs and Forestry (DWAF) formulated the following definition (Görgens et al. 1998)

> IWRM is a philosophy, a process and a management strategy to achieve sustainable use of the resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits.

This definition shows remarkable differences compared with the example from The Netherlands (Rijkswaterstaat 1989), regardless of the fact that in both cases the definitions are formulated by a ministry of a national government. The South African definition gives different attributes to IWRM, thus implicitly acknowledging its duality. It emphasizes the "background" and philosophical characteristics and calls it a strategic approach instead of specifying how it should be implemented. One can see that experiences made in the 1990s with attempted implementations of IWRM are already mirrored in this definition. It repeats the multistakeholder view of the Dublin principle and boasts the basin scale approach. The term "agreed limits" reflects the negotiations-based decision making process involved. Compared to the definition in the Derde Nota Waterhuishouding (Rijkswaterstaat 1989) the DWAF definition involves all levels of the jurisdictional hierarchy including the international level. It is a logical extension should the basin scale principle be consequently pursued.

The definition of the Global Water Partnership (GWP 2000)

> IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

calls IWRM a process and explicitly refers to the necessity of coordinated land and water management, a recommendation which has been repeatedly been called for (Bogardi et al. 2012). While this definition is much less prescriptive than that of the Derde Nota it explicitly links the elements of sustainable development to IWRM.

Needless to say that these three definitions are only examples—albeit the most important ones—of the broad spectrum of interpretations of IWRM. This "liberal" use of definitions was not and is not really conducive for the breakthrough of IWRM as a practical and commonly deployed tool. The critical evaluation by Biswas from 2004

> The definition of IWRM continues to be amorphous, and there is no agreement on fundamental issues like what aspect should be integrated, how by whom, or even if such integration in a wider sense is possible … in the real world, the concept will be exceedingly difficult to be made operational.

unfortunately has not lost its actuality during the last decade.

As the popularity of IWRM seems to continue unabatedly, at least as a slogan in the international water discourse, the calls for IWRM continue. The call for implementation of IWRM on all levels even appears in the recently adopted Sustainable Development Goals (SDGs) of the United Nations (Goal 6, Target 6.5), including transboundary cooperative setups by 2030. Compared to the "deadline" set out in the Johannesburg Plan of Implementation in 2002 (5 years) (United Nations 2002) at least the world gives itself 15 years to comply this time. Whether it means that the inherent obstacles are adequately assessed is yet to be seen. After the unrealistic resolution in 2002 in Johannesburg the elevation of IWRM to be part of an SDG is an opportunity, but not without risks. The credibility of the professional community, but also that of the concept is at stake. This forthcoming challenge, to be encapsulated in an intergovernmental binding resolution, underlines the importance of this book in providing a broad review of the state-of-the-art of IWRM and its various components.

After almost 30 years of less than satisfactory IWRM implementation the impression is emerging that stakeholder and other non-water professional interest groups increasingly attempt to equate IWRM with the concept of multi-stakeholder involvement (with integration thus mainly in the sociopolitical domain). While this is a fundamental requirement of planning in a pluralistic society, not only for IWRM, it can by no means be equated with IWRM. While multi-stakeholder involvement has its merits in reaching sustainable consensus solutions, reducing IWRM to a "simple" integration of various interest groups in the decision making process remains a long way from the originally high aims of IWRM as reflected for example in the Derde Nota definition in 1989.

