Chapter 5
A Systematic Review on Groundwater Management: Opportunities and Challenges

Shaghla Parveen, Bushra Praveen, and Vaseem Akram

Abstract In both urban and rural settings, groundwater supports various aquatic habitats and plays a critical role in the economic growth and human well-being. Therefore, if properly assessed and sustainably used, groundwater has considerable importance to the development and well-being of people in underdeveloped nations. Although groundwater resource development potential is still discussed in the literature, there is still a lack of quantitative knowledge about these problems. The chapters goal is to draw attention to the key groundwater concerns and difficulties that developing nations face, as well as the existing and foreseeable potential for sustainable subterranean water governance. The purpose can be consummate through reviewing current groundwater resource information as well as current and upcoming groundwater management programs and efforts. Due to increased demand to fulfill human and agricultural requirements, groundwater resources in developing countries are increasingly at risk of contamination from urban spaces, manufacturing firms, farmlands, and excavation operations, as well as from inadequate hygiene standards and overexploitation. This paper will look at the importance of groundwater importance, groundwater challenges in developing countries, and a systematic review of drought management policy. Therefore, it is necessary to implement methods to corroborate with sustainable management and flourishment of groundwater reserves. These include developing groundwater monitoring systems, comprehending the connections between groundwater aquatic ecosystems, managing transboundary aquifers, addressing the repercussions of climate alterations on underground water, and determining how accelerated expulsion of subsoil waters will affect its retaining capacity.

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Abbreviations

AI	Artificial intelligence
ML	Machine learning
ANN	Artificial neural network
FAO	Food and agriculture organization

5.1 Introduction

Groundwater is considerably a substantial freshwater body which is expected to threaten due to over-drafting. Nearly two million people utilize groundwater resources, causing a share of 33 percent water withdrawal. Therefore, over-drafting is noticeably one of the major causes of groundwater-level drop and directing toward crises. Figure 5.1 indicates the water that exists below the surface of the land is typically thought of as groundwater. More specifically, all cracks and pores beneath the surface of the earth are completely saturated by subsurface water. Thus, water that is more transiently held between soil granules close to the land surface is typically excluded from the concept of groundwater. An aquifer is a layer of gravel or stone in the earth that can produce groundwater. The world's total water resources ranged 46,000 km^3/year, with around 36,000 km^3/year of groundwater (Trenberth et al. 2007). The patchwork of climatic conditions and physiographic features determine how these resources are spread around the earth. At the continental level, America, with 45% freshwater globally, has the highest proportion at the continental level, accompanied by Asia with 28%, Europe 15.5%, and Africa 9%. America possesses 24,000 m^3 of resources per person/year, Europe contains 9300 m^3, Africa owns 5000 m^3, and Asia holds 3400.1 m^3 per year (FAO 2003).

The natural water cycle depends on groundwater, which is found almost everywhere beneath our feet. Groundwater contributes significantly to the flow of many streams and rivers as part of the water cycle, and it has a significant impact on the ecosystems of rivers and wetlands for both plants and animals. It creates the biggest accessible freshwater reserve on Earth. There are around 23,400,000 km^3 of groundwater on Earth, of which 10,530,000 km^3 are freshwater and 54% are saltwater (Gleick 1996).

Groundwater is a secret resource that is produced by rainwater that has seeped into the earth through continental surface waters (about 80%), oceans (20%) assisting waterways and retaining ecosystems. Therefore, throughout the summer or during

