Chapter 1
Introduction to Groundwater and Society: Applications of Geospatial Technology

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Abstract Water is the basic requirement for the development of civilization. The primitive civilizations were developed along the surface water bodies to meet the demand of water for the society. With the progress of time, the population-led demand for water was increased in those civilizations and which ultimately led to conflicts. The Indus valley civilization was destroyed mainly because of issues related to water management. In the recent times with the advent of modern tools and gadgets, the issues related to water have increased manifold. The demand from drinking, domestic, agriculture and industry has also increased alarmingly. To meet these demands, use of groundwater has increased tremendously all over the world. With the higher demand, the problems also became higher. In this context, modern tools and techniques like remote sensing, geographical information system, geostatistics and modelling have the potentiality to manage the groundwater-related problems and play a vital role for societal development. In this book we intended to offer novel advances and applications of remote sensing, geographical information system and geostatistical techniques in a precise and clear manner to the research community to achieve in-depth knowledge in the field. The scientific understanding, development and application of geospatial technologies related to water resource management have been advanced. Geostatistics and geospatial techniques for groundwater science assemble the most up-to-date techniques in GIS and geostatistics as they relate to groundwater. Therefore, this book will help the readers

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to find the recent advancement of the geospatial techniques and its application in the groundwater resources in a single volume.

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1.1 Introduction

Groundwater is the water found below the earth surface and accounts for 30% of available freshwater of the earth. It is a very important natural resource and has a significant role in the economy of any nation. People from all over the world are using sub-surface water to meet their various needs like drinking, washing, etc. for a long period of time (WWAP-UNESCO 2009). The increase in population increases the demand, and thus the exploitation of groundwater is gradually increasing. The contribution of groundwater to irrigation and food industry is highly significant and slowly leads to its over-exploitation (Smith et al. 2016). Globally, we use nearly 70% surface and sub-surface water as irrigation. India is the largest user of groundwater in the world followed by China and the USA, using an estimated 250 km^3 of groundwater per annum. The developing countries are using groundwater at a faster rate. For example, in India, the contribution of groundwater is 62% in agriculture sector, 85% in rural water supply and 45% in urban water consumption. All over the world, groundwater is being used for industrial development, and it triggered unprecedented changes in the state of groundwater level. The groundwater is pumped out faster than it can replenish itself through underground recharge. This imbalance of input and output in groundwater extract creates a lot of problem (Chenini and Mammou 2010).

The groundwater crisis is an issue which can be solved at local level but has a global concern. The issue of groundwater management needs to be addressed in a global scale to ensure sustainable use of groundwater resources and to reverse the depletion of reserved groundwater. If this valuable resource cannot be managed properly, it will be a threat to the existence of living beings in the near future. Despite the increasing pressure placed on water resources by population growth and economic development, the laws governing groundwater rights have not changed accordingly, even in developed nations. Nor is groundwater depletion limited to dry climates: pollution and mismanagement of surface waters can cause over-reliance on groundwater in regions where annual rainfall is abundant.

Availability of good quality water in abundant quantity is the prime concern for the establishment of human settlement. The early settlers were totally dependent on surface water (Maisels 2001), and with the advent of civilization this demand enhanced considerably. This leads to the competition for faster development among the people (Taylor et al. 2013) which leads to the gradual increasing of water demand as well as scarcity. The earlier settlers were also exposed to climate change and other monsoonal aberrations (Pereira et al. 2009), although water

pollution was not so much important. To get rid of this crisis, people started the groundwater extraction to overcome the water scarcity problem. The regulating water demands are also dramatically increased, promoting the deficit of groundwater storage, depletion of the water table (Qureshi et al. 2010) and reduction of recharge rate. The humans are in dire need to find out the adaptive strategies and restrain water demands alongside the increase of rainwater recharging capacity, groundwater storage and efficiency in water utilization.

Therefore, for the optimal utilization and preservation of this treasure, systematic planning and management using modern tools and techniques are essential. For the greater interest, a measurement of groundwater resource is really significant for the sustainable management, and with the advent of powerful and high-speed personal computers, efficient techniques for water management have evolved, of which RS (remote sensing), GIS (geographic information system) and GPS (Global Positioning System) and geostatistical techniques are of great significance (Magesh et al. 2012; Kumar et al. 2014; Adhikary et al. 2011, 2015; Thapa et al. 2017; Nasir et al. 2018).

1.2 Key Aims of the Book

Groundwater is inarguably the world's single most important natural resource. It is the foundation of the livelihood security of millions of farmers and the main source of drinking water for a vast majority of people residing in rural as well as urban areas. The prospects of continued high rates of growth of the world's economy will depend critically on how judiciously we are able to manage groundwater in the years to come.

Over the years the world is consuming huge amount of groundwater for its growth and development. The contribution of groundwater is immense to make our world better in food security and many other aspects. Even as groundwater has made us self-sufficient in food, we are now facing the crisis of depleting water tables and water quality. The deep drilling by tube wells that was once part of the solution to the problem of water shortage now threatens to become a part of the problem itself. We, therefore, need to pay urgent attention to the sustainable and equitable management of groundwater.

Our intention in editing this book is to offer novel advances and applications of RS-GIS and geostatistical techniques in a precise and clear manner to the research community to achieve in-depth knowledge in the field. It will help those researchers who have interest in this field to keep insight into different concepts and their importance for applications in real life. This has been done to make the edited book more flexible and to stimulate further interest in topics. All these motivated us towards novel advances and applications of geospatial technologies and geostatistics.

