Integrated study of bennethora catchment area by using geographic information system (GIS) and remote sensing (RS)

Vinod.T *, S.G.Patil **

*Student, Department of Civil Engineering (M.Tech Environmental Engineering), P.D.A College of Engineering,
Gulbarga, Karnataka state, India
**Professor, Department of Civil Engineering, P.D.A College of Engineering,
Gulbarga, Karnataka state, India

Abstract

The catchment area requires a host of inter-related information to be generated and studied in relation to each other. GIS (geographical information system) and RS (Remote sensing) is used in this study. ArcGIS 9.2 and ERDAS 8.5 has been applied to analyze terrain characters, to determine potential of water capacity and computing the geographical references data, which add new dimensions to environmental management for a part of Bennethora catchment area in Gulbarga district, Karnataka and is located between longitude 17°27'33"North and latitude 76°58'16"East.The Bennethora river is major tributary of river Kagina which in turn is a tributary to Bhīma in Krishna basin. The study area covers 1577 sq.km in Karnataka region. The thematic maps of catchment area have been generated. The check dams and percolation tanks are proposed at catchment area.

KEY WORDS: Topography, Catchment area, GIS (geographical information system) and RS (Remote sensing).

I. INTRODUCTION

During the last three decades there has been drastic change in the geo-hydrological scenario of the State leading to the degradation of land and water resources. The reason for such change is both natural processes and human interventions. Irregular frequency of the hydrological processes like rainfall, runoff and ground water recharge are primarily due to vagaries of nature posing a serious challenge to water managers in fulfilling the water demand.

India has a vision to be a full developed and industrialized country by the year 2020. With respects, the infrastructures provision is now become a major consideration to develop widely in the country. In order to achieve the vision, the government is still confronting with one main enigma and obviously referred to the water resources system, especially in protection and the distribution process. This situation become critical in 1987 where 60% of Gulbarga city mostly are residential consumer experienced a very painful insufficient water supply until the government imposed a water-transporting program to the consumer.

However, the overexploitation of water resources has resulted in a condition of un-sustainability and environmental degradation. The information on spatial and temporal availability of water will be helpful for the optimum utilization of water resources. Hence, there is an urgent need to analyze the geo-hydrological process, to analyze terrain characters leading to the catchment area and obstacles for ground water recharge.

Hence, there is an urgent need to analyze the geo-hydrological process, to analyze terrain characters leading to the catchment area and obstacles for ground water recharge. Such a comprehensive and integrated study to evolve set of action plans for rejuvenation of irrigation system, warrants to use of frontier technologies like Remote Sensing (R.S) and Geographical Information System (G.I.S) techniques.

OBJECTIVE:

To address it, this study describes on

i. The application of GIS as a new technique of approach to determine the potential   water catchment area of Bennethora reservoir.

ii. To provide an opportunity to compute processing of geographically references data, which add new dimension on environmental planning, management and development.

ii. To understand the geo-hydrological process to analyze terrain characters.

iv. To generate thematic maps.

v. The drainage patterns of the catchment.

vi. To determine potential sites for check dams and percolation tanks.

II. LITRATURE REVIEW

A. **Sharifuzan Haji Anuar** (International Islamic University, Malaysia).He reported that Malaysia has a vision to be a full developed and industrialized country by the year 2020. In order to achieve the vision, the government is still confronting with one main enigma and obviously referred to the water supply system, especially in the generation and the distribution process. This situation becomes critical in 1998 where 80% of Klang Valley area mostly is residential and industrial consumer experienced a very painful insufficient water supply until the government imposed a water-rationing program to the consumer. Thus, according to Department of Forestry of Selangor State, the water problem mostly caused by illegal logging, uncontrolled agricultural land opening and illegal or unsuitable industrial site location includes harvesting activities which, eventually at the end altering and declining the existing and potential water catchment areas.

To address it, this paper describes on the application of GIS as a new technique of approach to determine the potential of water catchment areas in Selangor State and to provide an opportunity to computer processing of geographically references data, which add a new dimension on environmental management and planning development. [1]

B. **V.K.Srivastava** *(Dept. of Applied Geophysics, Jharkhand)*.He reported that water is an important natural resource, which is available both on surface as well as in recharge zone of weathered layer and in various other suitable water reservoir formations/structures below the surface. As the availability of surface water is erratic and irregular one needs to study and map the underground water reservoirs. Dhanbad district of Jharkhand state is in general part of hard rock terrain, which is mainly covered by Chottanagpur Granite Gneissic Complex and has no perennial river sources for water supply. Therefore, in view of the upcoming industrialization in the region there is need to exploit groundwater resource, which is limited and confined to fractured and weathered zones. Even though the region receives copious rain, the terrain and soil condition allows little storage of water. Hence, the region faces shortage of water in dry seasons.

