Lars Ribbe · Andreas Haarstrick ·
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Towards Water Secure Societies

Coping with Water Scarcity and Quality Challenges

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About This Issue

This book is a collection of papers, that were presented in the framework of the International Conference Series: Water Security and Climate Change (WSCC) (https://watersecurity.info/). The thematic scope of the volume is on water scarcity including droughts and water quality challenges.

About Conference Series: Water Security and Climate Change (WSCC)

Water Security as a 21st Century Challenge for Science, Politic and Society

Water resources form a pivotal base for economic development, social wellbeing and environmental integrity. However, achieving water security in the face of rapid change—in populations, economies, geopolitics and climate—is one of the major challenges faced by society today, at both a global and local level. More efficient use and integrated management of water are critical to addressing the growing demand for water and the increasing frequency of droughts and floods resulting from climate change. However, according to the *"Sustainable Development Goals Report 2019"* of the United Nations most countries are unlikely to reach full implementation of integrated water resources management by 2030 (United Nations, 2019).
Furthermore, attaining water security is a multidimensional challenge that implies a range of issues from protection of the environment and water quality, coping with scarcity to flood control. These diverse facets of water management require interdisciplinary approach including environmental, engineering and social sciences as well as cross sectoral cooperation between business, civil society and government.
In response to these requirements, the Conference Series on "Water Security and Climate Change" (WSCC—https://watersecurity.info/) was initiated in 2016 by the international network of universities comprising the Centers for Natural Resources and Development—CNRD (TH Köln—https://www.cnrd.info/), the International Network on Sustainable Water Management in Developing Countries—SWINDON (TU Braunschweig—

http://www.exceed-swindon.org/) and the Food Security Center—FSC (University Hohenheim—https://fsc.uni-hohenheim.de/en/home).
The WSCC aims to bring together scientists, policy-makers and stakeholders from around the world and from various sectors and disciplines to discuss the diverse facets of water security in dynamic environments and its relation to climate variability and change. The first WSCC took place in 2016 in Bangkok (Thailand), and subsequently conferences were organized in 2017 in Cologne (Germany), 2018 in Nairobi (Kenya) and in 2019 in San Luis Potosí (Mexico).

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Editors and Contributors

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Lars Ribbe is a Professor for integrated land and water resources management and Dean of the Faculty of Spatial Development and Infrastructure Systems at the TH Köln (University of Applied Sciences). Holding a PhD in the field of hydro-informatics (Friedrich Schiller University Jena), his current work in research and teaching is river basin assessment, modeling, and management and he is specifically interested in developing knowledge systems helping decision-makers to cope with prevailing water resource-related challenges. He is actively involved in promoting a global network of Integrated Water Resources Management (IWRM) master programs and is the lead of the Exceed project Centers for Natural Resources and Development (CNRD).

Andreas Haarstrick has studied Chemistry at the Technische Universität Braunschweig in Germany (1983–1989) and received his doctorate in 1992 in the field of biotechnological up- and downstreaming processes of biopolymers. Since 2006, he is Professor of Bioprocess Engineering at the TU Braunschweig. His teaching and research interests cover modeling biological and chemical processes in heterogeneous systems, development of models predicting pollutant reduction in and emission behavior of landfills, growth kinetics at low substrate concentrations under changing environmental conditions, Advanced Oxidation Processes (AOP), and groundwater management. Since 2012, he is the Managing Director of the exceed-Swindon project dealing with the sustainable water management in developing countries (www.exceed-swindon.org).

Mukand Babel is a Professor of Water Engineering and Management and the Chair of Climate Change Asia initiative at the Asian Institute of Technology (AIT), Thailand. He was the Chair of Academic Senate of AIT. He has been a Visiting/Honorary Professor at the University of Exeter, UK; Kyoto University, Japan; University Teknologi Mara, Malaysia; and Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), India. His professional experience in teaching, research, and consultancy spans over 35 years mainly in Asia. He has been a Member of the Executive Committee, Asia Pacific Division of IAHR. Similarly, he was a member of the Executive Board of IWRA (2016-18) and a Board

Member of the Asia Water Council. With over 250 publications in international refereed journals, books, and book chapters and conference proceedings, he conducts interdisciplinary research relating hydrology and water resources with economic, environmental, and socioeconomic aspects of water to address diverse water problems and issues including water security assessment, water-energy-food nexus, and climate change impact and adaptation in water sector.