This book advances the scientific understanding, development and application of geospatial technologies related to water resource management. Geostatistics and

geospatial techniques for groundwater science assemble the most up-to-date techniques in GIS and geostatistics as they relate to groundwater, one of the most important natural resources. Therefore, this book will help the readers to find the recent advancement of the geospatial techniques and its application in the groundwater resources in a single volume.

1.3 Sections of the Book

The book is organized into three parts: (I) Groundwater Resources and Societal Development; (II) Groundwater Availability, Quality and Pollution; and (III) Sustainable Groundwater Resources Management.

1.3.1 Section I: Groundwater Resources and Societal Development

This section concerns itself with the specific uses and management of groundwater as a component of integrated water management for societal development. Modern geospatial and geostatistical technologies have been described and used to address the issue of groundwater-related conflicts generally arising in the society. Overall, these fundamentals are tried to capture in five chapters of the section. These chapters are essential either to understand the spatial process of groundwater variation or to quantify these variations through the lens of society. The second chapter talks about how societal development has been started with the availability of freshwater in the world and how the conflicts have arisen because of water scarcity and pollution. In this context how the integrated approach of remote sensing and geographic information system has the potentiality to address the issue of groundwater scarcity and quality on a spatial scale through the involvement of the society has been described in Chap. 3. Chapter 4 deals with geospatial and geophysical approaches for assessment of groundwater resources in alluvial aquifers. This has been described through a case study from India. There are many issues related to groundwater management using space technology. Chapter 5 deals with those issues and suggested comprehensive solution to deal with those issues. The village level assessment of groundwater quality has the most importance to solve the problem comprehensively. Thus Chap. 6 documented the village level assessment of groundwater quality through multi-criteria-based GIS analysis. Overall, this section talks about how geospatial techniques will be useful to address the groundwater-related societal conflicts and how modern tools can play a greater role for societal development.

1.3.2 Section II: Groundwater Availability, Quality and Pollution

The second section deals with the regularity and monitoring of groundwater resources. This section discusses about the groundwater potential zone identification, the amount of water available in the aquifer, recharge and discharge characteristics of groundwater resources. Here remote sensing and GIS techniques have been extensively used. In this section, the threats of over-extraction and subsequent groundwater pollution emerging out because of high dependency led to high exploitation of groundwater resources by societal, economic and environmental development. The evolution of effective management systems to address these threats has been discussed. Ten chapters have been dedicated in this section. Delineation of groundwater potential zones is a very important issue which serves as the first point for groundwater management. Chapters 6, 7, 8, 9, 10 and 11 discuss about the delineation and mapping of groundwater potential zones using modern tools, techniques and modelling. The applicability of GIS-based Fuzzy Analytical Hierarchy Process approach has been highlighted in these chapters. The performance of Frequency Ratio Approach and Artificial Neural Network has also been discussed with case studies in this section. The appraisal of groundwater quality is the topic of present-day research. Chapters 12, 13 and 14 deal with this aspect. Multi-criteria-based GIS approach, use of groundwater quality indices and HPI were used to understand managing groundwater pollution through case studies. Chapter 15 deals with fluoride dynamics in Precambrian hard rock terrain of North Singhbhum Craton and effect of fluorosis on human health and society. Thereby the problem of fluoride has been dealt with in this section. Salt water intrusion in the coastal aquifer is a problem. Therefore Chap. 16 assesses the coastal aquifer vulnerability for saltwater intrusion using GALDIT model and geo-informatics. This thing has been explained through a case study of Chennai coast.

1.3.3 Section III: Sustainable Groundwater Resources Management

The third section deals with the application of geospatial techniques to tackle man-induced changes in groundwater conditions. The environmental and socio-economic impacts on groundwater resources have been dealt with in detail. How different approaches like watershed management and agro-forestry can remediate the twin problem of groundwater quantity and quality deterioration and the role of RS and GIS to support in this aspect has been addressed. The role of stakeholder's participation to tackle the groundwater-related problems for long-term basis through which viable national, regional and local systems can be evolved has also been addressed. Altogether there are seven chapters to cover these aspects. Chapter 17 discussed about the impact of watershed development models on water resources

especially on groundwater utilization. This has been illustrated with a live case study from a tribal watershed of India. Chapter 18 deals with the impact of long-term groundwater behaviour on agricultural development. This has been discussed with a case study from an agriculturally developed state of north-west India. Chapter 19 deals with the spatial appraisals of groundwater recharge potential zone identification using remote sensing and GIS. Water stress is an important aspect which controls the agricultural activity through the world. In this aspect Chap. 20 deals with spatial mapping of groundwater depth to prioritize the areas under water stress in the Rayalaseema region of Andhra Pradesh, India. Groundwater vulnerability was explored using AHP and GIS techniques in Chap. 21 with the help of a case study from India. A geoscientific study on Birbhum District, West Bengal, India, was presented in Chap. 22 where the applicability of geospatial technology, weight of evidence and multilayer perceptron was used for groundwater management. This study critically examined the modern tools and techniques for efficient management of groundwater resources. The last chapter deals with water resources management in the context of sustainable development goals of the United Nations. This is addressed with the help of a good case study from India. Overall, this section has given comprehensive idea about the importance of RS, GIS, modelling and other modern tools and techniques for sustainable water resources management.

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