Introduction: Groundwater, sustainable livelihoods and equitable growth

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Abstract: In many areas of the world, groundwater represents the primary source of water for domestic supply and agriculture, supporting livelihoods and lifting many out of poverty. However, the hidden nature of groundwater often means that its important role both historically and in the present is overlooked, hampering its effective management and putting future supplies at risk. For the benefits of groundwater abstraction to continue to be realized and sustained, the links between groundwater availability and quality, climate change, and groundwater-dependent livelihoods need to be explored and articulated. This becomes even more important with growing climate uncertainty and decreasing water security in some marginal and vulnerable areas, with an increasing threat to livelihoods. This introductory chapter presents the main concepts of this book, introduces the different chapters, and discusses emerging themes. There is compelling evidence that the development of groundwater has profoundly improved many people's lives and continues to lift people out of poverty today. The examples in this book provide a wide variety of case studies from Asia, Africa, and South America that show how groundwater, often invisibly, improves people's lives and livelihoods and promotes equitable growth. However, the studies also demonstrate how vulnerable groundwater can be over-used and contaminated, and how ignorance of the nature of groundwater is one of the greatest threats to its sustainable use. It is, therefore, of critical importance to increase investment in characterizing, monitoring, and governing groundwater, to explore links between science, policy, and practice, and to effectively communicate existing knowledge so that groundwater will continue to improve people's lives for centuries to come.

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1 Introduction

From the earliest times, the use of groundwater has been critical for human life and sustaining and growing livelihoods. Perennial springs in east Africa are thought to have helped early humans survive extended drought (Cuthbert et al., 2017). Access to groundwater through springs and shallow wells enabled early civilizations to develop settlements away from rivers and extend the growing season (Angelakis et al., 2020; Tzanakakis et al., 2020). The development of groundwater facilitated growing urbanization in the eastern Mediterranean during Greek and Roman times (Angelakis et al., 2016; Crouch, 1993); however, it is in the last two centuries, and particularly since 1970, that the world has come to rely more on groundwater to underpin growth. For example, India's Green Revolution, which transformed the country from a food deficit to a food surplus, was only made possible due to intensive groundwater irrigation (Mukherji, 2020; Pingali, 2012). Deep boreholes supplied many cities with clean drinking water and provided a reliable water supply for rapid industrial expansion throughout the 19th and 20th centuries, and for the green revolutions in agriculture in the latter half of the 20th century (Siebert et al., 2010). It is clear that groundwater continues to solve many water security issues today, but equally, the invisibility of groundwater means that its critical role is often overlooked. This book aims to provide an initial evidence base for how groundwater is contributing to reducing poverty, increasing resilience to climate and environmental change, and helping to develop equitable growth.

The benefits of groundwater are well understood by users: storage is several orders of magnitude greater than any other freshwater resource (Gleeson et al., 2016). Groundwater also buffers water supplies against droughts (MacDonald et al., 2019) and has been instrumental in agricultural growth and poverty alleviation in regions that make intensive use of groundwater for irrigation (Salem et al., 2018; Sekhri, 2014). Natural quality is generally good (Lapworth et al., 2020) (with some notable exceptions in some areas for geogenic contamination such as arsenic and fluoride; Selinus et al., 2013), and groundwater can be found in many different environments, often close to the point of need. These benefits can deliver water, food, and livelihood security, and help in reducing current poverty. However, although the benefits are enjoyed, groundwater itself is poorly understood, and continued unregulated development can lead to overexploitation (Gleeson et al., 2020) and degradation in certain hotspots (Elshall et al., 2020). Degradation reduces the benefits, for example, in the form of reduced access to reliable irrigation (Asoka & Mishra, 2020; Jain et al., 2021); reduced adaptive capacity of rural populations (Blakeslee et al., 2020;

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Fishman, 2018); quality deterioration (Mas-Pla & Menció, 2019); higher costs for pumping and treatment (McDonough et al., 2020; Turner et al., 2019); land subsidence (Shirzaei & Bürgmann, 2018); and poor ecosystem services (WLE, 2015). However, in many parts of the world, and particularly in Africa, groundwater is still under-used (Cobbing & Hiller, 2019), and there is still considerable potential for new groundwater development to contribute to sustainable livelihoods. What is clear is that groundwater resources and the sustainability of water supplies need to be better understood and managed for the benefits of groundwater to continue to accrue to society.

