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IDENTIFICATION OF LAND AND WATER RESOURCES DEVELOPMENT FOR A WATERSHED THROUGH GEO-INFORMATICS

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Abstract:—Land and water are the limited natural resources; those are most vital natural resource which needs to be utilized according to its potential. The land and water development area identify by the different thematic maps such as Land capability classification, Ground water prospect, Landuse/Landcover, Drainage density have been prepared for the watershed using modern technology viz. high resolution Remote Sensing data i.e. Cartosat-1 and LISS-IV merged satellite data, CartoDEM satellite data and other secondary data.

The watershed is selected from hard rock area i.e. in Bundelkhand region falls in Lalitpur district (Longitude 78º 38′ 15″ E – 78º 46′ 52″ E and Latitude 24º 35′ 1″ N to 24º 0′ 15″ N) Uttar Pradesh. The district in general deprived of groundwater and water is not sufficiently available for irrigation and other purposes. Main objective is identification of land and water resources development plan in the watershed by integrating the information obtained from various themes.

The integrated land and water development map is obtained for the watershed by integrating four thematic maps (Land capability classification, Ground water prospect, Landuse/Landcover, Drainage density) in terms of weighted overlay method using the spatial analysis tool in ArcGIS. Remote sensing techniques will improve the efficiency and speeding the process of resource evaluation and action plan measure.

Keywords—Watershed, Micro-watershed, Remote Sensing, LCC, DEM, Drainage Density, LISS, Integration.

I. INTRODUCTION

The demand for food, fuel, fodders, fiber, shelter, communication etc. are due to rampant growth of population and advancements in life style have tremendously increased. Those growing demands are putting the resilience of the natural resources base under threat. The vertical and horizontal expansion of production, to ensure food and water security is very much needed to be effective without degrading productivity. In view of those existing watersheds are to be givenimportance to develop further for improving productivity. Therefore it is needed proper management of watershed.

Watershed management is considered as the process of formulating and carrying out a course of action involving manipulation of natural, agricultural and human resources of the watershed to provide resources that are desired by and suitable to the watershed community but there should be condition that land and water resources are not adversely affected. It must consider the social, institutional factors and economic operating within and outside the watershed. Watershed planning is an interdisciplinary and integrated approach. The highly complex nature of human and natural systems, the ability to understand them and plan sustainable conditions using a watershed approach has increasingly taken a geographic dimension. Geo-informatics technology has played critical roles in all aspects of watershed management for assessing watershed conditions to visualizing impacts of alternative management scenarios.

Development through watershed approach is one such developmental option which can play a vital role in the country. Watershed management is the study of the relevant characteristics of a watershed, aimed at the process of creating and implementing plans and at the sustainable distribution of its resources and projects and Programme to sustain and enhance watershed functions that affect the plant, human communities and animal within a watershed boundary.

II. STUDY AREA

Lalitpur District is located in the Bundelkhand region which is extreme south-west part of Uttar Pradesh state of India.

The watershed located in central part of district (Fig.1) is part of Yamuna Basin and watershed code 2C2D3 included 28 villages in Mehroni block with in Mehroni tehsil of Lalitpur district. Watershed lies between longitude 78.6370 E to 78.7806E and latitude 24.5879N to 24.4815N covered by Survey of India Toposheet nos. 54L/10, 54L/11, 54L/14 and 54L/15 on 1:50,000 scale. Total area covered by the watershed is 86.46 km2.

In general, the relief is normal to excessive. Sub normal relief is seen in the narrow valleys. The **highest elevation** is 626 m while lowest elevation is 300 m. thus there is 326 m variation in the altitudes in the district.

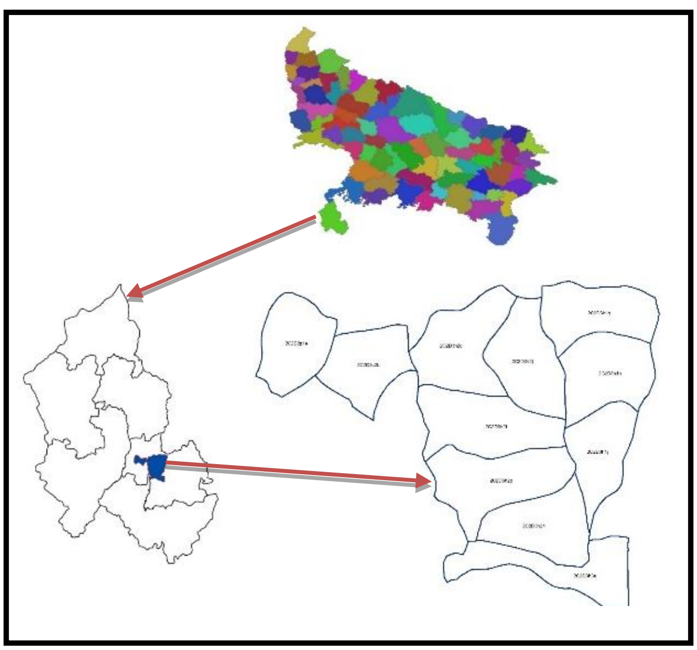


Fig. 1 Location Map

III. MATERIAL AND DATA USED

The following data have been in this study:

1. Survey of India Toposheet
2. High resolution satellite data
3. Field survey and GPS data
4. Micro Watershed Map
5. GIS Software etc.

