CHAPTER 1
INTRODUCTION

1.1 Introduction

Water is the most indispensable resource after air for the existence of life on planet earth. Population explosion, urbanization, rapid industrial development and increase in demand for agricultural practices have put a continuous pressure on this natural resource. Trends indicate that water usage has almost doubled against population rise in the past hundred years with more than 80% accounting for irrigation in the developing countries (UN, 2006). It is estimated that by 2050, about two-third of total population of the world will be living in water scarce areas (Wallace, 2000). As per Government of India report (2009), the per capita availability of water in India has decreased from 5177 cubic metre (cum) per year in 1951 to 1545 cum in 2011. It is expected that water availability will further drop down to 1341 cum by 2025 and to 1140 cum in 2050 as shown in Fig. 1.1. The widening gap between availability and requirement poses a threat to poverty reduction, ecological sustenance and sustainable economic development in many developing countries (UNDP, 2006). Therefore a balance is to be maintained between demand and supply for sustainable development of water resources under natural climatic variability as well as long term climate change (Morehouse, 2000).

The estimated freshwater present on the earth is $37\text{Mkm}^3$ out of which about 22% exists as groundwater and constitutes about 97% of all liquid freshwater potentially available for human consumption (Foster, 1998). Thus groundwater is the largest source of fresh water on planet earth excluding the polar icecaps and glaciers.

Usage of groundwater has increased at an alarming rate in recent years and indications are that this trend will continue (Todd and Mays, 2005). In India, more than 90% of the rural and nearly 30% of the urban population depend on groundwater for meeting their drinking and domestic requirements (Reddy et al., 1996). The most drastic change in groundwater scenario of India is that the share of tube wells in irrigated areas has increased from a mere 1 percent in 1960-61 to 40 percent in 2006-07 which clearly
Fig. 1.1: Water availability per capita – from past to future (Source: Government of India report, 2009)

indicates the growing dependency of households on tube wells (CGWB, 2011). The volume of groundwater pumped out by these structures for irrigation accounts for 91% of the total groundwater draft of India while the share of domestic draft is 7% and 2% is the industrial draft (CGWB, 2011a). Vagaries of monsoon and intensive agricultural practices over the years have resulted in excessive withdrawals of the groundwater than the natural recharge. This unchecked extraction has sparked off the declining of groundwater levels with severe consequences such as drying of wells, reduced yield and even complete failure of shallow tubewells, increasing installation costs of pumping wells, higher vulnerability to droughts and salinity intrusion (Chatterji et al., 2009).

India is the world's largest groundwater user in terms of both absolute volumes pumped and total number of users. An increasing trend of over development has been observed (Scott and Shah, 2004). The stage of groundwater development of the country is 61 percent which is not uniform in all the regions. It has been found very high (more than 100 percent) in the north-western region (Delhi, Haryana, Punjab and Rajasthan) (CGWB, 2011). The continuous and uncontrolled development of groundwater in this region has lead to the depletion of groundwater table. A recent assessment by NASA
showed that during 2002 to 2008, three states (Punjab, Haryana and Rajasthan) together lost about 109 km$^3$ of groundwater leading to a decline in water table to the extent of 33 cm per annum (Rodell et al., 2009). Groundwater decline rate in case of Haryana has been estimated about 35 cm per annum (Chatterjee and Purohit, 2009). Hence, it becomes more important to assess the groundwater source so that an optimal utilization of this precious resource could be planned on a sustainable basis. The major requirement for planning is the quantification of groundwater availability and demand. This data will give an idea about the level of groundwater development and gap between the demand and supply of groundwater at block level, on the basis of which the management practices could be implemented to check further decline of groundwater table.

One of the very important measures taken for groundwater management is the groundwater recharge by which water percolates down the soil and reaches the water table, either by natural or artificial methods. Surface water harvesting is the most common practice being practiced in the country since ancient times. Water stored in these surface storage structures gets lost due evaporation. Also during rainy season water drains into rivers and is not available for use in other months of the year. Thus there is need for artificial recharge where surface water can be directed to aquifer by constructing some suitable structure according to terrain conditions. Recently a number of studies have focused on sites election process for artificial recharge of groundwater using hydrogeological parameters and integrated approach of remote sensing and GIS techniques (Saraf and Chaudhury, 1998; Anbazhagan and Ramaswamy, 2002; Ghayoumian et al., 2005; Ravi Shankar and Mohan, 2005; Chowdhury et al., 2010). Several researchers (Saraf and Jain, 1993; Krishnamurthy et al., 1996; Punithavathi et al., 2011) demonstrated successfully in their study that an integrated remote sensing and GIS platform is best suited for convergent analysis of large volume of multidisciplinary data and decision making for groundwater studies. Researchers (Saraf and Chaudhury, 1998; Kumar et al., 2008; Chowdhury et al., 2010) used remote sensing and GIS techniques and attempted to select suitable sites for artificial recharge. In all these studies researchers have used hydrogeological parameters such as soil, lithology, physiography, land use/landcover, topography slope, drainage density, lineament density, aquifer transmissivity etc. which were integrated in GIS environment using spatial modeling
techniques to identify suitable zones and sites for artificial recharge. Each theme was
assigned an importance (weightage) by experts depending upon its influence on
groundwater recharge. Assignment of weights to different themes and their features is
subjective and depends upon the experience of the domain expert and preference of the
decision maker. No method could be standardized as such for this. Chowdhury et al.,
2010 computed normalized weights for different parameters and their features using
Saaty’s analytical hierarchy process (AHP) for West Medinipur district in West Bengal to
suggest potential sites for artificial recharge.

