Study of Gandorinala Catchment Area by using Geographic Information System (GIS) and Remote Sensing (RS)

Ashish Biradar[1] Dr.Shivasharanappa.G.Patil[2]
[1]Student [2]Professor
[1,2]Department of Civil Engineering
[1,2]P.D.A College of Engineering, Kalaburagi, 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 10.1 and ERDAS 8.7 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 Gandorinala catchment area in Gulbarga district, Karnataka and is located between longitude 17°35'51"North and 76°54'52"East. The Gandorinala is a medium irrigation project located near Belkota village in Gulbarga district in Karnataka State across river Gandorinala, a tributary to river Bennithora which in turn joins Bhima river of Krishna Basin. The study area covers 371 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), 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. The situation just open up the eyes of responsible departments and the role of planners become significant as such as to look after the comprehensive land use planning approach as a tool-kit to solve that problem. The water problem mostly caused by illegal logging, uncontrolled agricultural land opening and illegal or unsuitable industrial site location including harvesting activities which, eventually at the end altering and declining the existing and potential water catchment areas.

The demand for water is increasing with growing population and industrialization. Water supply is considered to be one of the key factors for rapid development and urbanization. However, the overexploitation of water resources has resulted in a condition of un-sustainability and environmental degradation. Hence, 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. 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.

A. Objective

To address it, this study describes on

1) To study the catchment area, planning and development.
2) To determine the potential sites for structure.
3) To improve the structure of lake source and water source.
4) To ensure the stream flow and quality discharge from the catchment area.
5) To improve ground water resources.

II. LITERATURE REVIEW

A. Emilio J. Magaia-Eduardo Mondlane University, Mozambique

The efficient management and use of water resources is a prime concern all over the world. This sometimes leads to scarcity creating an environment of tension and conflict, on the other hand excess of water can cause flooding and became a threat to the citizens. This research addresses the use of remote sensing to assess water storage in the reservoirs in Komati Catchment in the Incomati Basin. The objective of this research was to *Assess Water Storage* in the reservoirs located in the Komati Catchments and to use it as a trust building tool using remote sensing and GIS. Fieldwork was carried out to get data to calibrate the information from images. Reservoirs in the Komati Catchment were studied namely: Nooitgedacht, Vygeboom, and Driekoppies. The main input from remote sensing was the delineation of the reservoir area and estimation of water storage in the reservoir using the relation water surface area-water stage and water volume. The surface areas that were obtained from ground data and that from remote sensing were compared. The Normalized Difference Area Index and Percentage of Difference Area Index were used to compare the results. The study found that the area assessment in this reservoir could be done using remote sensing with an overall accuracy between 69-94 %. While the volume estimation showed that the remote sensing could estimate the volume in the range between 70 to 88%. [1]

B. Yaseen T. Mustafa and Mohamad J. Noori - University of Duhok, IRAQ

The use of satellite remote sensing (RS) has salient progress in water budget calculation and it performs in watershed management. An RS technique can properly enhance hydrogeologic surveys. Moreover, to have an intimate understanding of the changes in water level fluctuations, it is also important to relate them to the surrounding eomorphic, structural, climatic and geologic factors. This research serves twofold. The first one is to operationalize the use of RS and Geographic Information Systems (GIS) techniques to assess the change of water surface area in Duhok dam located in Duhok city, Kurdistan region-Iraq. The second is to present and interpret the available statistical data on water level fluctuations in Duhok dam. The change of water surface in the Duhok dam is examined over a 11 year period using satellite images taken between 2001 and 2012. The change is tracked from the images using Band 7 with the help of Normalized Difference Water Index (NDWI). The accuracy assessed by using the Normalized Difference Area index (NDAI), and the change in water surface area analysed by comparing it with the related meteorological data of the dam. Results show that the estimated water surface area by RS matches the one on the ground with small relative error (less than 2.15%). A decrease of slightly more than 23% was observed in the water surface area this 11 year period. In addition, over this time period, climate conditions (rainfall, temperature and evaporation) in the study area have been changed significantly. These changes could have affected the reservoir surface area, but so also could external human interference around the dam. [2]