Therefore, it is necessary to explore and study the ground water resources effectively using suitable techniques. Various workers have successfully applied Remote Sensing technique in exploration, evaluation and management of ground water

resources in an area as a whole and the results have been published. In this paper also mapping and management strategies for ground water resources have been studied, by analyzing IRS LISS II multi band remote sensing data along with geological as well as geophysical resistivity sounding data carried out at places in GIS environment. Finally, based on the integrated thematic maps, weighted analysis in Arc GIS ground water resource prospect map of the area has been prepared and discussed. The study has brought out that the high groundwater potential zones are confined along lineaments and in pediment areas. Also alluvial fills, valley fills form potential zones. The other geomorphic units like buried pediplain, pen plains and denundational hills form zones of moderate to good groundwater prospects. Dissected pediments, inselberg complex, undulating upland and buried pediment with intermontane valley are zones of poor prospects. Very poor regions occupy a small part of total study area and are mainly confined to undulating upland and residual hills.

Geologically it is observed that the groundwater is mainly confined to secondary porosity i.e. fractured zone, fault, joint and weathered column. It is observed from field survey and also from various wells located in the region the hard granite gneisses and Meta basic dykes sometimes act as barriers for the groundwater flow in the region. [2]

C. **SREENIVASULU et.al,** *(J&K 2001)*.He reported that Estimation of Catchment Characteristics using Remote Sensing and GIS Techniques an attempt has been made to evaluate the physical characteristics of the Devak Catchment up to Gura Slathian in Jammu region of Jammu and Kashmir (J&K), India. The results of the study are useful for further findings the Devak Catchment there is no existing network of hydro meteorological observation. The slope, order of streams was also determined. The estimated catchment characteristics and relationships are useful to simulate hydrological response of the catchment. [3]

D. **MAIDMENT** *(UNIVERSITY OF TEXAS)*.He reported that *"Arc Hydro GIS for Water Resources"* is a data structure that links hydrologic data to water resources modeling, designed by the Center for Research in Water Resources at the University of Texas at Austin. Arc Hydro software is used with Arc Map for water resource modeling. Arc Hydro is an extension for ESRI ArcGIS

software, used for Watershed delineation, stream network generation and surface water flow tracing. The Arc Hydro Tools can be used to perform the different functions like terrain preprocessing stream burning, sinks filling, flow direction and flow accumulation calculation, stream definition, stream segmentation, catchment delineation, drainage point processing, etc.[4]

E. **J.P. SINGH,** *(UTTARANCHAL).*A case study was conducted to identify the suitability of potential sites for groundwater recharge structures in Bandal watershed, Uttaranchal, using Remote Sensing (RS) and Geographical Information System (GIS). Watershed concept was used for conserving excess water during monsoon period and storing in water harvesting structures such as check dams, percolation tanks and farm ponds. The check dams were constructed across the ephemeral streams to intercept runoff and storing it for optimum utilization. These structures were found to significantly help in raising the water table from 0.3 m to 2.5 m in wells at different locations. It also emerged that these structures would differ due to variations in location, land slope, soil type, rainfall, land cover and settlements. Sites for 8 check dams, 86 groundwater recharge structures (percolation tanks) and 15 farm ponds and check dams were identified covering an area of 449,531 m^2, 449,531 m^2 and 36,448 m^2, respectively.[5]

III. MATERIALS AND METHODS

The study will be fully conducted by utilizing GIS related software's which are chosen due to their ability to produce map, to manage data and to operate analysis which is capable to edit and create analysis within a shorter time in map development (which is crucial in planning environment).

A. Remote Sensing (RS)

Remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed. The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The output of a remote sensing system is usually an image representing the scene being observed.

