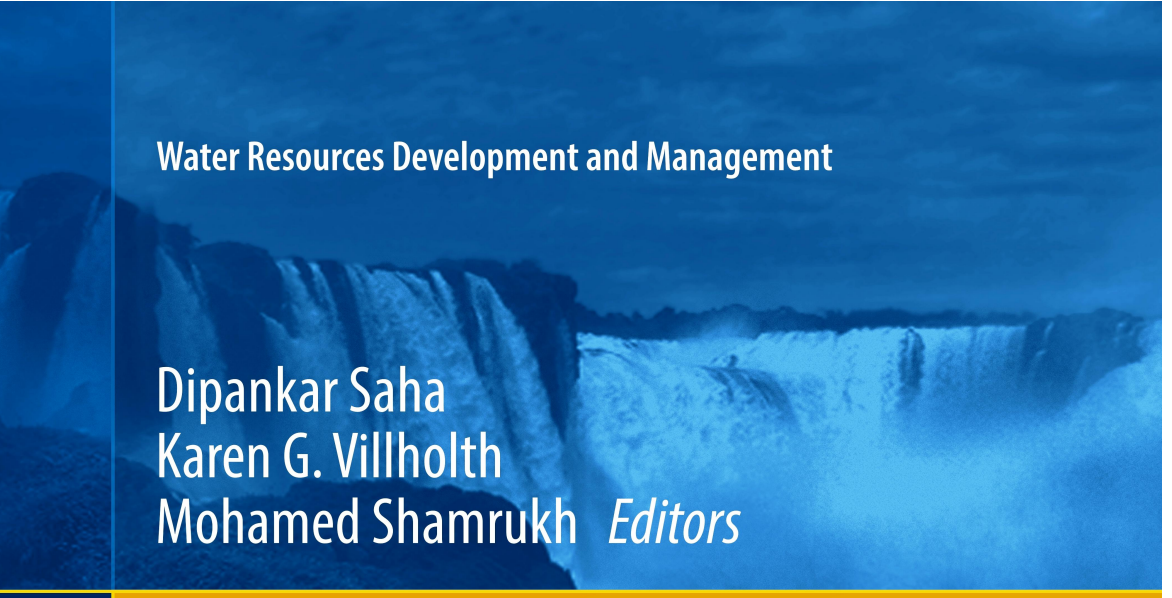

Water Resources Development and Management

Dipankar Saha
Karen G. Villholth
Mohamed Shamrukh *Editors*

Managed Groundwater Recharge and Rainwater Harvesting

Outlook from Developing Countries

Springer

Water Resources Development and Management

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Mohamed Shamrukh
Editors

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Foreword

Water policies and programmes all over the world, throughout the twentieth century, were formulated ignoring the profound inter-connectedness of different elements of the water cycle. Many parts of the world today face water crises, almost entirely engendered by the way we have gone about managing, or rather mismanaging the groundwater. Groundwater is a shared, common pool resource that needs to be shared and managed collectively, with careful attention being paid to maintaining a balance between the rates of extraction and rates of recharge. Degraded environments and climate change underscore the need and challenge of restoring these natural balances in the wider ecosystem. The very future of the planet is at stake in this era of the Anthropocene.

'Command-and-control over nature', the dominant paradigm of the twentieth century, is no longer an option. We need to urgently move towards a paradigm of 'working with, not against nature', weaving our interventions into the contours of nature, to leverage beneficial natural and ecosystem-based functions and processes that may help to support the protection and regeneration of natural resources, including water, as part of integrated human-natural systems.

This volume critically examines a set of nature-based solutions, namely managed groundwater recharge and rainwater harvesting, which hinges on the purposeful use of the subsurface formations (soil and aquifers, the natural storage 'container' for groundwater) as a workable space for water capture and storage. Water storage and its judicious management are becoming increasingly important parameters in climate change adaptations to address the growing variability, extremes, and unpredictable nature of water resource availability as evidenced globally.

The approaches span widely and get increasingly refined and adapted as per the bio-geo diversity, which this volume aims to convey. From relatively simple capture of rainwater in agricultural fields, overland flows, or on rooftops, to be diverted to underground storage, to advanced technologies to harvest and induce recharge into aquifers through the application of a new understanding of the system and technology, across a multitude of contexts, from rural to urban, from developing to developed countries, and across a variety of sectors, agriculture, water supply, and industry. These methods are also increasingly applied to improve groundwater

quality through dilution. The source water for additional recharge is getting scarcer at places and allowing the use of treated wastewater for recharging under strict control can be adopted, underlining the circular approaches to water use. Importantly, such methods may also reduce flooding risks and erosion and can help counteract seawater intrusion. Using the systems as part of aesthetic and recreational amenities and ecosystem restoration, the micro-climate may be improved, environmental flows can be augmented, and biodiversity can be enhanced, creating a multitude of potential co-benefits of these approaches.