1.2 IWRM in the Context of Adaptive Management and the Nexus Approach

IWRM gained momentum with the adoption of the Dublin principles at the World Summit in Rio de Janeiro in 1992 (Savenije and Van der Zaag 2008). The IWRM principles comprise three elements (i) the integration of different sectors and different uses and users of water, (ii) the balancing of three pillars—economic, social and environmental sustainability and (iii) the participation of stakeholders in decision-making and the strengthening of the role of women. IWRM clearly takes into account the importance of governance and management systems as well as water infrastructures and technological approaches. Emphasis is given to demand management and to some extent, the perspectives of blue and green water management are included. Nevertheless, implementation of the IWRM concept in the real world has been slow and unsatisfying and has not induced major transformations in the management of freshwater resources (Jeffrey and Gearey 2006; Mukhtarov 2008). A United Nations status report on IWRM prepared for the Rio +20 Conference documents progress in the inclusion of IWRM in national policies and legislation but also states that only half of the countries with IWRM plans report an "advanced state of implementation" (UN-Water 2012). Similarly, at the 2011 Dresden International Conference on IWRM, experts concluded that "the actual implementation of IWRM is lagging behind". They urged that "the implementation of IWRM and the realization of the respective programs have to be accelerated" (Borchardt et al. 2013). It seems that several barriers to implementation impede progress.

Recently the concept of “adaptive management” has appeared as a response to increasing uncertainty und instability (Walters 1986; Pahl-Wostl 2007). The implications of climate change and the expected increase in uncertainties have triggered a debate about how to better capture real-world water dynamics. The adaptive management approach to natural resource management emphasizes learning and is based on the assumptions that our knowledge is always incomplete (Allen et al. 2011). The adaptive decision-making process is well structured and includes careful consideration of goals, identification of alternative management objectives and knowledge of causal connections, implementation, monitoring and evaluation followed by reiteration. Hence, although adaptive management can reduce uncertainty in decision making, it is primarily a means for enabling decision making despite uncertainty (Allen et al. 2011; Pahl-Wostl 2007). Adaptive management recognizes people and ecosystems as inherently complex, unpredictable and difficult to control, and encourages ongoing learning as the key to coping with complexity and uncertainty (Schoeman et al. 2014). The concept has been widely promoted as a solution to complex natural resource management problems and a supporting approach to integration. However, the concept runs the same risk of vagueness as IWRM and it remains more an ideal than a reality (Allen and Gunderson 2011).

The question remains, in which way are the two concepts of IWRM and adaptive management different or parallel developments. A recent review by Schoemann et al. (2014) points out that each approach has its own strengths to contribute to improved water management. While IWRM provides a political platform for broad stakeholder participation and a process for consensus solutions in the range of hydrological boundaries, the adaptive management approach sets a norm for learning by the application of experimentation and ‘learning-by-doing’ principles which can improve responsiveness to biophysical feedbacks. It is clear that the IWRM concept in the 1990s did not explicitly tackle the newly arising challenges of interconnected social-ecological systems and global environmental change. Water governance must deal with these new risks and uncertainty and there is a strong call for the development of flexible institutions and policies that facilitate learning, adaptation and the ability to transform (Pahl-Wostl et al. 2011).

The Bonn 2011 Conference, The Water, Energy and Food Security Nexus: Solutions for the Green Economy (see also Hoff 2011) triggered an unprecedented series of international conferences and events dedicated to exploring this widened integrative framework of problem formulation and searching for sustainable solutions. This integrative view on the linkages between water, energy, land and food was promoted during the 2013 Bonn conference on *Water in the Anthropocene: Challenges for Science and Practice* (Gupta et al. 2013; Ringler et al. 2013). The nexus approach, which grew out of systems analysis, recognizes that water, energy and food are closely linked through global and local water, carbon and energy cycles or chains. Water, land and energy are also essential resources, but billions of people have limited access to them and all three are under pressure from supply constraints and rapidly growing demand.

Compared to the IWRM paradigm the nexus approach clearly steps ‘out of the water box’ and focuses on water’s central role in linking the conceptual domains of energy systems, aquatic and terrestrial ecosystems and food production. While the nexus approach accentuates the interlinkages of different domains and economic sectors, the IWRM concept has concentrated predominantly on the water sector although the need for cross-sectoral views have already been addressed in the first definitions of IWRM (GWP 2000). When translating IWRM into projects the connections easily become obvious, for example during the development of concepts for the use of treated wastewater in agricultural production (see Liehr et al., Chap. 26). Thus, we do not see a contradiction between the two concepts and rather see that the possibility of linking integrated management plans prepared for different sectors through the nexus approach.