B. Geographic Information System (GIS)

A geographic information system is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. "Every object present on the Earth can be geo-referenced", is the fundamental key of associating any database to GIS. Here, the term 'database' is a collection of information about things and their relationship to each other and 'geo-referencing' refers to the location of a layer or coverage in space defined by the co-ordinate referencing system. The figure.1 gives the simplified meaning of GIS.
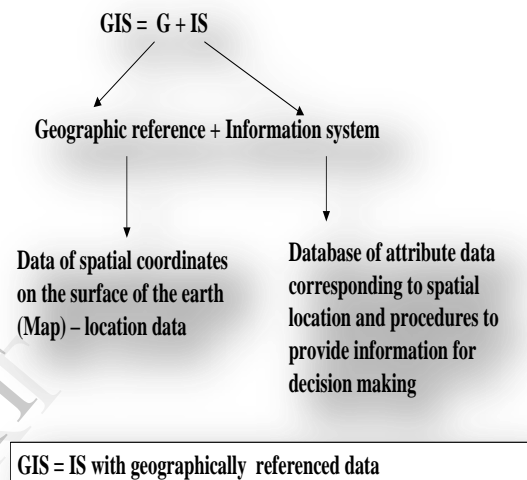

Figure.1: Meaning of GIS

C. Data representation by Vector and Raster Models

GIS can create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions. GIS works with two fundamentally different types of geographic models, the "**vector**" model and the "**raster**" model. The vector data structure organizes spatial feature by the set of vectors, which are specified by starting point co-ordinates, while raster organizes spatial features in regular spaced grid of pixels. (Table 1)

Table 1. Data Model Types

Vector Data Model	Raster Data Model
Based on geometry of	**Digital Representation as Grid Cells**
➢ Point	➢ Satellite Images
➢ Line	➢ Aerial Photographs
➢ Polygon	➢ Digital Elevation Models (DEM)

D. DATABASE OF GIS

Basically there are two types of data in a GIS input.

   i.   Spatial data

   ii.   Non Spatial data or attribute data

Spatial data includes information such as latitude and

longitude for geo-referencing, the features on a map like soil units, administrative districts etc. Analog maps of topography, land use map, soil profile map, geology etc. are the main building units of the input. Other spatial data include aerial photos and satellite images.

Non Spatial or Attribute data involves information of agriculture, industry, economy, population etc as shown in below table. (Table 2)

Table 2. Spatial and Non Spatial Data

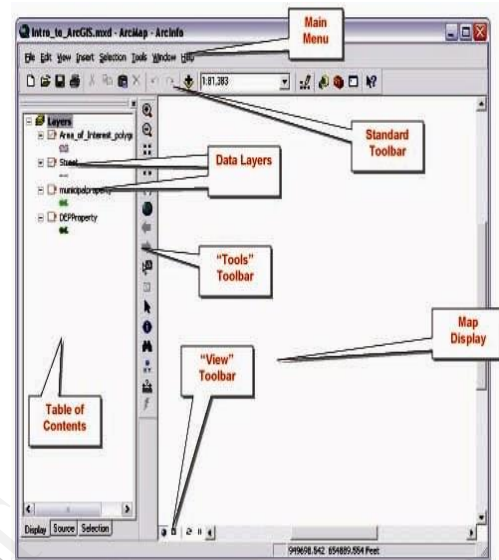| Spatial Data	Non-spatial Data
✓ Topography	✓ Descriptive Attributes
✓ Land Use Land Cover	
✓ Soil	✓ Soil Type
✓ Water bodies	✓ Land Use Type
✓ State, District, Blocks	✓ Village Name
✓ Villages	✓ Street Name
✓ Forests	
✓ Geology	
✓ Road Network	

E. Software scenario

   i.   ArcGIS 9.2

   ii.   ERDAS 8.7

ArcGIS is a suite consisting of a group of geographic information system (GIS) software product produced by Esri.

ArcGIS is a system for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.

The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the web.

Figure2: Overview of ArcGIS 9.2

   i.   ArcReader, which allows one to view and query maps created with the other ArcGIS products.

   ii.   ArcGIS desktop, is licensed under three functionality levels:

   iii. Arcview, which allows one to view spatial data, create layered maps, and perform basic spatial analysis;

   iv. ArcEditor which, in addition to the functionality of Arc View, includes more advanced tools for manipulation of shape files and geo databases; or

   v.   ArcInfo which includes capabilities for data manipulation, editing, and analysis.

GIS software provides the functions and tools needed to store, analyze, and display geographic information. GIS software's in use are ARC/Info, MapInfo, AutoCAD Map, etc. software overview is shown in figure 2.