This volume is a testimony to the benefits accrued to a multitude of stakeholders engaged in managed groundwater recharge and rainwater harvesting, through real-life cases from varied terrain, geology, land use, and water use profiles. Contributions have been made from fifteen developing countries spanning the entire globe namely Afghanistan, Bangladesh, Chile, Colombia, Egypt, Guatemala, India, Jordan, Morocco, Nigeria, Palestine, Qatar, South Africa, Sri Lanka, and Tunisia. Historic developments, progress, outcomes, challenges, and emerging policies and regulations guiding and regulating these practices are investigated.

Much remains to be done further, especially on the management and regulatory side. Without addressing the demand side of water, a mere supply-side focus will remain endlessly condemned to playing catch-up! The supply-side requires integration of surface water, coastal waters, wastewater, and groundwater, as well as the subsurface space, land, and ecosystems, with the make-or-break key factor being public participation and equitable access to the benefits of these solutions. They should support, rather than being detrimental to the deprived communities.

In this regard, India has been somewhat of a pioneer when it comes to rainwater harvesting and managed aquifer recharge, often conceived and implemented as part of an integrated watershed management approach, backed by a scientific understanding of aquifers. India now holds a dedicated and ambitious Master Plan for Artificial Recharge to Groundwater from 2020 (revised from 2013), aiming at advancing and directing these approaches, which to a larger extent originally were initiated and pursued through a civil society movement in response to growing droughts and local groundwater overdraft.

Global institutions, like the World Bank, UNESCO, International Water Management Institute, the Global Environment Facility, and many others, are increasingly advocating and supporting developing countries in accomplishing these endeavours. For example, the summary of the proceedings of the 2023 Water Conference held in March 2023,[1] a global summit on water reinvigorating commitments from the only previous United Nations Water Conference held in 1977 in Mar Del Plata, Argentina, highlighted water storage and rainwater harvesting as innovative technologies needing accelerated investments.[2]

[1] United Nations Conference on the Midterm Comprehensive Review of the Implementation of the Objectives of the International Decade for Action "Water for Sustainable Development", 2018–2028.

[2] https://digitallibrary.un.org/record/4012972/files/PGA77SummaryforWaterConference2023.pdf.

I must compliment the Corresponding Editor, Dipankar Saha, and the Co-editors, Karen G. Villholth and Mohamed Shamrukh, for their tireless labour of love in putting together such an enriching volume. Particularly heartening is to see the contributions made by the developing countries across the world. I must also put on record the efforts made by the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre) in bringing out such a wonderful monograph, which is timely, and I daresay, will prove of immense value across multiple contexts and stakeholders.

Dr. Mihir Shah
Former Member
Planning Commission, Government
of India and Distinguished Professor
Shiv Nadar Institution of Eminence
New Delhi, India

Preface

Sustainable management of freshwater resources is a global issue of growing concern in both policy and practice. With an increasing gap between water demand and supply, compounding challenges and complexities of water resources management are negatively affecting people, nature, and economies across the globe.

Worldwide, in various geographic, geological, topographic, land use, and climatic conditions, aquifers are a major source of water for human development. The dependence on groundwater is increasing because of low availability and reliability of surface water and its widespread pollution. Groundwater provides an important insulator and buffer against climate change, especially droughts, though groundwater itself is also impacted by climate change and droughts, though in less predictable ways and with a certain delay.

Over-exploitation of groundwater resources is a global phenomenon, particularly in arid and semi-arid areas. Pollution of groundwater is also happening widely, while often going unnoticed until critical public health or environmental problems emerge. Sustainable management of groundwater is a great challenge as the resource is distributed, hidden, and mostly not subjected to monitoring and regulation. At the same time, as the water demand is increasing, with existing drilling and pumping technologies, a large volume of groundwater is getting extracted, often in great excess of natural replenishment. Finally, groundwater and surface water are connected as parts of the natural water cycle, making conjunctive and integrated management of the water resources imperative.

Solutions are sought to combat escalating water insecurity, which potentially leads to social unrest and political tension. A critical part of this is to adopt various water supplies and demand-side interventions tailored to local conditions.

