CHAPTER-1

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1.1 PREAMBLE

Water is perhaps the most vital resource for many aspects of a healthy and stable environment. It is essential for sustaining all forms of life, food production, economic development, and for general well being. It is impossible to find substitute for most of its uses, difficult to de-pollute, expensive to transport, and it is truly a unique gift to life form from nature. Water is also one of the most manageable of all the natural resources as it is capable of diversion, transport, storage, and recycling. All these properties of water impart its great utility for human beings. The surface water and groundwater resources of the country are being utilized for agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities, etc.

It is now a well-recognized fact that water is a finite and vulnerable resource, and it must be used efficiently and in an ecologically sound manner for present and future generations. Presently, only about 17% of the world’s available land (260Mha) is covered under irrigation and the rest 83% depend upon only on rainfall and are thus prone to seasonal or prolonged water deficits and droughts.

In recent years, water availability has become a problem in many countries of the world. In most cases, climate change has been an additional stress that compounds the impact of long-running stresses due to human activities. Activities, such as urbanization and irrigated agriculture, have adversely affected water availability across the world. As surface water becomes a limiting factor in water availability, it is common for groundwater to be seen as an alternative perhaps unlimited source. This poses the challenge to scientists in effective management of such limited recourses.
1.2 WATER RESOURCES OF INDIA

Rainfall in India is dependent on the south-west and north-east monsoons, on shallow cyclonic depressions and disturbances and on local storms. Most of it takes place under the influence of south-west monsoon between June and September except in Tamil Nadu, where it is under the influence of north-east monsoon during October and November. India is gifted with a river system comprising more than 20 major rivers with several tributaries. Many of these rivers are perennial and some of these are seasonal. The rivers like Ganges, Brahmaputra and Indus originate from the Himalayas and carry water throughout the year. The snow and ice melt of the Himalayas and the base flow contribute the flows during the lean season. Lal (2001) mentioned that more than 50% of water resources of India are located in various tributaries of these river systems. Average water yield per unit area of the Himalayan Rivers is almost double that of the south peninsular rivers system, indicating the importance of snow and glacier melt contribution from the high mountains.

Apart from the water available in the various rivers of the country, the groundwater is also an important source of water for drinking, irrigation, industrial uses, etc. It accounts for about 80% of domestic water requirement and more than 45% of the total irrigation in the country. As per the international norms, if per-capita water availability is less than 1700 m$^3$ per year then the country is categorized as water stressed and if it is less than 1000 m$^3$ per capita per year then the country is classified as water scarce. In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m$^3$ and these are projected to reduce to 1401 and 1191 m$^3$ by the years 2025 and 2050 respectively.

India receives annually an estimated precipitation of about 400 million hectar meter (Mham) of which about 70 Mham is lost to atmosphere as evaporation and about 115 Mham which soaks in to the ground about 165 Mham is retained as soil moisture allowing 50 Mham to be stored as ground
water. In addition, lateral seepage of 5 Mham from irrigation systems and 30 Mham from rivers and streams together constitute about 85 Mham of groundwater. Countries annual exploitable groundwater potential is about 42.3 Mham. At present the groundwater utilization in the country is 13.5 Mham of which about 85-90% is used for irrigation and remaining used for other purposes.

Bulk of the minor irrigation programme in the rural India is achieved through groundwater development. Groundwater system provides an instant and reliable source of irrigation. Nearly 50% of crop area under irrigation (68 Mham) is irrigated through groundwater. This dependence on groundwater became a necessity owing to the high cost and long time required to construct major irrigation project and dams, as well as from environmental consideration.

1.3 WATER RESOURCES IN KARNATAKA

The State has diverse hydrogeological conditions mainly occupied by Peninsular gneisses, granites, schists, basalts along with sedimentaries. The hard rock terrains mainly sustain dug wells and bore wells.

The average annual rainfall received by the state is 1138 mm which suggests that the availability of water through precipitation is adequate. However, the level of average rainfall differs among different regions leading to uneven distribution of water availability. In the eastern part of the state, the average annual rainfall is only 569 mm while that of the western part is 4092 mm. In other words, the west-flowing rivers of the state receive relatively higher amount of rainfall while the east flowing rivers receiving relatively lower amount. Therefore, there exists a distributional discrepancy in relation to water availability in different regions of the state. Even within the 'water abundant' regions, non-availability of water for economic use poses serious problem. It is estimated that around 80 percent of the water resources in the west flowing rivers is not utilizable for any economic use because of difficulties in constructing storage reservoirs.
CGWB has assessed the groundwater potential during 2009 (CGWB 2011) in 270 assessment units in command and non-command areas and has categorized 71 as Over-exploited, 11 as Critical, 34 as Semi-critical, and 154 are Safe. The Over-exploited assessment units are concentrated in the north western part of the State particularly in Belgaum and Bagalkot, south eastern part of the State in the districts of Bangalore Rural, Bangalore Urban, Kolar, Chikaballapur, Ramanagaram, and Tumkur and in the central districts of Koppal, Bellary, Chitradurga and Davangere.