IWRM is obviously neither a unique, nor lonely concept in the field of resource management. Its ultimate value could be proven by its documented contribution to solving multilevel, multisectoral, multiple-stakeholder resource allocation and other problems. In this jigsaw puzzle IWRM, the nexus concept and adaptive management have their potential role. However, without fitting the pieces together all of these concepts and methods will lose credibility.

1.3 Concept of the IWRM Projects

This edited volume on IWRM intends to provide a multidisciplinary perspective on problem-driven analyses of water-related challenges as well as the development and implementation of practical solutions. The sources of this rather diverse collection of studies and projects on IWRM were two large research programs; GLOWA (Global Change and the Hydrological Cycle—GLOWA) and IWRM (Integrated Water Resources Management) which were both funded by the German Federal Ministry of Education and Research (BMBF).

The GLOWA program was initiated in 2000 with the overall goal of developing solutions for the extraordinary challenges presented by the regional impacts of global environmental change on the users and managers of water resources (von Witsch 2008; Klepper 2011). The GLOWA program ran until 2012 working in five different regions of the world (Upper Danube River, West Africa region, Volta River basin, Jordan River basin, Elbe River basin). The five projects focused on the development of water management tools that enabled the analysis of both natural and human impacts on the water cycle at the river basin level. A characteristic approach of GLOWA was the development of integrated simulation (modelling) tools for decision-makers to treat complex scenarios of how determining factors in the water cycle will change in the future. The GLOWA program included intensive multi-stakeholder-dialogues and knowledge-transfer activities in order to ensure the practical application and further development of the available management models. While the results of some GLOWA projects have already been published elsewhere (like Speth et al. 2010) the results of the GLOWA Jordan River project are presented in this edited volume (Tielbörger et al., Chap. 27).

In the following years, under the BMBF program 'IWRM' the focus was widened to a larger variety of water related problem-settings, the development of integrated solutions and their real-world implementation. The program started in 2006 with the aim "to develop new approaches and concepts for Integrated Water Resources Management in suitable model regions of manageable size outside the European Union" (Ibisch et al. 2013). The funding program also aimed at improving the local population's access to clean drinking water and reliable sanitation. With this objective on the agenda the program was rooted in the research domain but simultaneously targeted towards social and economic development in the particular regions. Within this program seventeen projects were funded altogether, three of which were still running in 2015. In adherence with the German government's funding scheme, the projects within this IWRM initiative included German universities, research facilities and private sector companies together with partners from the case study regions. The projects were complemented by (minor) co-funding from the governments of the specific countries.

The present volume contains a unique compilation of both original data and synthesis papers on the different topics of IWRM research in fourteen different regions and river basins around the world (Table 1.1). The studies presented here were conducted under completely different natural, cultural and socio-economic conditions including extreme arid environments (such as the upper mega aquifer system in the Arabian Peninsula, Siebert et al., Chap. 4), the outer tropics (such as Central Brazil, Lorz et al., Chap. 21), sparsely populated regions in Mongolia (Karthe et al., Chap. 25) and the densely inhabited Mekong Delta (Kuenzer et al., Chap. 15) (Table 1.1). We aimed at identifying general lessons learnt from the two programs GLOWA and IWRM while looking at the diverse conditions in the different case study basins at the same time. It becomes evident that there are inherent difficulties in integrating the results of a large number of independent and methodologically diverse studies, but this could be approached by identifying joint topics and thematic areas (Table 1.2) and framing these with a comprehensive structure (Fig. 1.1).