To enhance groundwater supply, one of the most important and globally widely adopted techniques is to increase and manage recharge to groundwater. While ample literature covers interventions and experiences in developed countries, it is acknowledged that for less developed countries and communities, though a wealth of traditional knowledge and practice exists, there is a need to document current and evolving practices and further strengthen approaches through support from science, policy, practice, and partnerships.

The idea of developing a book addressing groundwater recharge management and rainwater harvesting emerged from Dr. Amitava Bandopadhyay, Director General, Centre for Science & Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi, India.

The book, through its 19 chapters, provides novel information, via status papers, case studies, and research outputs, on the manmade applications of groundwater recharge enhancement and rainwater harvesting across Africa, Asia, and Latin America. The contributions provide examples of how to resolve the water crises and address climate change impacts on available freshwater resources. The issues addressed through these approaches include supplementing potable water supply, reducing the intensity of groundwater overexploitation, stormwater management, intensifying greywater reuse, and improving groundwater quality, environmental flows, and other ecosystem services. The chapters deal with local-scale experimentation and management, adopted government schemes, community involvement, private sector engagement, and socio-economic, environmental, legal, institutional, and policy aspects.

The book collates contributions from 15 NAM and other developing countries, namely, Afghanistan, Bangladesh, Chile, Colombia, Egypt, Guatemala, India, Jordan, Morocco, Nigeria, Palestine, Qatar, South Africa, Sri Lanka, and Tunisia. The contributions have been made by researchers, government departments, civil societies, non-governmental organizations, policymakers, and water management practitioners.

The overall aim of the book is to place before the readers, the efforts being undertaken in developing countries to address water resource sustainability and climate change resilience through traditional and innovative groundwater recharge, rainwater harvesting, and water storage methods. It also takes a broader outlook on the prospects of these methods and techniques to enhance long-term socioeconomic development for millions of communities globally through enhancing water security.

The Editors would like to express our sincere gratitude to all the authors who kindly accepted to write the chapters, revise the content based on the reviewer's comments, and submit final versions well in time in spite of their busy schedules.

We are thankful to Dr. Amitava Bandopadhyay, Director General; Mr. Madhusudan Bandyopadhyay, Senior Adviser; Mr. Pankaj Buttan, Data Processing Manager; Ms. Abhirami Ramdas, Research Associate; and other staff members at the NAM S&T Centre for all the technical and administrative support rendered towards the publication of this Monograph.

We are grateful to Dr. Mihir Shah, Former Member, Planning Commission, Government of India and Distinguished Professor, Shiv Nadar Institution of

Eminence, India, for writing the 'Foreword' of this book. We also express our gratitude to Dr. Loyola D'Silva, Executive Editor, Springer Nature, Singapore, and his team for making this endeavour a reality and a success.

New Delhi, India — Dipankar Saha, Ph.D.
Bela-Bela, Limpopo, South Africa — Karen G. Villholth, Ph.D.
Doha, Qatar — Mohamed Shamrukh, Ph.D.

Introduction

The World Economic Forum has consistently identified water crises among the top five global challenges since the last few years. Seventy per cent of the world's megacities are already water-stressed and the problem is much more alarming in developing countries, where groundwater levels are depleting rapidly. Groundwater is a critical natural resource for efficient and cost-effective supply of domestic, agricultural, and industrial water in both urban and rural areas. However, population growth, expansion of agriculture, and urbanization coupled with climate uncertainties and unsustainable surface water storage have accelerated groundwater extraction. The storage in surface bodies and groundwater is gradually decreasing due to changes in land use patterns and the depleting trend of groundwater recharge. All these have caused over-extraction of water from ground storage and surface water bodies, thus making potable water, an increasingly scarce commodity.

Natural replenishment of aquifer is not able to balance the excessive and persistent exploitation of groundwater in numerous parts of the world. In order to increase the natural supply of groundwater, artificial recharge to groundwater has emerged as a vital management approach. The ever-increasing imbalance of water availability and requirement can be resolved either by capturing the overflowing water in the continental regions through dams or by storing the available rainwater as groundwater through artificial recharge techniques.

Despite the advantages of rainwater harvesting as a sustainable development tool to mitigate water-related issues, there still exists a significant knowledge gap among the water management professionals to deliver desirable results. It is abundantly clear that access to water is a fundamental issue that requires solutions from the active engagement of stakeholders as well as the mobilization of knowledge and emerging technologies.

In order to address the above issues, the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi, is bringing out this Monograph for dissemination of relevant knowledge and information to the scientists, researchers, managers, policymakers, and other stakeholders engaged in the groundwater management sector.