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Introduction

Justyna Sycz and Lars Ribbe

1 Water Scarcity in the International Development Discourse

1.1 Water Resources Under Pressure

The United Nations Water (UN-Water) defines water security as "the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water (…)" (UN-Water 2013). In terms of quantities, this definition encompasses both water scarcity and water abundance. The presented book focuses on water scarcity where the water demand excesses the water availability.

Stable distribution systems to serve the water supply has been a central aspect of all development and urbanization processes since ancient times. The first civilizations were formed on the banks of rivers: Ancient Egyptians on the Nile, the Mesopotamians in the Fertile Crescent on the Tigris/Euphrates Rivers, the Ancient Chinese on the Yellow River, and the Ancient Indian on the Indus (Terje and Coopey 2010). At present, 158 of 239 national capitals are located along rivers with access to surface water (own study). The continuing availability of water is a basis for food and energy and, industry, economic growth, as well as human health and environment. Hence, sustainable access to required quantities of acceptable quality water has been and will continue to be a pivotal condition for human development and welfare.

However, currently, the world's water resources are under considerable pressure due to both climatic as well as anthropogenic factors. Global water withdrawal had increased at a rate of 15% per decade between 1960 and 2010 as a function of population growth, economic development, and changing consumption patterns (Wada et al. 2016; WWDR 2020). Moreover, water abstractions are expected to increase by some 55% between 2000 and 2050, mainly in conjunction with growing demands from manufacturing (+400%), thermal power generation (+140%), and domestic use (+130%) (OECD 2012).

As demand rises, freshwater becomes increasingly scarce. Organic waste, fertilizers, pesticides, and emerging contaminants significantly influence water quality reducing the availability of usable resources (WWDR 2020). While the hydraulic infrastructure developed over the late 19th and 20th century have allowed economic development and enabled large-scale agriculture (Schmandt et al. 2013) it has led to the overexploitation of surface and groundwater resources with continuously declining water levels (Savenije et al. 2014). Climate change is expected to aggravate the situation with predicted

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increases in temperature causing sea level rise and saltwater intrusion as well as changes in the frequency and severity of precipitation and associated droughts (IPCC 2014). According to FAO increasing drought events have affected more people worldwide in the last 40 years than any other natural hazard (FAO date not defined nd).

Taking into account the monthly variation of water availability, about two-thirds of the global population—"4.0 billion people"—are currently living in areas under conditions of severe blue water scarcity for at least for 1 month of the year (Mekonnen and Hoekstra 2016, p. 1). In these areas, the ratio of the blue water consumption to total blue water availability is in the range of 2.0 or higher (Mekonnen and Hoekstra 2016). The demand, which more than two-fold exceeds the supply results in conflicts between users, the irreversible depletion of groundwater, dry rivers, and negative impacts on the environment. The number of people living under conditions of severe blue water scarcity for at least 1 month of the year is expected to increase to 4.8–5.7 billion people by 2050 (Burek et al. 2016).

1.2 Water Scarcity Gains Attention in the International Development Discourse

In the global development discourse, the concern about water as a pivotal base for economic growth, social well-being, and environmental integrity that may become scarce, dates back to the first intergovernmental conference on water: the United Nations Water Conference in Mar del Plata in 1977. Although the emphasis was placed on water supply and sanitation while water scarcity itself was not a major concern, the final conference report called for urgent action to avoid expected water crisis in the face of "the alarming increase in world population, the enhanced requirements of industry, the needs of urban concentrations and the often irrational utilization of natural resources, and increasing pollution." (UN 1977, p. 96).

The next milestone in the discourse was marked by the Dublin Statement on Water and Sustainable Development. The statement was adopted on January 31, 1992 during a meeting of water experts that took place at the International Conference on Water and the Environment (ICWE) in Dublin, Ireland (ICWE 1992). In contrast to the conference in Mar del Plata the key message from Dublin was not a warning but rather a recognition that scarcity and misuse of freshwater already pose a serious threat to sustainable development and protection of environment. To address the emerging water crisis, the Dublin Statement set out recommendations for action at local, national, and international levels based on four guiding principles: "Fresh water is finite and vulnerable (…)"; "Water development and management should be based on a participatory approach (…)"; "Women play a pivotal role as providers and users of water (…)."; Water has an economic value (…) (ICWE 1992, p. 4).