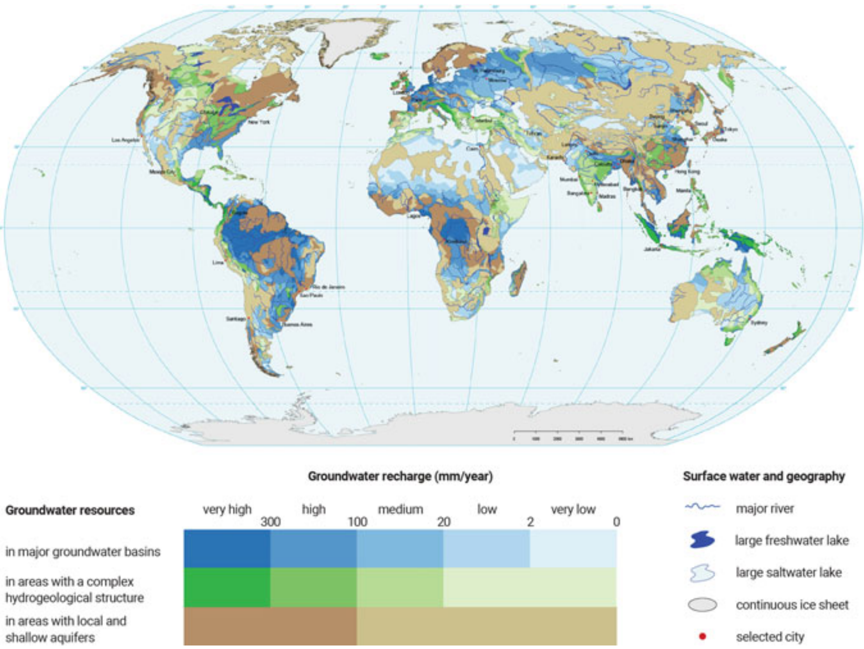

Fig. 5.1 Groundwater resources across the countries. *Source* Groundwater resources of the world Image Credit BGR/UNESCO (2008)

dry spells, groundwater serves as river's or lake's main supply of water. This review explained groundwater's significance, challenges, and possible solutions.

5.2 The Role of Groundwater

5.2.1 Importance

Only 0.2% of the freshwater on Earth is contained by lakes, streamlets, or rivers/rills; besides 70% is frozen; therefore, the statistics account for roughly 30% of all freshwater on Earth. Pragmatically, the water consumed for agriculture, industry, drinking purposes, domestic use, etc., comes from the groundwater resource.

Numerous crucial responsibilities for our environment and economy are carried out by groundwater. It sustains rivers, lakes, and wetlands in the ecosystem, particularly during the dry season with acute downpour.

5.3 Groundwater Management and Challenges

- Inadequate data and statistics for planning is one of the obstacles toward the governance and expansion of sustainable groundwater resources. For instance, it is not evident how far constructing wells can be placed apart from each other to avert leakage and how distant the extraction locations must be placed to restrict contamination. Thus, in order to conserve and develop groundwater resources for water supply, it is important to address the following practical issues: How much of the zonal space encompassing wells and springs needs to be protected from continuous pumping through various waterholes in order to prevent overexploitation of water reserves and an unwanted fall in the water level.
- Contamination of the groundwater. In both urban and rural regions, there are a growing number of documented cases of water-borne illnesses brought on by drinking tainted groundwater. This is linked to sanitary facilitie's poor placement, particularly pit latrines, whose contents seep into and mingle with groundwater. Urban area's crumbling solid waste disposal facilities and sewer systems, whose contents and leachates readily seep into groundwater and mix with it, are also to blame for groundwater pollution.
- Intricate geology fractures and worn zones that are present in intricate geological formations are where groundwater occurs. Due to the complicated geology, understanding the nature of groundwater occurrence and flow is highly challenging. As a consequence, this poses a significant obstacle in development of sustainable groundwater assets.

5.4 Climate Change and Groundwater

5.4.1 Impacts

Groundwater is frequently left out of the most recent assessments of how climate change ability influences water resources. This exclusion raises concerns, especially in developing nations where groundwater is heavily relied upon to supply the household, agricultural, and industrial water needs due to present practices and anticipated adjustments to climate change and rapid population expansion. Africa has already experienced climate change and variability, and this century is expected to see a significant rise in both (Taylor and Tindimugaya 2009).

5.5 Opportunities for Improving Groundwater Management

The developing countries have several active groundwater-based projects offering chances to enhance groundwater management. These may be divided into three categories: information management programs, capacity training programs, and frameworks for institution-formed cooperation and shareholder involvement.