C. K. Babu Govindha Raj –Ladakh, Jammu & Kashmir

Application of Remote Sensing and Geographic Information System in Groundwater Resource Management: A Case Study from Ladakh, Jammu & Kashmir. Leh district is situated at 32° 20’ to 35° 15’ North latitude and 76° 20’ to 79° 40’ East Longitude. It has an area of 45100 sq. km, major part of which is rugged hilly terrain occupied by glaciers and snowfields. The elevation varies from 5900 m to 8500 m above mean sea level. Regionally, the study area forms part of a major Himalayan mountain belt comprising Proterozoic to Recent formations. The soil type is characterised by sandy soil and hilly soils. Groundwater development in the district is in moderate scale and restricted to valley portions only. Many of the drinking water sources depend on the natural springs, rivers and nalas. As Leh is part of the Ladakh Cold 29 Desert’, freezing of water is a major concern during winter season. Snow water harvesting is also an artificial recharge technique which can be adopted in the district for augmenting the water. Spring development along major fracture zones can provide more groundwater in many hilly terrains. Check dam type recharge structures are suggested along the foot hill zones for recharging the groundwater. Valley fill deposits, river terraces and moraine deposits are the highly productive zones for construction of tube wells for water supply. Due to the high elevation and snow-melt runoff hydropower generating sites can be constructed at appropriate locations and the arrested water can be used for irrigation.[3]

D. Piyoosh Rautela - Indian Institute of Remote Sensing,- Dehradun India

GIS and remote sensing-based study of the reservoir-induced land-use/ land-cover changes in the catchment of Tehri dam in Garhwal Himalaya, Uttaranchal (India) Large dams, though necessary for national growth, adversely affect the life-support strategy of a large number of people living in the submergence zone and the hinterland of the reservoir. With the help of GISbased techniques and land-use/land-cover map prepared with the help of satellite remote sensing tools, it is estimated that the Tehri reservoir in the upper catchment of Ganga river would directly affect 2687 ha of agricultural land and another 3347 ha around the Under the reservoir rim would be rendered unfit for cultivation. GIS environment, a dam with 260.5 m height was simulated to assess the storage capacity of the reservoir as also the extent of the area that is likely to be impounded.[4]

E. D. Bagchi & R. Bussa – Dehradun

Application of Remote Sensing in Water Quality and Water Resources Management.A major factor in increasing agricultural production is development of irrigation practices, which in turn is essential for economic development of the country. In most of the Irrigation Command Areas (ICA) in India, the present scenario demands a more efficient water management programme. The ICAs in India suffer from problems of inadequate and unreliable water supply, wide gap between created and utilized irrigation potential, temporal imbalances of water demand and supply, excessive seepage loss and rise of groundwater table leading to water logging and salinity problems. Remote Sensing techniques can be immensely helpful in inventory of irrigated land, identification of crop types, crop extent, crop condition and estimation of crop yield, as demonstrated in various investigations in India and in other countries. Periodic satellite monitoring of Irrigation Command Areas has helped in evaluating increase in irrigation utilization and improvement in agricultural productivity over a period of time. Remote Sensing methods have been successfully applied in delineating saline and alkaline soils and detecting areas having ineffective water management practices leading to decrease in crop yield. Remote Sensing techniques are now increasingly applied in land use planning and in identifying areas suitable for sustained irrigated cropping with the help of “irrigability maps” prepared from satellite data. Vegetation Indices and demand-supply analysis is used in many Irrigation Command Areas in India to evaluate irrigation potential. Remote Sensing techniques have been successfully applied for performance evaluation of Mahi Right Bank Canal command with an area of 212,000 ha in Gujarat State (Ray et al., 2002). During this study, IRS-1C Linear Imaging and Self Scanning-III (LISS-III) and Wide Field Sensor (WiFS) data were used for calculation of Adequacy Index, Equity Index and Water Use Efficiency (WUE) for characterization of the Irrigation Command Area. The multi-temporal Remote Sensing data was finally used for crop inventory, generation of vegetation spectral index profiles and estimation of crop evapotranspiration.[5]