In the following section, we present a review of the different topics addressed by the studies (Table 1.1) which will help to gain an overview and an integrative picture of state-of-the-art IWRM research. The following dimensions of IWRM are considered in more detail (Table 1.2):

1. Water quantity
2. Water quality
3. Water demand
4. Climate change
5. Water governance
6. Public information and participation
7. Capacity Development
8. Decision support
9. Integrated land and water management
10. Pathways to sustainable water management

Table 1.1 Regional coverage of this volume: drainage basins and selected characteristics

Basin	Countries	Area (km^2)	Population (million)	Mean annual precipitation (mm/a)	References in this volume
Khorezm region	Uzbekistan	6,800	1.5	95	Kim and Hornidge (Chap. 9), Hornidge et al. (Chap. 22)
Western Bug basin	Poland, Belarus, Ukraine	40,000	0.950	700	Bernhofer et al. (Chap. 8)
Al-Batinah region	Oman	12,500	0.760	125	Bernhofer et al. (Chap. 8)
Upper Mega Aquifer, Arabian Peninsula	Saudi Arabia	1.8×10^6	ca. 15–20	<100	Siebert et al. (Chap. 4)
Zayandeh Rud basin	Iran	26,000	4.5	80–1,500	Mohajeri et al. (Chap. 23)
Brasília region	Brazil	5,790	2.5	1,300–1,700	Bernhofer et al. (Chap. 8), Lorz et al. (Chap. 21)
Jordan River basin	Israel, Jordan, Lebanon, Palestine, Syria	18,285	7.18	100–1,400	Tielbörger et al. (Chap. 27), Schacht et al. (Chap. 18), Onigkeit et al. (Chap. 12), Bonzi et al. (Chap. 16); Upper Jordan River: Reichmann et al. (Chap. 6); Lake Kinneret basin: Sade et al. (Chap. 2); Lower Jordan River: Klinger et al. (Chap. 28), Chen & Weisbrod (Chap. 3)
Dead Sea	Israel, Jordan, Palestine	43.223	0.680	50–800	Siebert et al. (Chap. 5)

(continued)

Table 1.1 (continued)

Basin	Countries	Area (km^2)	Population (million)	Mean annual precipitation (mm/a)	References in this volume
Mekong Delta	Vietnam	40,000[a]	17.2	1,900	Kuenzer et al. (Chap. 15)
Guanting basin	China	43,600	8.1	350–450	Otto et al. (Chap. 10)
Miyun basin	China	15,654	0.381	500	Meissner et al. (Chap. 20)
Huangshui River basin	China	1,560	0.620	550	Kaden & Geiger (Chap. 24)
Kharaa River basin	Mongolia	15,000	0.147	250–300	Hofmann et al. (Chap. 19), Karthe et al. (Chap. 25)
Cuvelai-Etosha basin	Namibia	84,589	0.844	300–600	Liehr et al. (Chap. 26)

[a]Surface area of the Mekong Delta

Table 1.2 Topics covered in this volume

Topic	Sub-topics and contributions to this volume
Water quantity	Water availability within the Lake Kinneret watershed, Israel (Sade et al., Chap. 2) Environmental flows and indicators of hydrologic alteration in the Lower Jordan River (Chen and Weisbrod, Chap. 3) Quantification of water fluxes in an extremely arid environment, Upper Mega Aquifer System on the Arabian Peninsula (Siebert et al., Chap. 4) Water budget of the Dead Sea basin (Siebert et al., Chap. 5)
Water quality	Impact of rainfall-runoff events on water quality of the Upper Catchment of the Jordan River (Reichmann et al., Chap. 6)
Water demand	Water use efficiency along the supply chain of agricultural products in Uzbekistan (Bekchanov et al., Chap. 7)
Climate change	Adequate climate information for Integrated Water Resources Management (Bernhofer et al., Chap. 8)

(continued)

Table 1.2 (continued)