Satellites are also produce high-resolution data almost the entire landmass on earth. The high resolution remote sensing data provides information on better spatial resolution.

IV. METHODOLOGY

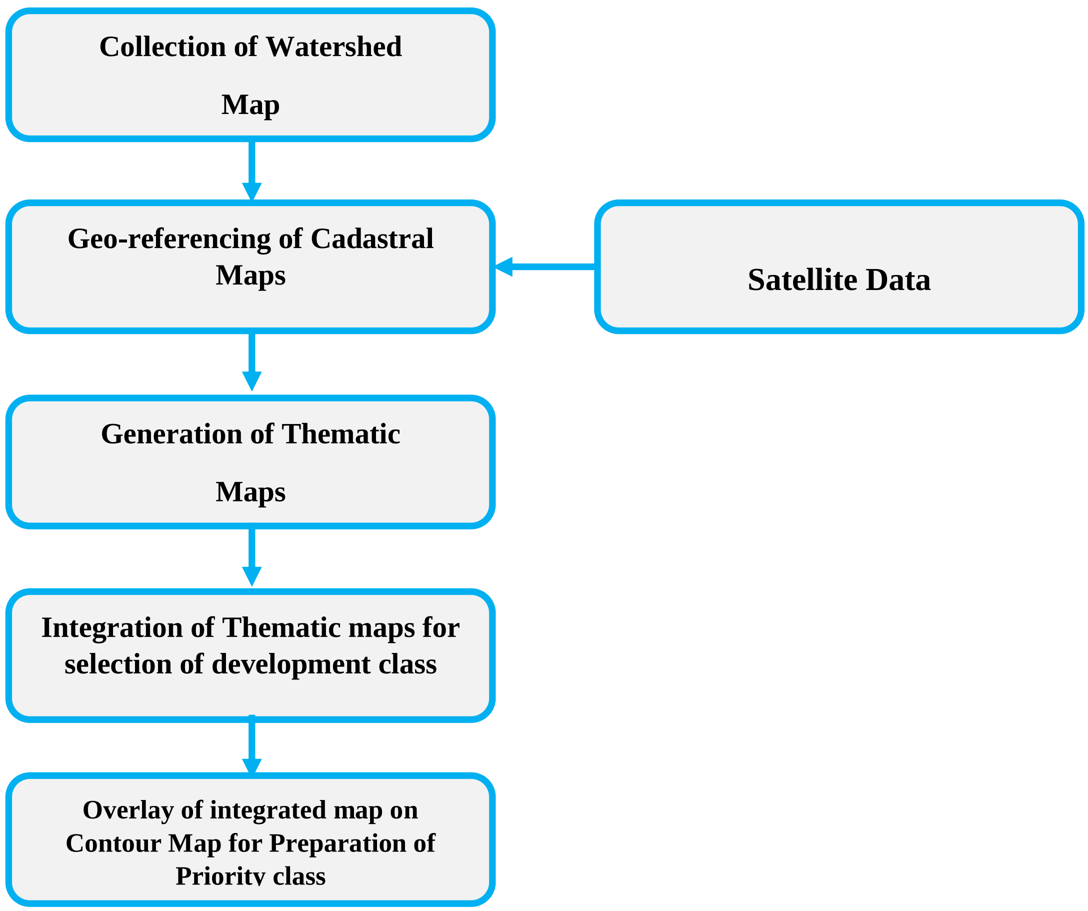


Fig. 2 Flow Chart of the Methodology

A. Preparation of Thematic Maps

Thematic map play an important role to understand the spatial nature and inter-relationship that exists between different resources [1]. Thematic maps viz., drainage, hydrogeomorphology, lineament, ground water prospect, landuse/land cover, soils, LCC, contour, slope, DEM, cadastral etc. have been prepared for the watershed using modern technology viz. high resolution Remote Sensing data and GIS techniques. Cartosat-1 and LISS-IV merged high-resolution satellite data, CartoDEM and other ancillary data were used. Arc GIS software is used during the entire course of work. The following steps were followed for the micro level mapping at cadastral villages. A flow chart is also prepared (Fig.2) for the support of Methodology.
Various thematic maps prepared are using the process described below-

1. Drainage Map

This map provides information on drainages, watershed boundary and distribution of surface bodies. Information on drainage like type, length, width, order and other information are derived on drainage morphometric to understand and characterize hydrological response of a watershed. Drainage map has been derived from SOI toposheets on 1:50,000 scale and updated with satellite imagery.