F. Arunangshu Mukherjee – Chhattisgarh

Identification of Suitable Area Using GIS Techniques for Artificial Recharge of Ground Water in Chhattisgarh State. Application of GIS technique to demarcate suitable areas for artificial recharge of ground water in Chhattisgarh by using six thematic layers namely i) decadal post monsoon depth to water level ii) decadal post monsoon water level trend iii) stage of ground water development iv) watershed v) geology and vi) geomorphology has brought out nearly 7049 sq.km area in 15 district in 23 isolated pockets. Total 456 mcm vadose zone is available for artificial recharge of ground water. These 23 identified areas were spread over 49 blocks and 15 watersheds. Out of these 15 watersheds 9 were from Mahanadi basin, where ground water development is maximum. The identified area needs 606 mcm of water to saturation, which is only3.6% of the available surplus runoff. For these 23 pockets, the total structure recommended are 1470 percolation tanks, 5050 cement plugs, 6060 gravity head recharge structures and 18180 rainwater harvesting structures. The construction of these structures required nearly 514crors of rupees and will generate peoples participation and rural employment. This also brings additional 87320 ha of land under assured irrigation and will enhance sustainability of ground water structures, particularly of hand pumps for drinking water supply.[6]

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.

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 coordinates, while raster organizes spatial features in regular spaced grid of pixels. (Table 1)

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)

Table 1: Data Model Types

D. Database of GIS

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

1) *Spatial data*
2) *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)

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

Table 2: Spatial and Non Spatial Data

E. Software Scenario

– ArcGIS 10.1
– ERDAS 8.7

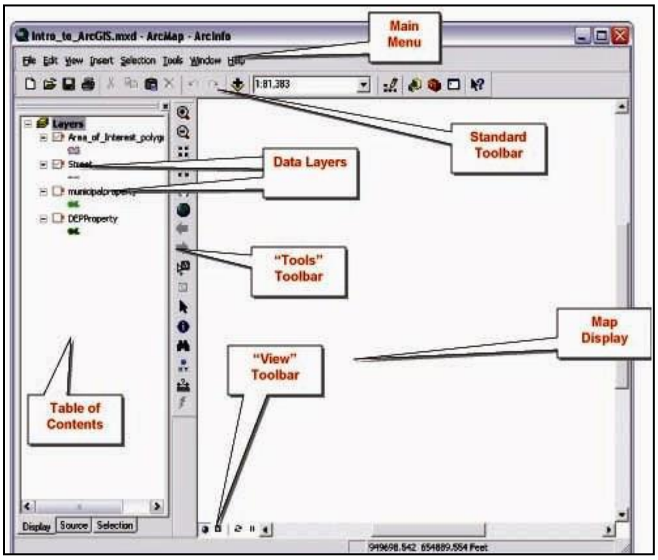

Fig. 1: Overview of ArcGIS10.1

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.

1) ArcReader, which allows one to view and query maps created with the other ArcGIS products.
2) ArcGIS desktop, is licensed under three functionality levels:
3) Arcview, which allows one to view spatial data, create layered maps, and perform basic spatial analysis;
4) ArcEditor which, in addition to the functionality of Arc View, includes more advanced tools for manipulation of shape files and geo databases; or
5) 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 fig.1

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 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:

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

IV. RESULTS AND DISCUSSIONS

A. *Study Area*

Gandorinala Dam is located near the Gulbarga city of Karnataka. This small but useful reservoir is built across the river Gandorinala that flows through the Krishna basin of Karnataka. The reservoir has been extending its services since the year 2002. It is a single-purpose dam built with the sole aim to provide water for the irrigation of nearby villages. The Gandorinala is a medium irrigation project located near Belkota village in Gulbarga district in Karnataka State across river Gandorinala, a tributary to river Bennithora which in turn joins Bhima river of Krishna Basin.