Topic	Sub-topics and contributions to this volume
Water governance	Water policies and institutions in the Region Khorezm, Uzbekistan (Kim and Hornidge, Chap. 9) Institutional responses to water scarcity, Guanting Basin, North China (Otto et al., Chap. 10) Handbook for context-specific institutional analysis (Monsees et al., Chap. 11)
Public information and participation	Participative scenario development as a method to integrate science and IWRM (Onigkeit et al., Chap. 12) Benefits and challenges of participation in applied IWRM research (Kirschke et al., Chap. 13)
Capacity Development	Lessons learned from a series of applied IWRM research projects (Ibisch et al., Chap. 14)
Decision support	Water related information system for the Mekong Delta (Kuenzer et al., Chap. 15) Application of a transboundary water resources simulation and planning tool for decision making in the Jordan River basin (Bonzi et al., Chap. 16) Approaches and functions of decision support systems in IWRM research projects (Stärz et al., Chap. 17)
Integrated land and water management	The use of treated wastewater for irrigation, evaluating site-specific soil suitability for the Jordan River basin (Schacht et al., Chap. 18) Water, land and fertilizer management in the Kharaa River basin, Mongolia (Hofmann et al., Chap. 19) Monitoring and modelling of water and solute fluxes in the Miyun basin, China (Meissner et al., Chap. 20) Dynamic land use change as challenge for IWRM, Central Brazil (Lorz et al., Chap. 21)
Pathways to sustainable water management	Reconceptualising Water Management in Khorezm, Uzbekistan (Hornidge et al., Chap. 22) Integrated Water Resource Management in the Zayandeh Rud basin, Iran (Mohajeri et al., Chap. 23) Measures for sustainable water resources management in the coastal area of Shandong Province, PR China (Kaden and Geiger, Chap. 24) Integrated urban water management in the Kharaa River Basin, Mongolia (Karthe et al., Chap. 25) Integrated Water Resources Management in Northern Namibia (Liehr et al., Chap. 26) Strategies and guidelines for sustainable water and land management under global change in the Jordan River basin (Tielbörger et al., Chap. 27) Challenges of implementing IWRM in the Lower Jordan Valley (Klinger et al., Chap. 28)

