Water Resources Management: Innovation and Challenges in a Changing World

Article *in* Water · April 2017

DOI: 10.3390/w9040281

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Editorial

Water Resources Management: Innovation and Challenges in a Changing World

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Academic Editor: Athanasios Loukas
Received: 13 February 2017; Accepted: 12 April 2017; Published: 17 April 2017

Abstract: The prudent management of water resources is essential for human and ecosystem well-being. As a result of ever escalating and competing demands, compounded by pollution and climate change-driven impacts, available freshwater resources are becoming increasingly stressed. This is further compounded by poor management practices and the unsustainable extraction of water. Consequently, many parts of the world, particularly urban areas, are facing water shortages. Therefore, water resources management requires a clear understanding of the ongoing challenges and innovative approaches. This Special Issue provides the platform for the dissemination of knowledge and best practices to strengthen the management of our precious water resources into the future.

Keywords: water resources management; water allocation; soil-water interaction; climate change; surface water; groundwater

1. Introduction

Globally, water resources are becoming increasingly vulnerable as a result of escalating demand arising from population growth, the need for increased food production, expanding industrialisation due to rising living standards, pollution due to various anthropogenic activities, and climate change impacts [1–3]. Due to water scarcity and poor water quality, it has been predicted that by 2050, at least one in four people are likely to live in a country with a shortage of freshwater. Consequently, ensuring availability and sustainable management of water has been adopted as part of the United Nations Sustainable Development Goals, Transforming Our World: the 2030 Agenda for Sustainable Development [4].

The significance of the competition between the water demand for food production and other consumptive uses needs to be viewed in light of the fact that, according to the United Nations [5], it will be necessary to produce 60% more food globally and 100% more in developing countries by 2050. This needs to be viewed in the context that currently, about 70% of freshwater resources are used for agriculture [6]. Furthermore, the predicted impacts of climate change on water resources are also significant. Based on long-term weather records and future climate projections, water resources are expected to be highly vulnerable, affecting water availability and quality, and in turn the reliability of supply for various consumptive uses [7]. This situation is further exacerbated by poor management practices and the unsustainable extraction of water [5]. Consequently, many regions around the world, particularly urban areas, are becoming increasingly water stressed and conflicts over access to water are becoming ever more common [3]. To overcome the significant challenges fundamental to the management of water resources, cutting-edge knowledge, innovative approaches and an in-depth understanding of the inherent scientific, economic, social and environmental issues is imperative.

This Special Issue has provided the platform for researchers and practitioners to contribute to the wide dissemination of knowledge and best practices to strengthen the management of our precious water resources into the future. The papers contributed to this Special Issue fall into four broad categories: modelling of surface and groundwater resources under complex scenarios including water allocation; understanding soil-water interactions; impacts of climate change on water resources; and water supply.

2. Contributions

The publication by Chinnasamy et al., Understanding Groundwater Storage Changes and Recharge in Rajasthan, India through Remote Sensing [8], provides a study of how temporal and spatial data collected using remote sensing platforms can be utilized innovatively to bridge current knowledge gaps in relation to groundwater resources. The importance of such approaches needs to be viewed from the fact that the management of groundwater resources needs to take into account, hydrogeology, the agro-climate and demand. However, the development of policies at agro-climatic zone levels is commonly constrained by the paucity of temporal data. This paper specifically focuses on the Gravity Recovery and Climate Experiment (GRACE) mission in 2002, which now makes it possible to obtain frequent data at broad spatial scales and use it to examine past trends in rain-induced recharge and groundwater use. This in turn would help in the identification of suitable groundwater recharge methods and sites where there is potential to achieve enhanced groundwater recharge, thereby improving water availability for various consumptive uses.

Wang et al. in their paper, Water Resources Compound Systems: A Macro Approach to Analysing Water Resource Issues under Changing Situations [9], provides an innovative approach for Integrated Water Resources Management (IWRM), to enhance the sustainability of regional water resources. Using four cities in China, namely, Beijing, Fuzhou, Urumqi, and Lhasa, with diverse geographical, climatic, spatial and demographic characteristics as case study sites, the authors demonstrate how a water resources system can be considered as a water resources compound system that constantly changes under the combined action of development, resistant, and coordination mechanisms. These different subsystems which comprise the compound system have different development and resistant mechanisms, which are influenced by a range of influential factors inherent to a specific region. Therefore, comparing these mechanisms with the water quotient provides the platform for identifying appropriate measures for the sustainable management of water resources.

The publication by Ding et al. [10] is in the area of water allocation, which is a critical issue facing water resources managers, as the demand for freshwater resources can outstrip supply. Water allocation demands in-depth assessment to underpin prudent decision-making for determining the appropriate mechanisms for distributing water among different regions, sectors and users. Over the years, a range of methodologies have been explored which can be broadly classified as centralised and decentralised approaches. Each approach has its inherent advantages and limitations. The paper, which is titled Agent Based Modelling for Water Resource Allocation in the Transboundary Nile River, presents a parallel evolutionary search algorithm to introduce a mechanism in redistributing the central planner revenue value among the competing agents based on their contribution to the central solution as the basis for water allocation among competing demands. The case study is the Nile River basin, where broadly there are eleven competing users represented as agents in various sectors with upstream-downstream relationships and different water demands and availability.

The publication by Nava et al., Existing Opportunities to Adapt the Rio Grande/Bravo Basin Water Resources Allocation Framework [11], further explores the challenges and opportunities for innovation in the area of water allocation. The case study area is the Rio Grande/Bravo (RGB) Basin, where a transboundary framework exists between the United States and Mexico for water allocation.