The Dublin Principles led the foundation for the concept of "integrated water resources management" (IWRM) that offers solutions to the water crisis by linking the social and economic development with protection of natural ecosystems (ICWE 1992).

Consequently, water and its governance have gained increased attention as a policy concern resulting in numerous initiatives to support integrated water management for sustainable development.

At the UN Conference on Environment and Development held in 1992 in Rio de Janeiro, world leaders adopted the Agenda 21, a global action plan for sustainable development. The Chapter 18 of the Agenda 21 set a framework for integrated water management with the overall objective to "make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases" (UN 1992).

In 1996, two important global organizations were established with the mission to coordinate implementation of integrated water resources management: the World Water Council (WWC) and the Global Water Partnership

(GWP). While the WWC focuses on awareness promotion and building of political commitment (WWC 2021), concentrates the GWP on the implementation of IWRM concepts at the operational levels (GWP 2021).

In 1997 the WWC launched the first World Water Forum (WWF) bringing together participants from all levels and areas, including politics, academia, civil society and the private sector around the world to collaborate and mobilize action on critical water issues. Since 1997, the WWF takes place regularly every three years.

The next significant milestones in the global water discourse placed the United Nations (UN). In 2000 the organization launched the Millennium Development Goals (MDGs) for the year 2015 addressing water aspects in the Target C of the Goal 7: "Ensuring environmental sustainability". The target aimed to reduce until 2015 by half the proportion of worlds population without access to drinking water and sanitation (United Nations, 2000). In 2015, the UN recognized water as an integral part of all human development and ecosystem needs by formulating the Sustainable Development Goal 6 (SDG 6): "To ensure availability and sustainable management of water and sanitation for all by 2030" (UN 2015).

The progress toward SDG 6 was recognized by the UN in 2020 as being "way off track" (UN-Water 2020). In response to this concern, *The SDG 6 Global Acceleration Framework* was launched to speed up the progress (UN-Water 2020).

The water governance and the evolving challenge of water scarcity were intensively discussed in an academic and political context after the meeting in Mar del Plata in 1977. However, it has been the only United Nations Water Conference until today. Indeed, the first conference since 1977 is scheduled for 2023 in New York (UN-Water 2020).

1.3 Paradigm Shift in Water Management

The milestones of the global development discourse on water mark a paradigm shift in the way to manage and think about water. Until the 1970s, the field of water management was known as "water resources development" with the guiding paradigm that "water is a resource to be exploited" (Savenije and van der Zaag 2008; Savenije et al. 2014). The main challenges of water management were to enforce water supplies. Consequently, the efforts to administer water and access aimed at developing technologies and large-scale, physical infrastructures, such as dams and reservoirs. After the conference in Mar del Plata in the 1980s, the term "water resources development" was progressively replaced by the term "water resources management" (Savenije et al. 2014). The change of terms reflects the paradigm shift from the notion "water is a resource to be exploited" to the recognition that "water can be overexploited" and becomes scarce. Accordingly, the challenges of water management changed from enforcing water supplies to avoiding overexploitation and establishing a balance between water availability and demand to fulfill all needs of humans and ecosystems.

To tackle the new challenges, in the 1990s emerged the concept of "integrated water resources management" (IWRM). The IWRM concept offers solutions to the current water crisis by promoting the coordinated development and management of water. This is ensured through linking water with other vital resources such as land, considering the entire hydrological water cycle together with human interventions, and promoting a balance between water use for socio-economic well-being and for maintaining the ecosystem functions (Global Water Partnership, 2000).