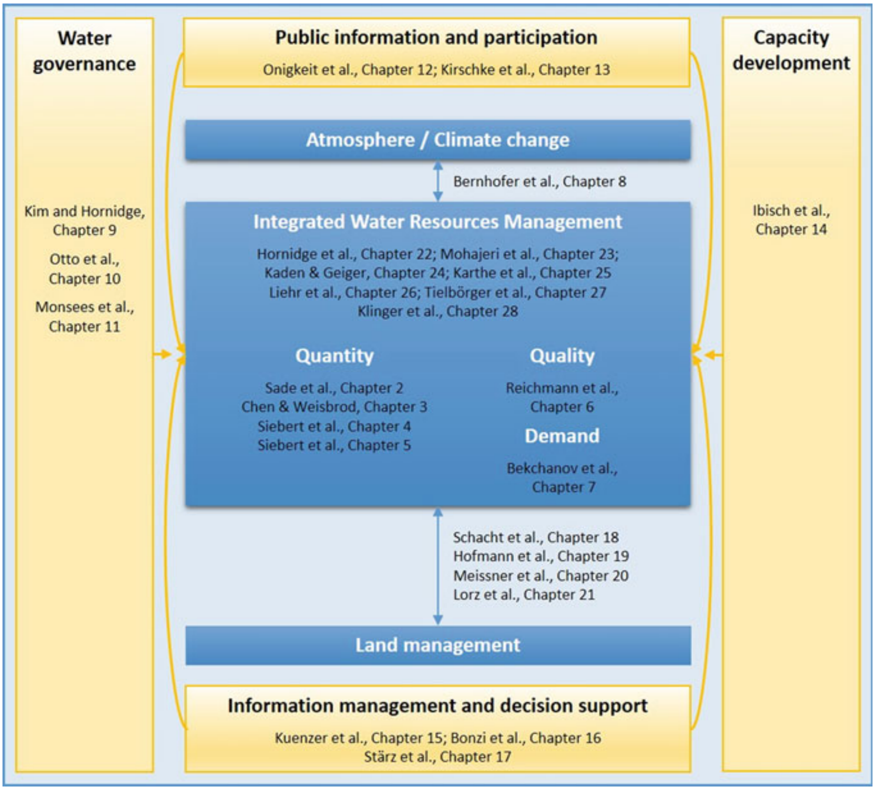

Fig. 1.1 Structural representation of the core elements of IWRM and contributions from the chapters of this volume (figure adapted from Kalbus et al. 2012)

1.3.1 Water Quantity

Precise knowledge of the quantities of available water resources within a region is an indispensable prerequisite for any management attempt. This includes an in-depth understanding of the components of the hydrological cycle and the variability over time and space within the individual region to be managed. All case studies presented in this book have been implemented in data-scarce regions. Monitoring networks were underdeveloped or entirely absent due to harsh conditions and large environmental gradients in the regions.

Siebert and colleagues emphasize the importance of combining different tools when analysing the water budget of the Dead Sea basin (Siebert et al., Chap. 5) or, in a different study when quantifying the water budget of the aquifer system in the Arabian Peninsula (Siebert et al., Chap. 4). They link four methodological approaches for the quantification of surface and groundwater influx to the Dead Sea: (i) direct and non-direct measurements and hydrological modelling to quantify surface runoff, (ii) chemical fingerprinting to characterize groundwater origin, flow, and evolution between recharge and discharge areas, (iii) thermal remote sensing to precisely identify the location and abundance of groundwater discharge and (iv) groundwater modelling to quantify discharge volumes. The authors showed that the combination of methods reduced data uncertainty when quantifying the different components of the water cycle.

In the same vein, Sade et al. (Chap. 2) claim that complex hydrogeological conditions in different areas of a catchment require the application of different statistical and modelling approaches. In their study on Lake Kinneret, Israel, two built-in catchment modules in the Water Evaluation and Planning (WEAP) tool, a model of karst hydrology (HYMKE), lake water balance calculations and artificial rain series based on a stochastic rainfall generation tool were used in order to assess water availability in the region.

Chen and Weisbrod (Chap. 3) look at the alteration and regulation of river flows in order to supply human needs. The concept of environmental flow assessments (Tharme 2003) was applied in the Lower Jordan River basin to determine the quality and quantity of water required for ecosystem conservation. The authors point out that the variability of natural stream flow quantity and timing is critical in determining water quality, temperature, habitat diversity and channel geomorphology. Thus, altering hydrological variability in rivers is ecologically harmful, and has chain reaction effects (Pahl-Wostl et al. 2013). Since there was no information available on ecological biodiversity and ecosystem services in the Lower Jordan River (Chen and Weisbrod, Chap. 3), the ecological flow requirements could be used as a precautionary principle in order to protect the river's ecosystem until relevant findings could be incorporated into an integrated restoration plan.

1.3.2 Water Quality

Water quality is a global concern as deterioration risks translate directly into social and economic impacts including human health and food security. As the water quality situation on a global scale is poorly understood, an important step is to develop a world water quality assessment framework to reduce the information gap and support decision-making and management processes (Bärlund et al. 2014). As agriculture accounts for about 70 % of global water use the potential risk of water quality impacts from agricultural return flows is significant (UNESCO 2012). Agricultural practices cause nutrient contamination, and the sector is the major driver of eutrophication, except in areas with high urban concentrations. Nutrient enrichment has become one of the planet's most widespread water quality problems (UNESCO 2009).

The impacts of flood events on the water quality in the Upper Jordan River was examined in the paper by Reichmann et al. (Chap. 6) in order to understand the spatial and temporal behaviour of nutrient transport in an agro-catchment. The understanding of nutrient sources, transport and retention was crucial in translating the result into the land and water management concepts presented by Tielbörger et al. (Chap. 27) for the Jordan River basin.