Recent studies examining how to ensure long-term and equitable benefits from groundwater development suggest the importance of strengthening the interactions between the science–policy–practice interface in groundwater systems (Milman & MacDonald, 2020), advancing groundwater governance (Villholth et al., 2019) and promoting transdisciplinary approaches, integrating the social dimension into hydrogeological assessments (Hynds et al., 2018; Re, 2015). Regardless of the angle of observation, all the recent debates on groundwater sustainability have two elements in common: fostering the connection and engagement with water users and managers; and promoting information and data sharing. Groundwater information (also critical for the achievement of SDG6) is only of use if shared in a timely manner; otherwise, possible remedial actions may already have become obsolete (Re et al., 2018).

Key to success is sharing lessons and experiences of groundwater development. For this reason, this book aims to provide a significant body of case studies in which groundwater has contributed to reducing poverty, increasing resilience to climate and environmental change, and helping to develop equitable growth. Such case studies and examples are lacking in the academic literature, particularly those that demonstrate the impact that groundwater development has had on households, communities, and regions. This missing voice has hampered the ability to demonstrate the positive role that groundwater development can have, and therefore, the importance of developing groundwater sustainably so that future generations can also benefit.

2 Contributions to the book

In this book, there is an attempt to cover different views and perspectives of groundwater development and management focusing on supporting livelihoods and reducing poverty worldwide. There are nineteen contributions from four different continents, Africa, Asia, South America, and Oceania, and sixteen

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different countries: Brazil, Cameroon, Chad, Ethiopia, Ghana, India, Indonesia, Laos, Libya, Myanmar, Niger, Pakistan, South Africa, Tanzania, Togo, and Zimbabwe.

From South America, the studies encompass the four corners of Brazil. Marques et al. (2022) established operational and water management strategies to build resilience, water security, and adaptation for the conjunctive use of surface and groundwater in the south. From the mid-western region, Gabbas et al. (2022) presented the role of groundwater in economic and social development, focusing on agricultural activities and minorities such as indigenous and quilombolas (former slaves) communities. Rêgo et al. (2022) highlighted the importance of alluvial aquifers in the Brazilian semiarid region. Tubbs et al. (2022) reflect upon an important water source of Rio de Janeiro city, the Guandu River basin, the management of private domestic wells, and its implications on water governance for coastal areas.

In Asia, Haryono et al. (2022) showed how community-based karst tourism recovered the Gunungsewu region in Indonesia, after the creation of a geopark. Pavelic et al. (2022) featured small-scale groundwater irrigation solutions in Laos, and how access to groundwater irrigation provided farmers with options to irrigate additional crops and improve livelihoods in the non-rainy season. From Myamar, May et al. (2022) presented the case of the Six Villages of Taunggyi, Shan State, where water is taken directly from springs without any treatment. Several contributions came from India: Shah et al. (2021) discussed the impact of energy tariff changes from a field pilot in Birbhum district (West Bengal state), showing the close linkages between electricity pricing and tariffs and groundwater use incentives; Patel and Saha (2022) explained the importance of groundwater and its rational use in the post-2001 earthquake in the Kutch district (Gujarat state); and Saha et al. (2022) examined the links between an Act that promulgates postponement of the date of paddy sowing to reduce groundwater extraction and increase in stubble burning later in the season, and found a complex relationship with other factors such as access to technology.

In the African continent, Cheo et al. (2022) compared two case studies from Cameroon and Niger, drawing synergies between the two countries for groundwater interventions in specific livelihood and agro-ecological zones. Woldearegay et al. (2022) focused on the Tigray region in northern Ethiopia and the continuous improvements in land and water management methods over the years to ensure food and water security. Hammad and Hasia (2022) showed the long-term importance of the Al Jabal Al Akhdar area karst springs, a source of water for local communities since ancient Greek and Roman civilizations.