The changing challenges of water management are also reflected in the internationally agreed global goals on water. The Target C of the Millennium Development Goal 7 aimed to reduce until 2015 by half the proportion of the worlds population without access to drinking water and sanitation (United Nations 2000). While MDG 7, Target C, focused only on sanitation and drinking water, the 2030 Agenda for Sustainable Development adopted by the United Nations in 2015 formulated the Sustainable Development Goal 6 "Clean Water and Sanitation" with eight global targets covering the complete water cycle: From sanitation and drinking water supply (Targets 6.1 and 6.2), water quality (6.3), water-use efficiency and scarcity (6.4), IWRM (6.5) to the protection of ecosystems (6.6) with two additional targets on capacity-building (6.a) and participation (6.b) (United Nations 2015).

Figure 1 summarizes the above-described milestones of addressing the water crisis in the development discourse and the parallel paradigm shift in the way in which to manage and think about water.

1.4 Water Scarcity is Local

Since 2015, the World Economic Forum has regularly listed water crisis as one of the five main threats to livelihoods in the current times in its annual Global Risks Report (WEF 2020).

Although water crisis is identified as a high global risk, water scarcity is a local phenomenon. At the global level, the "planetary boundaries" for freshwater availability have not been crossed (Steffen et al. 2015) and on annual basis sufficient