1.3.3 Water Demand

Integrated concepts for reducing water demand and using water more efficiently are especially needed in water scarce regions. Water scarcity threatens the livelihoods of billions of people as well as the functioning of ecosystems and valuable service provision by these ecosystems, particularly in arid and semi-arid regions (Rosegrant et al. 2002). The contribution by Bekchanov et al. (Chap. 7) takes a look at such a dry region, namely the irrigated drylands of Uzbekistan in Central Asia and analyses the direct and indirect water uses along the supply chain of agricultural products. The comprehensive analysis of efficient water use was conducted through an environmentally extended input-output model. Several options for increasing water productivity are discussed from a production and consumption perspective. The point is made here that a diversified strategy could enhance water productivity in Uzbekistan, not only during production, but also during the processing, consumption, and trading of commodities.

1.3.4 Climate Change

Which climate change information is needed and adequate for future water management decisions? This question is raised by Bernhofer and colleagues (Chap. 8) and analysed in three different river basins in Eastern Europe (Western Bug basin), the Arabian Peninsula and the region of Brasília (Brazil). Climate change was an IWRM relevant problem in all three regions, leading to increasing evaporation in irrigated agriculture in the Middle East, changing soil erosion and its accumulation in drinking water reservoirs in central Brazil or runoff in the basin of River Bug. The authors present a scheme for replacing measured data by climate model output and assessed model performance of global circulation models in the example regions. Finally, they conclude that there is no unique answer to the question of adequate climate change information, this depends on the specific IWRM problem setting.

1.3.5 Water Governance

Integrated water resources management is inherently complex and since the early 2000s the topic of water governance came into the global water discourse as a key issue (Mollinga 2008). Governance, in a broad sense, can be understood as "the art of governing" and embraces the full complexity of regulatory processes and their interaction. This is reflected in the United Nations Development Programme (UNDP) definition of water governance: "The term water governance encompasses the political, economic and social processes and institutions by which governments, civil society, and the private sector make decisions about how best to use, develop and manage water resources" (UNDP 2004).

The implementation of IWRM must be seen as both highly ambitious and very challenging to those involved in implementation (Mitchell 2005). The lack of progress in implementing IWRM projects is striking, especially in developing and transition countries and there is criticism on failing to adequately address the prevailing political and institutional circumstances at local, regional, national and transnational scales (Biswas 2004; Molle 2008; Butterworth et al. 2010). Monsees and colleagues present in Chap. 11 a methodological guideline, the IRS handbook (IRS is the acronym of the author´s institution Leibniz-Institute for Regional Development and Structural Planning), for analyzing political and institutional environments which was developed within this context and in order to give practical support on the ground to help tune management measures to fit the institutional contexts of implementation. "The IRS Handbook provides an analytical framework for refining projects in both planning and implementation phases, a methodological guide for utilization, an appendix of useful resources and general advice on the often difficult task of finding the necessary information for identifying relevant political processes and institutional arrangements" (Monsees et al., Chap. 11).

The paper by Kim and Hornidge (Chap. 9) describes how IWRM in contemporary Uzbekistan is locally operationalized and implemented in irrigation governance. The authors used a method of inquiry and analysis called "institutional ethnography" and discovered important points of misfit between the formal promises of IWRM-motivated policies and the actual outcomes of the policies for marginalized water users. Based on their analyses the authors could identify and formulate recommendations for suitable policy changes in existing documents which frame the organization of the national water management system.

In the study presented by Otto et al. (Chap. 10) a link is created between climate change adaptations in Northern China and existing institutional arrangements. The authors present the results of interviews with stakeholders from the Guanting Basin on the perceptions of climate change and adaptation needs. As in other studies, the authors observed weak coordination of water management across various government units and levels.