CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Groundwater is an essential resource of water for domestic, agricultural, and industrial requirements. It is the principal source of drinking water in rural and urban areas and is widely used for irrigation in most arid and semi-arid regions and rendering a considerable service for the ecosystem and human health (Gaikwad et al., 2020; Gleeson et al. 2016). It has also become apparent that many human activities have tremendously impacted both the quantity and quality of groundwater resources. In many parts of the world, groundwater resources are under increasing threat, and water scarcity has become one of the key threat to food security, human health, and natural ecosystems. Based on a recent study by the International Water Management Institute (IWMI), it has been estimated that nearly 1.4 billion people, amounting to a quarter of the world's population or a third of the population in developing countries, live in regions that will experience severe water scarcity within the first quarter of the twenty first century. It has also been pointed out that at present more than one billion people live in arid regions that will face absolute water scarcity by 2025. These regions do not have sufficient water resources to maintain 1990 levels of per capita food production from irrigated agriculture, even at high levels of irrigation efficiency, and meet reasonable water needs for domestic, industrial and environmental purposes by 2025 (Seckler et al. 1998). Groundwater plays a major role in the changing climate, due to its reliability in terms of quantity and quality. India is the major consumer of sub-surface water globally as India extracts 243 km^3 annually while China and USA remain the second and third highest consumers (NGWA 2016). Indian

aquifers fulfill, about 85% of drinking requirement in rural, 62% irrigation requirement, and about 50% urban requirement.

Population growth, industrialization, urbanization, and development of infrastructure have put groundwater in an aggressive demand. This has resulted in reduction of per capita annual available water from 5177 m^3 to 1545 m^3 in the last 70 years i.e. since India's independence. Aquifers are considered as safer source of drinking water and is available in all types of topography and agro-climatic zones. It is required to focus on managing and developing groundwater sustainability, to alleviate pressure developed due to continuously increasing population and its demand for freshwater (Saha et al. 2018). Central Ground Water Board (CGWB) has estimated India's total replenishable groundwater resources as 432 billion m^3 (BCM) out of which about 60% has already been developed and about 80% utilization is in agriculture domain (CGWB, 2019).

About 348 million people face severe water scarcity problems. They live in regions where the potential water resources are sufficient to meet reasonable water needs up to 2025, but they will have to embark on massive water development projects, at enormous cost and possibly by impacting present state of environment severely, to achieve this objective (Seckler, 2004). It is necessary to improve water use in agriculture and transfer it to other sectors, reducing domestic food production and importing more food, especially in context to these arid and semi-arid regions.

Rajasthan is the largest state in India, which stands at a very critical juncture due to its alarming decrease in ground water levels. As surface water potential is not promising and rainfall is very less, there is increased dependence on ground water for meeting almost all types of water requirements. Rajasthan has been classified into various climatic zones based

on the average annual rainfall (Figure 1.1), and the details of the rainfall is provided in Table 1.1.

Figure 1.1. Climatic Zones of Rajasthan

Table 1.1. Classification of the area based on average annual rainfall (in mm)

S. No.	Area	Category	Rainfall
1	IA	Arid Western	200-300
2	IB	Irrigated North Western Plain	100-350
3	IC	Hyper Arid Partially irrigated zone	100-350
4	IIA	Internal drainage dry zone	300-500
5	IIB	Transitional plain of Luni basin	300-500
6	IIIA	Semi-Arid Eastern plain	500-700
7	IIIB	Flood prone Eastern plain	500-700
8	IVA	Sub humid Southern plain	500-900
9	IVB	Humid Southern	500-1100
10	V	Humid South Eastern plain	650-1000

(Source: Rajasthan Agriculture Competitiveness Project, 2012)

At present, the stage of groundwater development for Rajasthan is 125%, which is significantly higher than the national average value of 58% in India. This, not only results in rapid decrease of groundwater levels but also in the deterioration of groundwater quality. Moreover, the state has the lowest average annual rainfall (504 mm) in India. Groundwater is the major source for irrigation (71%) and domestic (90%) needs in the state (Rathore M. S. 2005).

Indiscriminate use of underground water for different uses has depleted the ground water to the level of over exploited category. The agriculture in the state started transforming in sixties and seventies due to advent of electrification and green revolution. Due to high use of natural and artificial resources, the production and productivity noticed a marked increase. Though, the development of tube well irrigation has contributed significantly to the increase in food production and reduction in poverty, sustainable development and management of this resource has posed many challenges in recent years. Major problems associated with the ground water development and management are over exploitation of ground water, water logging and salinity, ground water pollution, and lack of precise evaluation of ground water potential. Continual debate on falling water table and deteriorating soil health has prompted general public, farmers, scientists and policy makers to rethink. This research has made an attempt to be an ambitious endeavor in the direction of groundwater sustainability, particularly in terms of quality and quantity.

A preliminary study has been carried out in Bikaner district of Rajasthan, which lies in the western part of Rajasthan between 27.11' 29.03' N to 71.54' 74.22' E, with a total area of 30381 sq. km. It comes under the category of hyper-arid zone receiving a few precipitations (100-350 mm) all through the year. Most of the area is underlain by highly permeable and

well drained sandy to sandy loam soils, which is coarse in texture. Domestic and irrigation needs of the district are completely met by groundwater alone. A number of pumping wells has reached to a drastic number with a total of 1399 for drinking purposes and 11868 for irrigation uses in the year 2013-2014. Because of this, the district is facing an acute shortage of groundwater resources with the stage of groundwater development for the study area as high as 146.66%. In the year 2009, the Central Ground Water Board reported that most of the water quality parameters are well beyond their permissible limits specified by the World Health Organization (W.H.O.) (CGWB, 2009).