The book through its nineteen chapters underscores the concept and principles of water harvesting techniques for groundwater recharge and its management. It provides readers with an overview of the groundwater occurrence, availability, and recharge; effective water harvesting approaches for groundwater recharge; issues on water harvesting and water security; case studies of implementing rainwater harvesting and the scope of rainwater harvesting for groundwater management strategies. The book intends to provide information on sustainable groundwater recharge practices to the developing world. The methods discussed in various chapters contribute notably towards achieving water-related sustainable development goals (SDGs) globally, especially the SDG-6.

The book brings together scientific communities from 15 countries namely Afghanistan, Bangladesh, Chile, Colombia, Egypt, Guatemala, India, Jordan, Morocco, Nigeria, Palestine, Qatar, South Africa, Sri Lanka, and Tunisia to share their knowledge and expertise to provide a detailed insight into the benefits and gaps in existing knowledge, implementation, and funding strategies, and public participation related to the improvement of groundwater management.

I am immensely grateful to Dr. Mihir Shah, Former Member, Planning Commission, Government of India, and Distinguished Professor at Shiv Nadar Institution of Eminence, India, for kindly agreeing to our request to write the Foreword of this book in spite of his very busy schedule.

I am thankful to Dr. Loyola D'Silva, Executive Editor, Springer Nature, Singapore, for his kind support and guidance towards bringing out this Monograph, and Ms. Shalini Monica C. Selvam, Project Coordinator, Springer Nature, India, for managing all the technical and administrative tasks for the publication process.

I would like to express my sincere gratitude to the Editors of this book, Dr. Dipankar Saha, Former Member, Central Ground Water Board (CGWB), New Delhi, India, and Chair Professor at Manav Rachna International Institute of Research and Studies (MRIIRS), Faridabad, Haryana, India; Dr. Karen G. Villholth, Director, Water Cycle Innovation (Pty) Ltd., Negester Klein-Kariba, Limpopo, South Africa; and Dr. Mohamed Shamrukh, Emeritus Professor of Water Resources and Environmental Engineering, Minia University, Egypt, and External Consultant at United Nations Environment Programme and Environmental Consultant at Ministry of Environment and Climate Change, Qatar, for their initiatives and efforts and sparing their valuable time in reviewing the papers for this book and taking charge of this publication project.

I also acknowledge the valuable support of the entire team at the NAM S&T Centre and am especially thankful to Mr. Madhusudan Bandyopadhyay, Senior Adviser, for his support and guidance, and Ms. Abhirami Ramdas, Research Associate, for her contributions in taking this publication project forward and bringing it to a successful conclusion.

I also record my appreciation for the assistance and support rendered by my colleagues Mr. Rahul Kumra, Assistant Administrative Officer, and Mr. Pankaj Buttan, Data Processing Manager, towards bringing out this Monograph.

I believe that this Monograph would serve as an excellent resource material for scientists and researchers from various R&D institutions, hydrologists, environmentalists, administrators, professionals from the water industry, hydraulic engineers, government officials, policymakers, and students who are actively engaged in the areas of water science and technology to make decisions to allocate water resources and to develop innovative cost-effective measures and approaches to achieve sustainable groundwater management.

Amitava Bandopadhyay, Ph.D.
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Contents

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Managed Groundwater Recharge and Rainwater Harvesting

Outlook from Developing Countries

This book, through its 19 chapters, highlights success stories, research outputs and various government schemes and actions taken on groundwater recharge and rainwater harvesting in developing countries. The interventions are focused on resolving water crises through supply side interventions, improving water quality and addressing climate change impacts. The contributions from across the globe shows how these approaches have been successful in supplementing potable water supply, reducing the intensity of overexploitation of groundwater resources, better storm water management, intensifying treated grey water reuse, and improving groundwater quality and environmental flows. The chapters deal with a wide array of issues, from local-scale experimentation and management to government schemes adopted, community involvement, private sector engagement, addressing socio-economic issues and policy interventions. The book includes contributions made by researchers, government departments, civil societies, policymakers and practitioners from 15 Non-Aligned Movement (NAM) and other developing countries, namely Afghanistan, Bangladesh, Chile, Colombia, Egypt, Guatemala, India, Jordan, Morocco, Nigeria, Palestine, Qatar, South Africa, Sri Lanka and Tunisia. The book places before the readers, the strives being undertaken in the Global South to address the sustainability of water resources and climate change adaptation through traditional and innovative methods to groundwater recharge, water harvesting and storage.

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