Gandorinala reservoir has a length of 1813.5 meters and a height of 24.27 meters. With full reservoir level (FRL) of 467 meters the maximum water level possible in the dam is 467 meters. This reservoir has gross storage capacity of 53.45 mcm.

The project comprises of the following components:

– An earthen dam 1800 m long and 24.27 m in height with a gross storage of 53.45 M Cum.

- Spillway on the right flank saddle comprising ogee weir 93.50 long with 8 crest gates of size 9.50 m x 6.00 m.
- Canal on right bank for a length of 7.00 km for irrigating 566 ha and left canal for length of 90.00 km for irrigating 7528 ha.
- The project, benefits 24 villages of Gulbarga & Chittapur taluks in Gulbarga district by providing irrigation to 8094 ha (CCA) in chronically drought prone areas.

B. Toposheet of Catchment Area Map

The SOI Toposheet of Gandorinala catchment area is digitalized to scale 1:135,000 is shown in below fig. 2

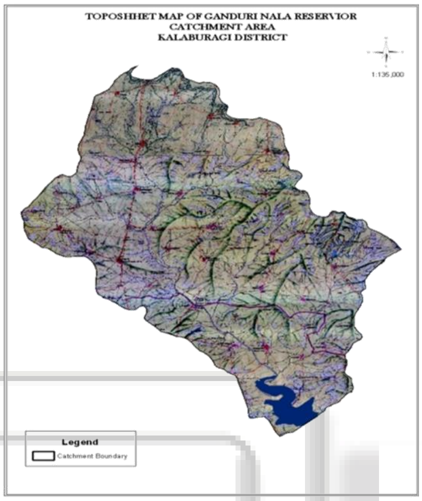

Fig. 2: SOI Toposheet of Gandorinala catchment Area

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 fig 3.

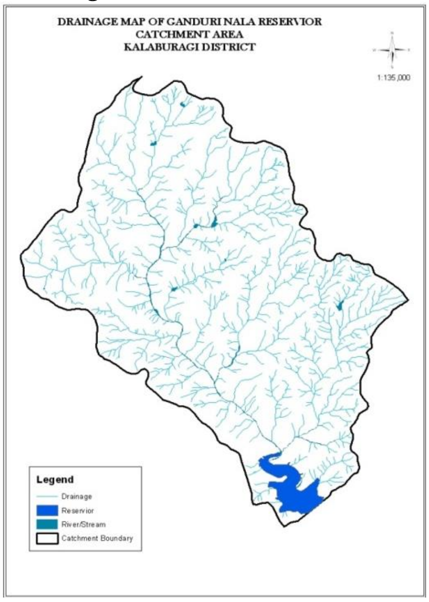

Fig. 3: Drainage Map

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.