However, the ever-increasing demands for water cannot be met by the existing framework. The paper explores opportunities for an improved management regime to readdress past issues and better balance competing demands.

Soil-water interactions are important for water resources management. Unfortunately, significant knowledge gaps still exist. The paper by Wu et al., titled Constraining Parameter Uncertainty in Simulations of Water and Heat Dynamics in Seasonally Frozen Soil Using Limited Observed Data [12], contributes new knowledge in relation to the water and energy balance in seasonally frozen soils for a better understanding of hydrologic processes and water resources management in cold regions. The investigations were undertaken using the Coup Model combined with the generalized likelihood uncertainty estimation (GLUE) method with uncertainty assessment of the key parameters which influence modelling outputs. The study outcomes confirmed that the Coup Model together with uncertainty-based calibration method provides a technically robust approach to understanding seasonal changes in hydrology and energy processes in cold regions where only limited data is available.

The publication by Wichelns, titled Managing Water and Soils to Achieve Adaptation and Reduce Methane Emissions and Arsenic Contamination in Asian Rice Production [13], contributes to bridging a knowledge gap in managing soil-water interactions to mitigate climate change impacts as well as to reduce greenhouse gas emissions and toxic metal contamination of food crops. These issues directly contribute to the sustainable management of water resources for human well-being. The review paper focuses on deltaic areas which play a primary role in rice production in South and Southeast Asia. The millions of farmers whose livelihoods are dependent on rice cultivation in these areas are vulnerable to sea level rise as a result of climate change, flood inundation and saline water intrusion into surface and groundwater resources. Among the adaptation measures discussed are improved soil and water management practices, which will also contribute to reducing methane generation and release from rice fields and the uptake of arsenic in rice plants, thus addressing an important public health issue.

The impact of climate change on stream flow characteristics is a key issue in relation to the management of water resources into the future. Also, it is not only climate change that can have a profound impact on water resources. The impacts of water harvesting and impoundments can be even more significant in terms of water availability. The publication by Kim et al., titled Assessment of the Impacts of Global Climate Change and Regional Water Projects on Stream Flow Characteristics in the Geum River Basin in Korea [14], is very timely in this regard. The authors have assessed the impacts of water harvesting (termed as an internal factor) and climate change impacts (termed as an external factor) on the third largest river in Korea using the rainfall runoff model SWAT (Soil and Water Assessment Tool). The quantitative assessment of the variability of runoff during two periods into the future (2011–2050 and 2051–2100) has been compared to the reference period (1981–2006). It was found that climate change is likely to lead to an increase in runoff, while three weirs which have been constructed across the river for water harvesting will contribute to an increase in the minimum discharge and a decrease in the maximum discharge. It was concluded that the impact of the weirs on the runoff characteristics of the river would be more significant than that from climate change.

The publication by Flores-López et al., titled Modeling of Andean Páramo Ecosystems Hydrological Response to Environmental Change [15], provides an in-depth case study of important wetlands which are contiguous across Peru, Bolivia, Ecuador, Colombia and Venezuela. These wetlands are a critical water resource to the entire region and to a large, directly dependent population. However, the hydrologic processes of these wetlands are not well understood within the larger hydrologic system. This acts as a significant impediment to the development of mitigation strategies to counteract the rapid environmental changes anticipated due to population growth and climate change. Using scenarios developed with stakeholder participation, modelling has been undertaken to study river flow, reservoir water levels, and demand coverage for downstream users when the wetlands are subjected to environmental changes such as temperature, precipitation, and land use. The study outcomes revealed that, though temperature and precipitation will influence water production, land use will be a primary driver of hydrologic changes.

The final paper is on water supply. Though it does not strictly fall within the scope of water resources management, water for various consumptive uses has a direct impact on the management of freshwater resources. Therefore, it is appropriate that a detailed overview of water use and reuse forms an integral part of this special issue focusing on water resources management. The publication by Sapkota et al. titled, An Integrated Framework for Assessment of Hybrid Water Supply Systems [16] provides that appropriate final segment to this special issue. As the authors have pointed out, the use of decentralised water supply systems are increasingly being adopted in combination with centralised water supply systems. This approach is based on the premise that the use of alternative water sources such as stormwater and wastewater at local scales can both extend the capacity of existing centralised water supply infrastructure and improve resilience to changing climatic conditions. However, this can have an impact on stormwater flows and, in turn, impact surface water resources. This paper presents a framework to assess the interactions between decentralised and existing centralised water supply systems using several tools, including water balance modelling, contaminant transport modelling and multi-criteria decision analysis to investigate the impacts due to changes in quantity and quality of wastewater and stormwater flows.

3. Conclusions

This collection of papers illustrates the diversity of issues inherent in the management of water resources, the challenges to be overcome and the knowledge gaps to be bridged. It also highlights the universality of the issues identified and the need for international initiatives for knowledge creation and best practice development. Taken together, the key challenges identified in the management of water resources are climate change, and increasing water demand due to population growth and agricultural production. The papers highlight the need for innovative approaches in the face of data paucity. The various data collection platforms such as satellite imagery and advanced analytical approaches provide solutions. Furthermore, the lack of data should not constrain decision-making if the associated uncertainties in analysis outcomes are clearly identified. In the context of prudent water resources management, the knowledge gaps are many and it is hoped that this special issue has contributed to bridging some of these gaps.

Acknowledgments: The authors who also served as Guest-Editors of the special issue wish to thank the Journal Editors for their support, the authors of the papers without which this special issue would not have been possible, and the referees who contributed to improve the quality and technical rigour of the published papers.

Conflicts of Interest: The authors declare no conflict of interest.

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