Collignon et al. (2022) created an atlas based on an extensive groundwater inventory, aiming to optimize investments to ensure water security in the northern part of Lake Chad. From Ghana, Kwoyiga (2022) explored how informal groundwater development has filled the gap between demand and municipal supply and enabled peri-urban growth in the Techiman municipality. Mosha et al. (2022) showed how groundwater development improves agricultural livelihoods by surveying three villages in Usangu Plains, Tanzania by undertaking an economic analysis to demonstrate the returns to groundwater investment. In Togo, Barry et al. (2022) presented how groundwater is essential to the population of Lomé, projecting its use in urban and coastal areas and the vulnerability to climate change. In Zimbabwe, Mujere (2022) studied the groundwater available in a suburb of Harare and the value of groundwater quality to prevent outbreaks of water-borne and water-related diseases. Finally, in Malawi, Sauramba et al. (2022) presented the legal framework established between 2017 and 2019 in order to identify gaps and challenges to develop an action plan for groundwater.

3 Challenges and future perspectives

The papers in this collection cover many different perspectives using a diverse set of methodologies and discuss successes, challenges, and opportunities common to many groundwater-dependent communities worldwide. Common to many were the tradeoffs required for society to both benefit from groundwater and protect the quality and quantity of the resource to sustain future use. This requires a good understanding of aquifers, the dynamics of the groundwater system, and the current abstraction rates and contaminants while placing groundwater in specific legal, economic, and social contexts. Many of the studies reflected on the paucity of sound data on groundwater and aquifer features at local, regional, and transboundary levels, despite the high dependency of local communities to this resource, which limited the ability to reliably forecast future opportunities and threats.

Data scarcity, or limited access to existing data, is often the result of limited long-term investments and a lack of meaningful interactions at the science–policy–practice interface for groundwater (Milman & MacDonald, 2020). Indeed, it is clear that improved monitoring is key for the successful achievement of SDG6, as evidenced by the recently launched UN-Water SDG 6 Data Portal (UN Water, 2021), although even here, groundwater is under-represented given the scale of groundwater use. New advances in data and information sharing offer opportunities to coordinate and plan effective groundwater monitoring and aquifer characterization, and make this information widely available and accessible. The rapid advance of open-access publications is providing opportunities to level up access to information, and facilitate lesson learning and knowledge transfer.

In some areas, the lack of qualified groundwater professionals was also highlighted as a threat to the continued use of groundwater for growth and livelihoods. Groundwater is often informally developed and poorly regulated with the result that expertise in inexpensive drilling and pump installation is valued over expertise in understanding the resource or developing it sustainably (Healy et al., 2020). Increasing the knowledge and capacity of users to understand more how groundwater behaves and how its sustainable use is linked to ongoing livelihood security may help develop demand for increased groundwater professionalization and regulation. Looking to the future, the implementation of transdisciplinary approaches may help to foster the dialogue among scientists, policymakers, and users, thus resulting in improved groundwater governance and sustainable benefits for all.

There is compelling evidence that the development of groundwater has profoundly improved many people's lives and continues to lift people out of poverty today. The examples in this book provide a wide variety of case studies from Asia, Africa, and South America that show how groundwater, often invisibly, improves people's lives and livelihoods and promotes equitable growth. However, the studies also demonstrate how groundwater can be over-used and contaminated, and how ignorance of the nature of groundwater is one of the greatest threats to its sustainable use. It is, therefore, of paramount importance to help an interdisciplinary community grow to facilitate sharing knowledge and to increase investment in characterizing, monitoring, and governing groundwater, so that groundwater will continue to improve people's lives for centuries to come.

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The Network is named in memory of the internationally renowned Irish hydrogeologist David Burdon, who had a long-time interest and work in global groundwater, and IAH operates a fund in his name to support these activities. This book is part of the IAH-BGID mission of creating an international groundwater knowledge base contributing to sustainable groundwater management and development in low-income countries.

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