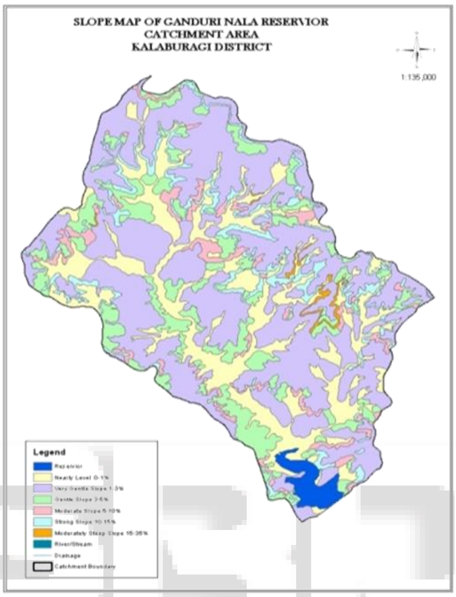

Fig. 4: Slope map

E. Contour Map

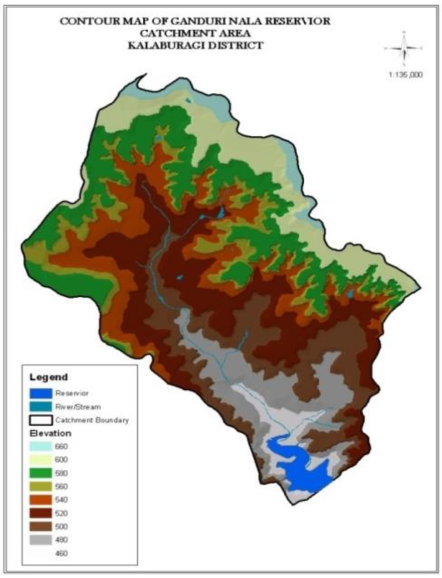

Fig. 5: Contour map

F. 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 5.

- The slope should be less than 15 per cent.

- The land use may be barren, shrub land and riverbed.
- The infiltration rate of the soil should be less.
- The type of soil should be sandy clay loam.
- The check dams are usually constructed on 3rd order stream.
- The Catchment area of 25 to 250ha and drain should be narrow.
- Adjacent to agricultural lands.

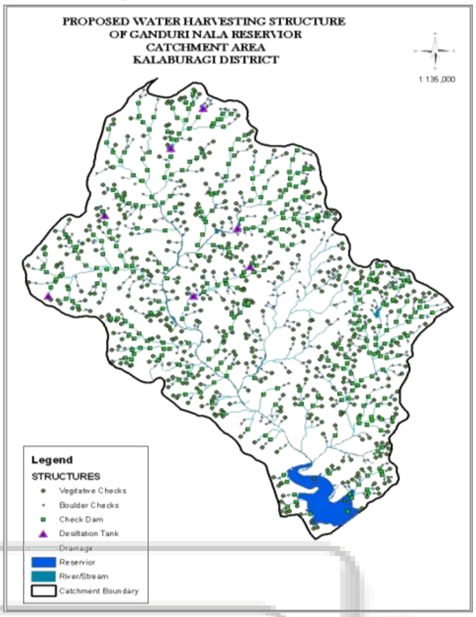

Fig. 6: Water Harvesting structures (check dams, boulder checks, check dams) map

G. *Percolation Tank Map*

The percolation tank map is shown below figure4.6, the percolation tanks were suggested on following criteria as per IMSD guide lines

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

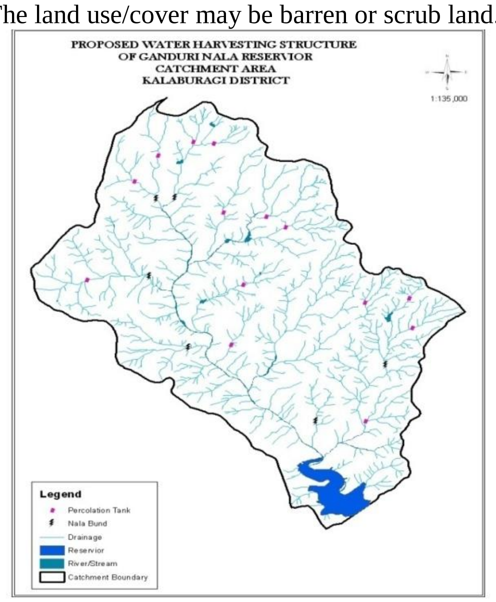

Fig. 7: Percolation Tanks Map

V. Conclusion

As discussed above that 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 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 Gandorinala region to determine surface water resources with potential use for irrigation. The Digitalization of Terrain and hydrological analysis in GIS environment are suitable tools for calculation of catchment area, slope of the area and drainage pattern. The check dams, percolation tanks, Vegetative checks, boulder checks were suggested for ground water potential recharge and soil erosion.

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 perform certain decision making planning activities for construction of check dams, percolation tanks and vegetative checks, boulder checks for improving water availability and resist soil erosion.

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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