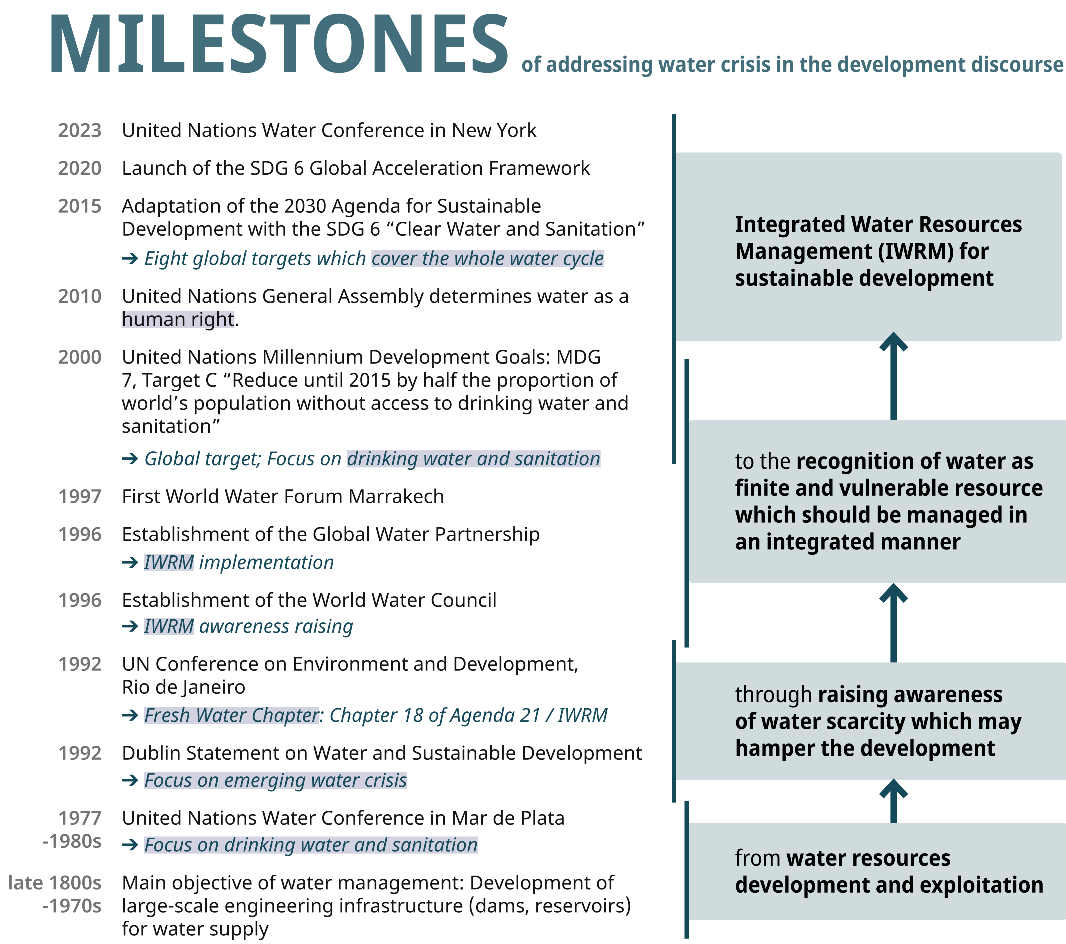

Fig. 1 Milestones of addressing water crisis in the development discourse

freshwater is available to meet the increasing water demand. However, the demand for and availability of water fluctuate in spatial and temporal variations as a result of natural hydrological variability (Mekonnen and Hoekstra 2016; Liu et al. 2017), socioeconomic changes, or as a consequence of inadequate planning and management approaches with lacking institutional capacity to provide the necessary water services and develop infrastructure to control the storage, distribution, and access to water resources (FAO 2012; Jaeger et al. 2013). This leads to water scarcity in several parts of the world during specific times of the year.

Hence, understanding water scarcity in the context of its regional dynamics is crucial for formulating adequate national policies and applying suitable local management strategies as well as technical and infrastructural solutions.

1.5 Research Demand at Local Scales: Water Scarcity Addressed in This Volume

In response to the evolving perception of water crisis in the development discourse the topic has also gained increasing attention in research. This is demonstrated in the rapidly growing number of publications after the 1992 conference in Dublin. For the overarching term of "water crisis" Google Scholar records 289.000 publications between 1900 and 1992 and 1.780.000 publications for the time between 1993 and 2020. However although the number of scientific publications has significantly increased since 1992, there remains an urgent demand to conduct extensive research on emerging water scarcity challenges at regional scales, document these studies, compare the results looking for the best solutions and disseminate them.

In response to this demand, this volume aims to bring regional cases to the center. It provides a balanced overview of contributions that reflect the interdisciplinary and context-specific characteristics of water scarcity and quality including its environmental, technological, and socioeconomic aspects. The book compromises thirteen studies from Africa, South-East Asia, Middle East, Chile, Russia, and Germany conducted by hydrologists, environmental and chemical engineers, agronomists, and social scientists. The thematic spectrum ranges from water security assessment framework, through water treatment technologies, wastewater reuse, adaptation to water scarcity in agriculture to the monitoring of sediment concentration in river ecosystems.

The following section includes a description of the main content of the chapters.

2 Main Content of the Chapters

2.1 Water Security Assessment Framework

The first chapter sets the scene and introduces a methodology for water security assessment. Achieving water security is a complex pathway that requires a holistic understanding and treatment of the interdisciplinary nature of water resources. This covers hydro-climatic, institutional, and socioeconomic aspects as well as spatial and temporal variability in water demand and availability determined by natural boundaries. Considering this interdisciplinary nature of water, Nguyen Mai Dang et al. in Chap. 2 argue that water security assessment has to be guided by an integrated approach applied not at local or national level but rather at the river basin scale. Accordingly, the authors develop an operational framework for assessing water security with five dimensions: water availability, water productivity, water-related disasters, watershed health, and water governance. Furthermore, they validate the framework through the application for the Red—Thai Binh River Basin in Vietnam.

2.2 Wastewater Treatment and Reuse

Safe wastewater reuse is recognized as a sustainable and efficient solution to reduce water stress (FAO 2020; Rodriguez et al. 2020). However, practical implementation of this method is still lacking due to both: sociocultural and political barriers as well as missing technologies to deal with the challenging treatment of emerging pollutants (UN 2018). The authors of the chapters from 3 to 8 investigate how to overcome these barriers.

Suha Al-Madbouh et al. in Chap. 3 address sociocultural dimensions of wastewater reuse for agriculture. Although the practice can significantly alleviate water stress especially in the arid and semi-arid zones, its application often meets strong opposition from farmers (UN 2018). The authors explain that understanding farmers reasons for opposition is crucial for developing solutions addressing implementation barriers. Accordingly, they design a conceptual model for examining farmers' opinion of and willingness to reuse wastewater and apply it in the Wadi Al-Far`a Watershed in Palestine, one of the most important catchments and agricultural areas in the West Bank (EQA 2006).