1.2 RESEARCH MOTIVATION

Remarkable depletion of groundwater resources in northwest India, especially in Rajasthan, is the main motivation behind this research work as the depleting groundwater also indicates deteriorating water quality. Northwest region i.e. Bikaner district in Rajasthan is facing severe water scarcity and quality issues since decades. A very few studies have been undertaken in the region and therefore the issues related to the water sector have not been fully addressed in the research domain. Quantity and quality both matters while fulfilling the demand for various purposes such as drinking, irrigation and for industries. Talking about quantity, Bikaner district is facing severe water scarcity and the quality parameters are also beyond safe limits as prescribed by WHO and BIS (Bureau of Indian Standard). Hence it was essential to assess the groundwater resources of the region both quantitatively and qualitatively. Due to overexploitation of groundwater, the water table in the region has dropped to critical levels and the groundwater quality issues have become prominent. The major health hazard related to groundwater is its salinity which has affected most of the area and the situation becomes critical in summer and draught conditions. Thus it was essential to explore and evaluate the

groundwater resources with the help of modern tools and techniques, so that the precious natural resource can be managed in a sustainable way.

1.3 OBJECTIVES OF THE STUDY

An extensive literature survey and in person meetings with hydro-geology expertise and persons from agricultural department and university were carried out to point out the various groundwater related issues and its effect on various activities. Based on the literature survey and expert opinions thus obtained, the following objectives were formulated:

- Study and assess the various groundwater quality parameters.
- Study the qualitative aspects of groundwater particularly hyper-arid region of Rajasthan.
- Outline the spatio-temporal aspects of groundwater, its potential and quality using Remote Sensing and GIS (Geographic Information System) methodologies in the western arid regions of Rajasthan.
- Develop a groundwater sustainability index based on the status of groundwater resources, it's health, availability, infrastructure, and its impact on population.
- Assess the environmental vulnerability due to excessive use of groundwater resources in the hyper arid region using life cycle assessment (LCA) approach.

1.4 RESEARCH SIGNIFICANCE

Groundwater and its importance for the existence of mankind cannot be overemphasized. It is the main source of freshwater for drinking as well as irrigation in India. As an integral part of hydrological cycle, its occurrence solely depends upon precipitation and recharge. The demand for fresh groundwater has drastically increased over the years, which has left most of

the regions in the world as water scarce regions. The situation is becoming worst due to anthropogenic contaminations. Improper management practices and degrading environment are the key factors which will transform India into a freshwater scarce region and will lead to inaccessibility to potable water to millions of people. In the recent past, the groundwater level in several areas is drastically going down due to overexploitation in the absence of strict regulating policies and controlling measures. Private drilling for groundwater extraction has been drastically increased to a critical number for fulfilling the various needs. Ever changing lifestyle and intense competence among various sectors are the key driving forces in lowering down the water table to a critical level. The quality of groundwater is also getting worse due to widespread surface pollution and leachate from improper disposal of solid and semi-solid waste. Many parts in India are endemic to various human health hazards such as fluorosis, nitrate related syndromes and are getting adversely affected due to contamination of groundwater resources. Considering the above said quantitative and qualitative issues related to groundwater, the study would play a key role for policy makers and to create mass awareness among the stakeholders.

1.5 ORGANIZATION OF THESIS

Chapter 1 presents the outline of the thesis and introduces the broad areas of the study undertaken and the need for the various research activities in context to suitability, potential, and sustainability of groundwater resources in the hyper-arid region of Rajasthan, India. in the area of groundwater quantity and quality management. It also highlights the objectives, scope and details of thesis organization.

Chapter 2 provides a literature review of groundwater, its management, and sustainability aspects. It discusses the historical and current practices to be followed in groundwater management in general and to assess quantity and quality of groundwater specifically. On the basis of literature review gaps in the existing research are identified and suitable research objectives are formulated.

Chapter 3 focuses on assessing the groundwater quality using multi criteria decision making (MCDM) tools and its suitability for drinking as well as irrigation suitability. The MCDM used in the chapter have capabilities to assess groundwater quality characteristics of large regions with robust dataset. However, in case of low quality data use of remote sensing and GIS can be useful tools.

Chapter 4 presents the application of remote sensing and GIS based techniques in developing groundwater potential maps for the study area and assessing the spatio-temporal aspects of groundwater.

Chapter 5 presents a composite groundwater sustainability index comprising of various groundwater sustainability indicators. The groundwater sustainability index can be easily used by the policymakers to develop suitable groundwater management policies.

Chapter 6 presents an analysis of environmental vulnerability due to the extraction and use of groundwater in the region, particularly for irrigation purpose. The hotspots are identified in the study can support the mitigation process for reducing the environmental impacts. The environmental impact assessed in the study are significantly important and are considered negligible by the government officials when devising suitable groundwater management plans.

Chapter 7 provides the conclusions of the current research work along with limitations and future scope.

The objectives set for this research work are quite essential for groundwater management especially in hyper arid region, which are explored further through comprehensive literature review as discussed in subsequent chapter of this thesis work.

1.6 Bibliographical note

Parts of Chapters 3, 5 and 6 appear in the following journal papers:

- Bhakar, P., & Singh, A. P. (2018). Life cycle assessment of groundwater supply system in a hyper-arid region of India. *Procedia CIRP*, 69, 603-608.
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