Approximately 58% of the water resources are found in the west flowing rivers where, a large percentage of water could not be harnessed for any effective use. Altogether, it is estimated that in the state, only 1695 TMC of surface water could be ‘economically utilizable’ for irrigation purpose. In the case of groundwater, it has been estimated that 485 TMC of groundwater is available in the state. However, the distribution of groundwater and its exploitation are not uniform throughout the state. A substantial amount of groundwater is found in the coastal areas, which cannot be effectively utilized. The situation with the groundwater is also not satisfactory. The Department of Mines and Geology, GoK has identified 56 watersheds (out of 380 in the state) in the state as ‘overexploited’ watersheds where the rate of exploitation of groundwater is found to be greater than the rate of recharge.

The yield of the bore wells ranges from 2 to 3 lps. The recent alluvium is restricted to coastal area and stream courses. Tube wells in the coastal alluvial deposits in general yield from 10 to 14 lps.

1.4 WATER RESOURCES IN UDUPI DISTRICT

This coastal agro climatic west flow river basin is characterized by maritime climate. It covers parts of Mulki, Shirva, Swarna Yennehole, Madisala, Sita, Haladi, Chakra, Kollur, Baindur and Sankadagudi hole sub basins. These rivers are perennial during normal rainfall years where as tributaries and smaller streams become dry during summer. The prevailing high gradient in the hilly terrain and heavy rainfall brings great volume of
water in these rivers during monsoon. These rivers join Arabian Sea and are prone to tidal effects to considerable lengths in the inland area. Udupi district is essentially an agriculture district with more than 80% of population depends on agriculture for their livelihood where as only 40% of the total geographical area of the district is used for agriculture. Rest is either forest land or land unsuitable for agriculture.

Agriculture is confined mainly to the valley area and is by and large confined to the traditional Kharif cultivations depending on the monsoon. Paddy is the main crop raised by 75% of the cultivated area in Kharif season. The other crops are chillies, sweet potato, ginger and vegetables. In Rabi season, paddy, chilies, black gram and green gram are raised. Pulses are raised during dry season. The crops raised during summer are limited with chief crop being sugarcane, groundnut, paddy and sweet potato. Plantation crops include coconut, cashew nut, areca nut and pepper. Cardamom is also grown in valley areas.

There is no any major irrigation scheme in Udupi district. The minor irrigation schemes include both surface water and ground water schemes. The ground water schemes consists of Dug wells, Shallow and Deep tube wells, while surface water schemes includes surface flow (tanks, anicuts, barrages) and lift irrigation schemes. Lift irrigation is the major irrigation practice. Water management practices like sprinkler irrigation is taking popularity in Udupi district.

Ground water in the region mainly occur in various geologic formations like beach alluvium, coastal sediments, laterites and in weathered and fractured granitic gneisses under phreatic and semi-confined to confined conditions, but mainly under water table conditions. Coastal alluvium along with the laterites, which underlie them, occurs as an aquifer of phreatic nature. Ground water occurs in weathered mantle and fractured crystalline formations under semi confined to confined conditions. The ground water that occurs in and below the black clayey horizons of coastal
sediments are highly saline. This marks the index bed for saline water and fresh water interface. Dug wells are the most common groundwater abstraction structures encountered in lateritic terrain.

1.5 WATERSHED DEVELOPMENT

A river basin is a natural entity for planning beneficial users for available water from precipitation, which are highly variable in space and time. Often some parts of basin are surplus in availability, while other face deficit (Sharma, 2002). Presently, only about 17% of the world's available land (260Mha) is covered under irrigation and the rest 83% depend upon only on rainfall and are thus prone to seasonal or prolonged water deficits and droughts.

Integrated watershed development program has been conceived and adopted for holistic development of rain fed farming in recent years. Watershed management is fast becoming a blue print for agricultural development in most parts of the country today. This program aims at conserving soil and moisture, as well as to put the lands to use according to their capabilities to improve the overall productivity of catchment. The major objective of the project is to increase / stabilize production of crops, forage, fruits, fuel and timber in rain fed areas by introduction of improved soil and moisture conservation measures; better crop and rangeland management practices, animal husbandry and afforestation. The ultimate goal of watershed management is to achieve and maintain a balance between resources development for welfare of the population and to safeguard resources for future exploitation to maintain ecological diversity - both for ethical reasons and as an assumed prerequisite for the survival of mankind.