Chapter 4 addresses technological challenges faced by the treatment of agro-industrial wastewater. Alcaraz-Gonzalez et al. describe the process of anaerobic digestion—a frequently applied biological method to treat agro-industrial effluents with the production of biogas as a by-product. Currently, the search for optimal operating conditions to enhance the production of biogas and ensure the best treatment quality lies at the center of research interests (Karlsson et al. 2014). The chapter contributes to this research by exploring how the latest instrumentation, control and automation approaches in wastewater systems can increase the efficiency of anaerobic digestion processes.

Chapter 5 addresses the water treatment challenges in the Rosetta Branch in the Nile Delta in Egypt. Several studies have documented poor water quality caused by the discharge from agricultural drainage transported to the Rosetta Branch through Tala Drain (Mostafa 2015; El-Sayed et al. 2020). The most applied wastewater treatment method in the Tala Drain is the treatment using dilution—a method that involves mixing freshwater with drainage water. A. A. Hassan et al. in Chap. 5 investigate how the dilution process affects water quality, identify quality gaps, and based on this knowledge they recommend additional water treatment methods.

While the previous chapters focus on agricultural wastewaters, chapters 6-8 bring municipal and industrial effluents to the center. Rögener in Chap. 6 provides a general overview of emerging challenges for the treatment of municipal and industrial wastewaters and describes the most applied treatment methods. Chaps. 7 and 8 trace these challenges from a regional perspective. In Chap. 7, Rögener offers a holistic comparison of the municipal wastewater treatment sectors in Germany and Russia comprising technological, institutional, and climatic factors. Based on the comparison results, the author indicates the *Membrane Bioreactor Technology* as an adequate method for both countries to tackle emerging municipal wastewater treatment challenges.

In Chap. 8 Eyüp Debik brings industrial pollutants to the center and examines the most adequate wastewater treatment methods for pollutions coming from the dominant industries in Turkey.

2.3 Evidence-Based Adaptation to Water Scarcity in Agriculture

As the largest water consumer accounting for 70% of withdrawals globally (FAO 2020) and for up to 90% in many developing countries (UN 2018), agriculture is especially vulnerable to water scarcity and droughts requiring urgent adaptation measures. Currently, thanks to research and practical experience a wide portfolio of adaptation strategies is available ranging from water harvesting, storage, and reuse through efficient irrigation technologies or increasing crop productivity. However, the selection of an adequate strategy from the portfolio always depends on local conditions and should be evidence-based. This includes a profound understanding of causes for water scarcity, adaptation capacities of local communities, and information about resources availability and demand. The authors in Chaps. 9–13 contribute to gathering this knowledge through five case studies from Ghana, Burkina Faso, Bangladesh, Chile, and Vietnam.

Abdul Rauf Zanya Salifu et al. in Chap. 9 investigate vulnerability and adaptation capacities to water scarcity of groundnut farmers in West Ghana depending on age, gender, economic status, and ethnic origins. The authors argue that understanding such socioeconomic determinants is crucial for selecting demand-oriented adaptation measures. They find that high land tenure insecurity and limited access to credit facilities faced by women and non-natives within the study area as well as a lack of knowledge about technological adaptation possibilities are the main barriers to water scarcity adaptation.

One of the main reasons for reduced water availability for agriculture in the coastal zones of Bangladesh is not the decreasing precipitation but rather the saltwater intrusion. Hence, Md Arman Habib et al. in Chap. 10 evaluate the progress of saltwater intrusion in the southwest coast of Bangladesh and its impact on freshwater availability for agricultural production. The chapter concludes by recommending integrated adaptation methods like the cultivation of saline-resistant crops combined with sullage water reuse and mulching technique for reducing the effects of soil salinity.

Mwenda Borona et al. in Chap. 11 investigate how staple cereals cultivated in the Sahel Region of Burkina Faso respond to climatic variability and changes in water availability at inter-annual and inter-decadal levels. The authors conclude that the study results are a crucial knowledge source for adapting to water scarcity through changes in the planting calendar and cultivation of water stress-resilient crops.

We close this section with two contributions dedicated to drought forecasting and monitoring. Drought events are a recurrent phenomenon not only in water scare arid and semi-arid climates but also in traditional water-rich tropical zones (Erfanian et al. 2017; FAO 2019) affecting more people globally than any other natural hazard (Wilhite and Glantz 1985; FAO nd). Agriculture as the main water user is the most strongly affected sector absorbing up to 80% of all direct impacts (FAO nd).