ERDAS IMAGINE 8.7 is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in geographic information system (GIS) or in Computer Aided Design and Drafting (CADD)

software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions.

By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc. Other usage examples include linear feature extraction, generation of processing work flows ("spatial models" in ERDAS IMAGINE), and import/export of data for a wide variety of formats, ortho-rectification, mosaicking of imagery, and stereo and automatic feature extraction of map data from image.

F. Preparation of Thematic Maps

A map is a collection of map elements laid out and organized on a page. Common map elements include the map frame with map layers, a scale bar, north arrow, title, descriptive text, and a symbol legend. The primary map element is the map frame and it provides the principal display of geographic information. The map frame, geographical entities are presented as a series of map layers that cover a given map extent, for example map layers such as roads, rivers, place names, buildings, political boundaries, surface elevation and satellite imagery. The detailed methodology for generation of thematic maps is shown in below flow chart.
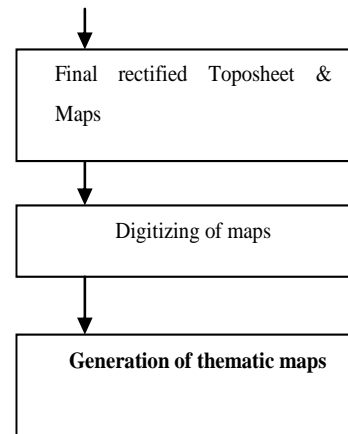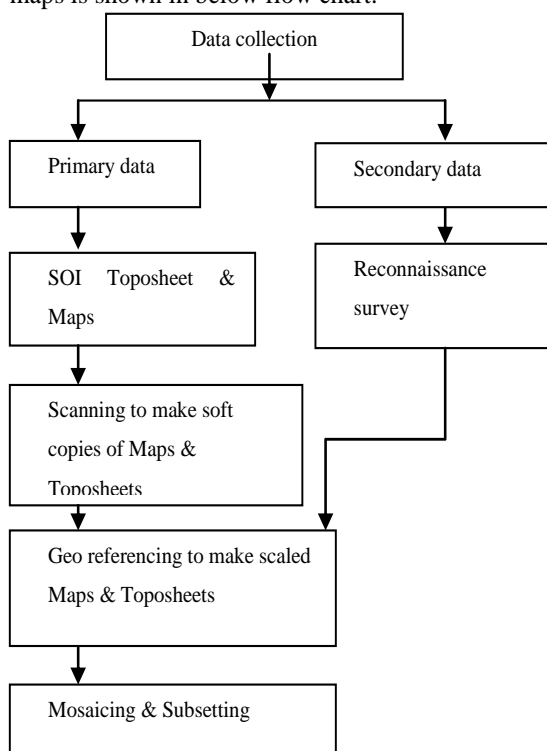
The detailed methodology has been explained below

Geo – referencing refers to the process of assigning map coordinates to image data. The image data may already be projected onto the desired plane, but not yet referenced to the proper coordinate system. Geo – referencing, by itself, involves changing only the map coordinate information in the image file. The grid of the image does not change.

Mosaicing, the project area pertaining to this project often spanned several image files. Hence, it was necessary to combine the images to create one large file. This technique is called Mosaicing**.**

Sub setting refers to breaking out a portion of a large file into one or more smaller files. At times, image files contained area much larger than a particular project area. In these cases, it was helpful to reduce the size of the image file to include only the Area of Interest (AOI). This is not only eliminated the extraneous data in the file, but it accelerated the processing due to the smaller amount of data to process. This was important even more because the project involved multiband data.

The steps involved in the digital image processing exercise have been given below:

i.   Registration of the PAN imageries with respect to SOI topo maps (1:400,000 scales) and maintaining a resolution of 5.0 m.
ii. Registration of the LISS III images with respect to PAN imageries and maintaining a resolution of 23.5m.
iii. Merging of PAN and LISS III imageries to obtain PAN+ LISS III merged data at a resolution of 5.0m.

iv. Mosaic-king and sub-setting of the merged data, wherever required, to generate the project area mosaics.