Watershed as a unit for developmental planning is the natural choice of present time. The sustainable development of natural resources in a watershed is based on maintaining the fragile balance between productivity functions and conservation practices through monitoring and identification of critical areas, existing agricultural practices, crop rotation, energy efficient
farming methods and reclamation of under utilized lands. Watershed management is fast becoming the blueprint for dry land agriculture development in our country. This programme aims at conserving soil and moisture, as well as to put the lands to use according to their capabilities to improve the overall productivity of the catchment. The major emphasis is on increase of food production, reduction in regional disparity between irrigated and dry land / rainfed areas, increasing employment opportunities and restoration of ecological balance within watershed through integrated approach. The goal of watershed development is to sustain the agriculture production without land degradation. Under watershed development, suitable measures are recommended for stabilization and improvement of drainage system, construction of soil and water harvesting structures, wasteland reclamation to establish vegetation cover, agro-forestry and agro-horticulture development etc.

1.6 ROLE OF RS & GIS IN WATERSHED MANAGEMENT

Remote sensing (RS) can be defined as the observation of targets or processes from a distance (without physical contact), in contrast to in situ measurements wherein measuring devices are in touch or immersed in the observed system and/or process. This is a broad definition, but this term usually refers to the gathering and processing of information about earth's environment, particularly its natural and cultural resources, through the use of photographs and related data acquired from an aircraft or a satellite (Simonett, 1983). Thus, remote sensing is not just a data-collection process; rather it also includes data analysis: the methods and processes of extracting meaningful spatial information from the remotely sensed data for direct input to the geographic information system.

Remote Sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in exploring, evaluating, and managing water resources. Satellite data provide quick and useful baseline information about
the factors controlling the occurrence and movement of groundwater like geology, geomorphology, soils, land use/cover, drainage patterns, and lineaments. Structural features such as faults, fracture traces and other such linear or curvilinear features can indicate the possible presence of groundwater.

Geographic information system (GIS) has emerged as an effective tool for handling spatial data and decision making in several areas including engineering and environmental fields. Remotely sensed data are one of the main sources for providing information on land and water related subjects. These data being digital in nature, can be efficiently interpreted and analyzed using various kinds of software packages. It is easy to feed such information into a GIS environment for integration with other types of data and then do analyses. The combined use of remote sensing and GIS is a valuable tool for the analysis of voluminous hydrological data.

Keeping these developments in the watershed management and potentials of latest technologies like Remote Sensing, Geographical Information System and Global Positioning System in mind the present research work is intended to study the soil and water quality and its compatibility with crop and to prioritization of sub-watersheds as well as identification of suitable sites for soil and water conservation measures. Hence, “Integrated Hydrological Studies of Sitanadi Basin, Udupi District, Karnataka” is taken-up.

1.7 OBJECTIVES OF THE PRESENT STUDY

The main objectives of the study are to:

1. Create a database for the basin.

2. Understand the spatial and temporal variability of rainfall in the basin.

3. Find out the relationships between the morphometric parameters and hydrological parameters.
4. Assess the physico-chemical characteristics of groundwater and physical as well as fertility status of soils in the basin.
5. Assess the soil-water-crop compatibility in the basin.
6. Generate natural resources layers viz., current land use/land cover, soils, hydrogeomorphology, slope, drainage etc.
7. Prioritization of sub-watersheds for water resource development using remote sensing and GIS techniques.
8. Identify suitable sites for soil and water conservation measures by integrating resource maps in the GIS environment using a set of decision rules.

1.8 BRIEF DESCRIPTION OF THE CHAPTERS

The thesis work is presented in seven chapters, the contents of which are highlighted as follows:

Chapter I explains the availability of water resources in India, Karnataka and in Udupi district, watershed management, role of Remote sensing and Geographic Information System in water resource management. It also covers objectives of the present study and brief description of the chapters.

In Chapter II, location, physiographic features and geological formations of the study area are discussed. Meteorology and hydrology forms Chapter III. It deals with temporal variation of temperature, relative humidity, wind speed, sunshine hours, and pan-evaporation in the study area. Rainfall data collected in different stations are analysed and to know the spatial and temporal variations across the basin are being discussed as well the methodology followed.

Morphometric analysis carried out for the Sitanadi basin and its sub-watersheds are discussed in Chapter IV. Morphometric parameters and their variation in different sub-watersheds of fourth order are discussed with respect to surface and groundwater availability.
Water and soil quality forms Chapter V. For evaluating the groundwater quality in Sitanadi basin for drinking and irrigation purpose methods adopted/proposed by various researchers are followed. Statistical analysis has been carried out to know the Groundwater quality index and to know the groundwater type in the study area during different seasons. Chemical and fertility status of the soils are also discussed along with soil-water-crop compatibility.

Various thematic maps prepared using IRS-1D LISS IV images of 2009 period are used for prioritization of sub-watershed by different methods. In the basin, sites identification for construction of water and soil conservation structures are also discussed in Chapter VI on Remote Sensing, GIS and Spatial Data Analysis.

In Chapter VII, summary and conclusions drawn on the basis of overall study are highlighted.