Experience shows that the impacts of drought can be mitigated through timely drought forecasting and pro-active drought management (Wilhite et al. 2014; FAO 2019). However, contrary to visible and immediate flood, drought is a creeping phenomenon resulting from complex interactions among meteorological anomalies, land surface processes, and human activities that make it very difficult to forecast (Andreu et al. 2015; Hao et al. 2018). Currently, the development of new methods and use of technological innovations, e.g., satellite imagery or land surface and crop model simulations for drought forecasting and monitoring lie in the center of drought research.

In line with the above, we selected two articles that contribute to this research focusing on two different climatic zones: one in the semi-arid Chile and another one in tropical Vietnam. Oertel et al. in Chap. 12 explore how results gained by standardized drought indices can be used for operational drought forecast in the Maipo River Basin in semi-arid Chile. Trung Tuan Luong et al. in Chap. 13 evaluate the application of remote sensing images for water balance monitoring in small reservoirs of Central Vietnam and describe how to use the water storage data to forecast water shortages for irrigated areas serviced by monitored reservoirs.

2.4 River Ecosystems: Monitoring of Sediment Concentration and Transport Using Satellite-Based Products

While previous chapters discuss the water availability challenges for agriculture and human use, the last chapter brings the river ecosystems to the center and covers the topic of sediments concentration and transport. Suspended sediments in rivers are an important parameter for sustainable river management. However, traditional in situ measurement is very challenging in terms of time, cost, and spatial coverage. New technologies such as satellite-based products

Table 1 Main content of the Chaps. 2–14

Thematic block	Content	Spatial scale
Water security	*Chapter* 2: Development of a holistic water security assessment framework	*River Basin*: The Red—Thai Binh River Basin, Vietnam
Wastewater treatment and reuse for agriculture	*Chapter* 3: Development of a conceptual model to assess farmers perceptions of wastewater reuse	*River Basin*: Wadi Al-Far`a Watershed, Palestine
	Chapter 4: Maximize biogas production in anaerobic degradation processes applying instrumentation, control, and automation approaches	General overview
	Chapter 5: Assessing the impacts of wastewater treatment using dilution on water quality; development of a water quality assessment framework	*River Basin*: Rosetta Branch and Tala Drain in the Nile Delta, Egypt
Municipal and industrial wastewater treatment and reuse	*Chapter* 6: Overview of upcoming challenges for industrial and municipal wastewater treatment	General overview
	Chapter 7: Municipal wastewater treatment and evaluation of *Membrane Bioreactor Technology* as a treatment method to remove microplastics, micropollutants, and multiresistant germs	*Country level*: Russia, Germany
	Chapter 8: Identifying the most adequate wastewater treatment methods for pollutions coming from the dominant industries in Turkey: the textile, poultry slaughterhouses, and olive processing industries	*Country level*: Turkey
Water scarcity and agriculture	*Chapter* 9: Exploring interlinkages between socioeconomic characteristics of farmers and their vulnerabilities and adaptation capacities to water scarcity	*Local level*: Lawra and Nandom Districts, Ghana
	Chapter 10: Evaluating the impacts of salinity driven freshwater scarcity on agricultural production and livelihoods	*Local level*: Tala and Shyamnagar Upazilas of Satkhira district in the southwest part of Bangladesh
	Chapter 11: Investigating how different staple cereals respond to climate variability at an inter-annual and inter-decadal level	*Local level*: Cassou, Ziro Province in Southern Burkina Faso
	Chapter 12: Using multivariate standardized drought indices to identify drought events	*River Basin*: Maipo River Basin in semi-arid Chile
	Chapter 13: Using remote sensing images to estimate water balance in irrigation reservoirs and assess water availability for agriculture	*Local level*: Central Vietnam
River ecosystems and sediment concentration	*Chapter* 14: Monitoring sediment transport and concentration using satellite-based products	*River Basin*: Lower Ganges River in Bangladesh

offer a range of alternative methods to collect this data. The last chapter of the book investigates the applicability of open-access Landsat Enhanced Thematic Mapper (ETM+) images to investigate the sediment concentration in the *Lower Ganges (Padma) River*.