1.2 Research Gap

In all the studies conducted on suitability analysis for groundwater recharge, the main
focus has been on the assignment of weightage (importance) to the available
hydrogeological parameters contributing to groundwater recharge. Assignment of
weights to different themes or factors (and their different features) by different
researchers is subjective and area specific and therefore cannot be used for different study
area unless the hydrogeological conditions are similar. The final output largely depends
upon the assignment of weights to different parameters and how these different thematic
layers are combined. Experts too sometimes find difficult to assign proper relative
importance to different factors and their features from recharge point of view
(Chowdhury et al., 2010). Therefore there is need to suggest a methodology for site
suitability for artificial recharge of groundwater that overcomes the problem of weight
assignment. Further, except a few (Saraf and Chaudhury, 1998; Chowdhury et al., 2010)
most of the studies in India have been conducted in hard rock terrain. Northern India in
general and Haryana in particular has not been explored for such studies. Therefore,
regions with different hydrogeologic settings also require such studies in this field
especially where water levels are declining.
1.3 The Problem

District Yamuna Nagar is agriculture dominated area with total cultivable area of approximately 137 thousand hectares. Due to limited canal water supply in the region and due to capricious nature of south-west monsoon in India the availability of surface water cannot be ensured in right quantity at the required time. Therefore the main source of irrigation in the district is groundwater. Intensive agricultural practices and existing cropping pattern of paddy-wheat and sugarcane has put tremendous pressure on groundwater resources. Increased use and limited recharge have contributed to the lowering of the water table so much that yields of many dug wells and tube wells have reduced substantially or even fallen to zero. Lowering of the water table has forced the farmers to add more pumps and replace diesel pumps with electricity operated pumps to extract water from deeper depths. Overexploitation of groundwater from deeper aquifers has not only increased the cost of irrigation but also resulted in further aggravating the problem of declining water table in the district. Although various state and government agencies have been monitoring the groundwater conditions in the region, but the gravity of the problem requires a detailed, systematic, sophisticated and powerful approach to assess and analyse the available water resources in the district for sustainable development and management of groundwater resource. This also requires identifying suitable sites for artificial recharge of groundwater so as to retard and arrest further decline of groundwater levels.

1.4 Objectives

In the backdrop of the above sited overview, preamble, discussions and information, the main objectives of the present work are:

- To make the quantitative assessment of groundwater resources in district Yamuna Nagar.
- To examine the exiting methods for targeting suitable sites for artificial recharge using integrated Remote Sensing, GIS and Decision Support System (DSS) Technique.
- To use neural network techniques for suggesting suitable sites to resolve the bottleneck in weight estimation for artificial recharge of groundwater.
1.5 Practical utility of the study

The present research has assessed the availability and demand of water resources. The information thus acquired will help the planners and policy makers to design an appropriate water resource development plan for the district to eliminate the prevailing imbalance of water resources. Moreover, the study will also help in making the judicious and sustainable use of water resources. The results of the present study can serve as guidelines for planning future artificial recharge projects in the study area in order to ensure dependable water supply and sustainable groundwater utilization on a long-term basis.

1.6 Organization of the chapters

The research work reported in the present thesis is arranged in seven chapters each covering important aspects of groundwater assessment. The introductory chapter (Chapter 1) outlines the general introduction highlighting an overview of assessment and issues pertaining to groundwater resources at global, national and regional scale. The chapter also highlights the objectives and scope of the study, justifying the need for this research work. Recent literature on groundwater evaluation in terms of quantity and quality, use of Remote Sensing and Geographical Information System in groundwater studies has been reviewed in chapter 2. The general features and characteristics that govern the groundwater prospects of study area are briefly described in chapter 3. Assessment of the dynamic groundwater resources of the area is done in chapter 4. Chapter 5 explains GIS database creation and adopted methodology for delineation of recharge sites in the area using spatial multi-criteria and neural network modeling. Chapter 6 contains the selection and grouping of criteria for suitability map for artificial recharge and results obtained by spatial multi-criteria and neural network modeling are compared. Based on these observations and ground truth information, suitable locations for artificial recharge are suggested. Chapter 7 presents the conclusions and recommendations.