The above exercise generated the division's level mosaics from the satellite date which were subsequently subjected to reconnaissance survey and on screen interpretation to generate the preliminary maps. [6]

IV.RESULTS AND DISCUSSIONS
A. Study Area
The Bennethora River is major tributary of river Kagina which in turn is a tributary to Bhīma in Krishna basin. It takes its origin near Malegaon village in osmanbad district of Maharashtra state. After flowing for about 45 Kms in Maharashtra, it enters Karnataka state and flows for about 91 Kms over Aland, Gulbarga, and Chitapur and Sedam taluks of Gulbarga district and joins the river Kagina near Malakhed village in sedam taluka of Gulbarga district The Bennethora project comprise construction of a storage reservoir across river Bennethora near Herur K. village in the Chitapur taluka of Gulbarga district, with canal on either flanks, to provide irrigation facilities over an area of 20,234 ha. (50,000 acres) of land in Chitapur and Sedam taluks if Gulbarga district.

B. TOPOSHEET OF CATCHMENT AREA MAP

The SOI Toposheet of Bennethora catchment area is digitalized to scale 1:3, 00,000 is shown in below figure.4.1
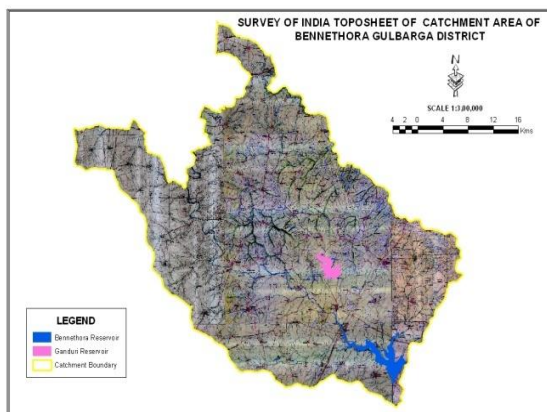

Figure4.1: SOI Toposheet of Bennethora catchment area

C. DRAINAGE MAP
The area has a dendritic drainage system having stream network upto 3rd order. The most common form of drainage system, dendritic systems form in V-shaped valleys as a result; the rock types must be impervious and non-porous is shown in below figure 4.2.
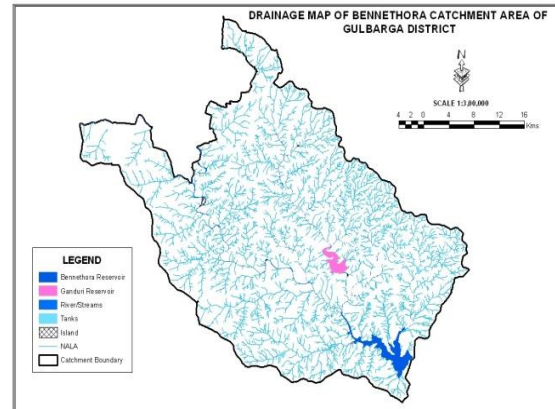

Figure 4.2: Drainage map

D. SLOPE MAP
Slope gradient is an angle of inclination of the soil surface from the horizontal. It is expressed in percentage, which is the number of feet rise or fall in 100 ft of horizontal distance. Slope gradient is important because it influence the rate at which runoff flow on the soil surface and erodes the soil. Slope shape (straight, concave or convex) and slope length are also important properties of soil surface. The infiltration capacity of the water below and above the surface and sub-surface soil depend on the slope, if the type of the slope is gentle the infiltration capacity will be less where as in the steep slope infiltration capacity will be less. The slope in the study area, majority area occupies moderately steep slope of 15-35% of area, strongly slope of 10-15% of area, rest of the area is moderate slope, gentle slope, very gentle slope and nearly level as shown in below figure 4.3.
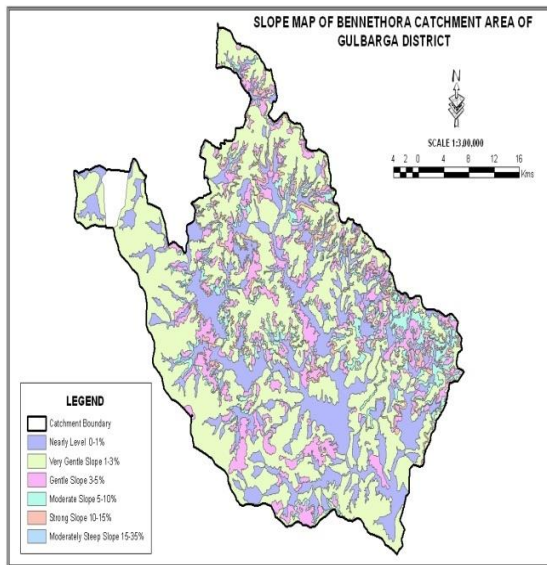
Figure 4.3: Slope map