There are several institutional coordination and stakeholder association structures that are essential for sustainable groundwater management. In addition to the African Union, the African Minister's Council on Water, specialized Africa Groundwater Commission, Regional Economic Communities, River Basin Organizations, member states (water ministries), and sub-national (basins, counties/districts, and local communities) organizations are among them.

The discourse of sustainable groundwater management gives a comprehensive clasp over the recent stature and the forecasting of the imperative resources. A number of automated models simulate differential techniques to stimulate the effective groundwater system**,** for instance MODFLOW (MacDonald et al. 2001).Various researches suggest that soft computing techniques are used to project groundwater contamination, such techniques are artificial neural network (ANN) and adaptive network-based fuzzy inference system. At some point, the literature review explains that in the process of predicting groundwater behavioral systems, physical and numerical techniques played their part; however, conventional techniques are convoluted to elaborate the results; therefore, AI is used to enhance the modeling technique and quality (Quadri 2017).

In the last many years, researchers inclined to machine learning (ML) and database methods and incorporated them in groundwater modeling (MacDonald et al. 2012). The subterranean water system has compounded features which remained unresolved in the conventional modeling. The acquisition of simulation and prediction techniques streamline a number of presumptions and undergo considerable groundwater unpredictability**.** A significant attribute of black-box models, for example ML, is that it does not need a thorough understanding of all the physical and mathematical operations to settle down nonlinear linkages among all the factors. Besides, linear stochastic and pre-processing methods demonstrated a propitious approach in level forecasting (Quadri 2017).

This research tries to bring a systematic review on ML techniques incorporated into modeling and forecasting of groundwater resources. This chapter also explores the appropriateness of ML models to envision the quality base aggregate groundwater. The extent of the review considers groundwater-level predictability through artificial intelligence (AI) and soft computing procedures amalgamated into various studies**.** Moreover, this review chapter fashioned upon earlier research articles corresponding to ML and deep learning techniques in the arena of hydrology, water resources, and groundwater (Nijsten et al. 2018). This attempt helps in bridging a research gap for systematic meta-analysis ML modeling in groundwater. ML modeling in groundwater contemplates spatiotemporal scale, meteorological studies, sample division, input factors. The modeling ensembles results of predicament indices, resolution-based spatiotemporal scale, and forecast time. Accordingly, a collective and sturdy collation of the ML model's presentation in observance and prediction of groundwater attributes can be exacting. A coherent meta-analysis assembles this study with a pooled summary of various studies and sequels (GRAC 2013). The present chapter fulfills the research gap with a notion of CEBC protocol to coordinate an orderly review of the environment (Agency 2011). In the words of CEBC, a systematized review is a methodological synthesis of resolving the queries in an unbiased mode with precision (Quadri 2017). We intended to resolve the notion of the accuracy of ML modeling for prediction of groundwater resources. Therefore, using meta-analysis, the performance of ML techniques in groundwater studies can be studied well.

5.6 Conclusions and Recommendations

The groundwater systems confer gradual response to the changes occurring in the biome (climate and human) as compared to the subsurface water systems. However, climatic alterations possess a considerable impact on groundwater through changes in groundwater recharge, storage, and use.

Other factors like increased water demand, transformation in land use land cover, and variations in temperature and downpour act as contributing keys to the changes in groundwater complexities. Despite being a resource that is crucial to both socioeconomic development and ecosystem, groundwater mechanism has endured unacknowledged and unsupervised. Groundwater supplies are becoming widely contaminated, and groundwater's crucial environmental functions are being ignored. The organizational structure and the development of institutional capacity for groundwater appear to have serious flaws. To meet this challenge, it will be necessary to have a much greater knowledge of how groundwater contributes to the goals set by state coordination committees for its management and integration structures that facilitate local actions.

The chapter also suggests groundwater observance projects to understand storage and discharge systems which will help in preserving aquatic ecosystems. A thorough appraisal of interactions between various aquifers (including transboundary aquifers) would eventually increase capacity of pumping water from the subterranean waters.

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