E. CHECK DAMS MAP

As per Integrated Mission for Sustainable Development (IMSD) guide lines. The following criteria have been followed for making decision on selecting suitable site for water harvesting structures figure 4.4.

i.   The slope should be less than 15 per cent.
ii. The land use may be barren, shrub land and riverbed.
iii. The infiltration rate of the soil should be less.
iv. The type of soil should be sandy clay loam.
v.   The check dams are usually constructed on 3rd order stream.
vi. The Catchment area of 25 to 250ha and drain should be narrow.
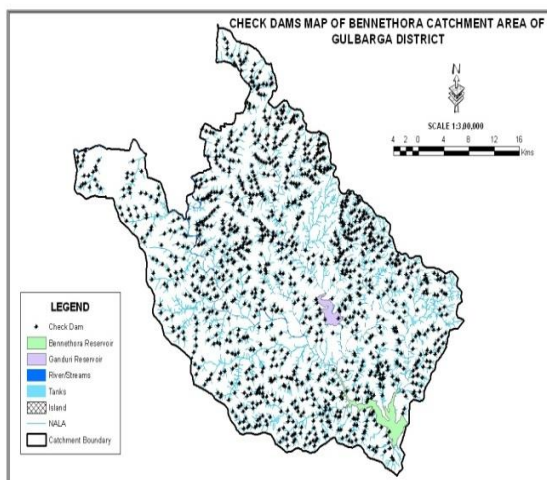vii. Adjacent to agricultural lands.

Figure 4.4: Check dams map

F. PERCOLATION TANK MAP:

The percolation tank map is shown below figure4.5, the percolation tanks were suggested on following criteria as per IMSD guide lines

i.   The catchment area upto 500 ha.
ii. Slope less than 2 per cent.
iii. Deep ground water table.
iv. Suggested for 2nd or 3rd streams.
v.   No salt-affected area around.
vi. The land use/cover may be barren or scrub land.

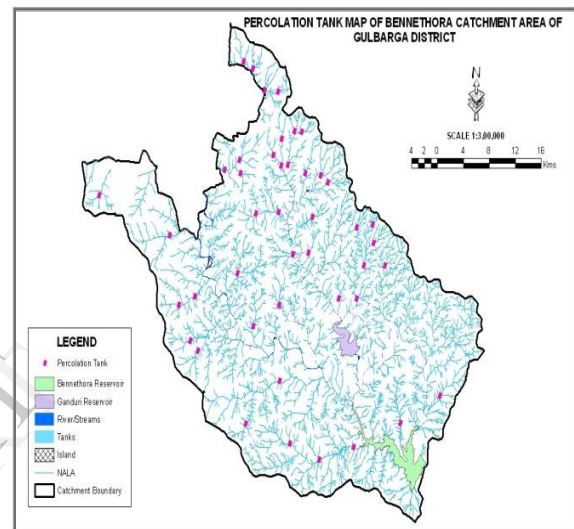
Figure 4.5: Percolation tanks map

V. CONCLUSION

As discussed above that integrated approach of GIS and RS can play very important role in the study of catchment area, planning and its development. With the development and availability of fast and efficient computer and hardware and software GIS and RS tools are going to have more vital roles in natural resources development and environment. The findings of the analysis have been used to develop a comprehensive Management Plan pertaining to the development of catchment areas for the selected districts with the highest degrees of sensitivities.

This study analyzed topography and hydrology characteristics of Bennethora region to determine surface water resources with potential use for irrigation. The Digital Terrain Model and hydrological analysis in GIS environment are suitable tools for calculation of catchment area, slope of the area and drainage pattern. The check dams and percolation tanks were suggested for ground water potential recharge.

The derived information could be very much useful for the administrative authorities to take certain measures in management of water resources in the study area and they can also performed certain decision making planning activities for construction of check dams and percolation tanks for improving water availability.

The linking of GIS with simulation of environmental considering heralds a new era in environmental management. Indeed, the multifaceted nature of the environment calls for a multi-disciplinary approach to better understand, monitor and manage it. But, the greater challenge is the very nature of the environment. The more we learn to model its complex structures and process, the more it yields of its complexities that demands even more integrated systems to model it.

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