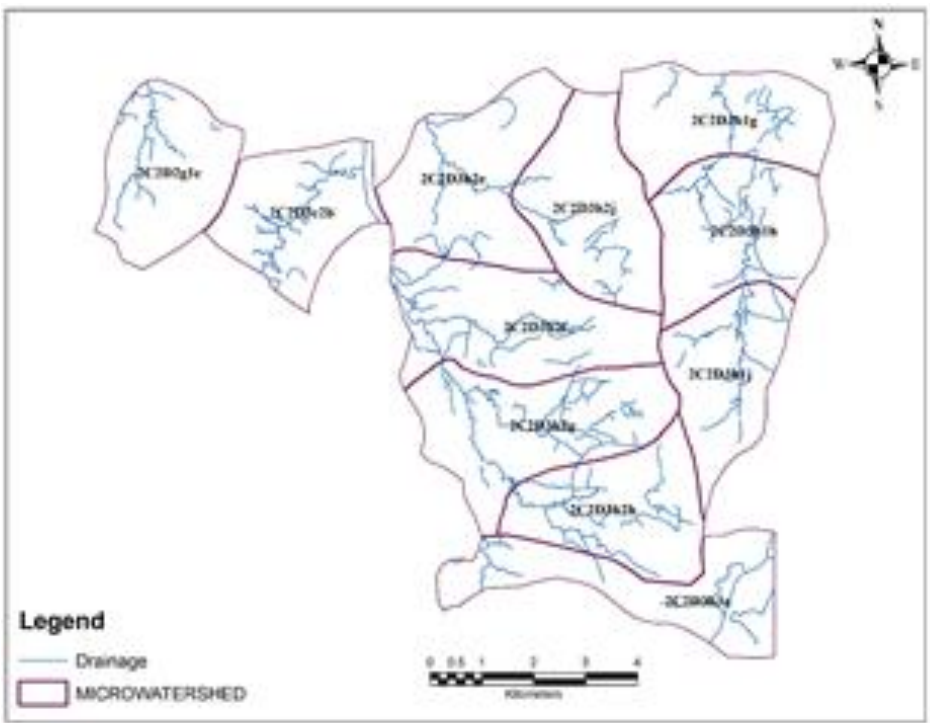


Fig. 3 Drainage Map

2. Drainage Density Map

The drainage density is an inverse function of permeability. The less permeable a rock is the less the infiltration of rain fall, which conversely tends to be concentrated in surface runoff. This gives rise to a well-developed and fine drainage system. Since the drainage density can indirectly indicate the suitability for groundwater recharge of an area because of its relation with surface runoff and permeability, it was considered as one of the indicators of groundwater potential [2]. Drainage density is defined as total stream length per unit area. More the density high would be the runoff. Drainage Density within watershed is grouped in to 6 classes: 0.002189-0.97515 km-1, 1.013252-1.891861 km-1, 2.0836-2.920055 km-1, 3.228813-3.917141 km-1, 4.038359-4.958146 km-1 and null value. The drainage and drainage density map shows (Fig. 3 &4 respectively) the flow of water throughout the study area. The suitability of groundwater potential zones is indirectly related to drainage density. (Sedhuraman M. et. al.2003).

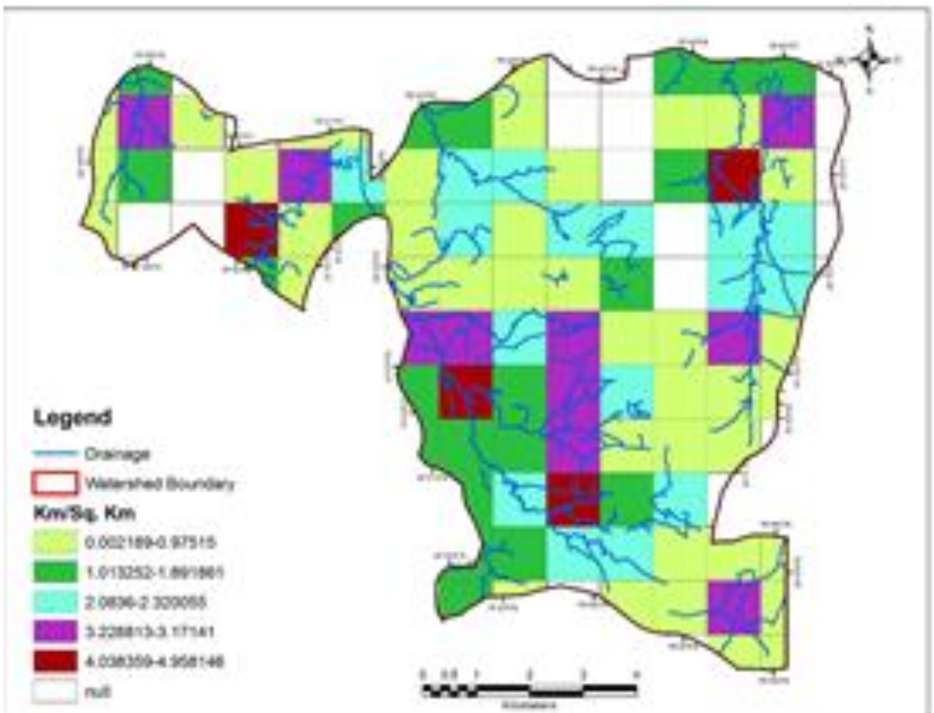
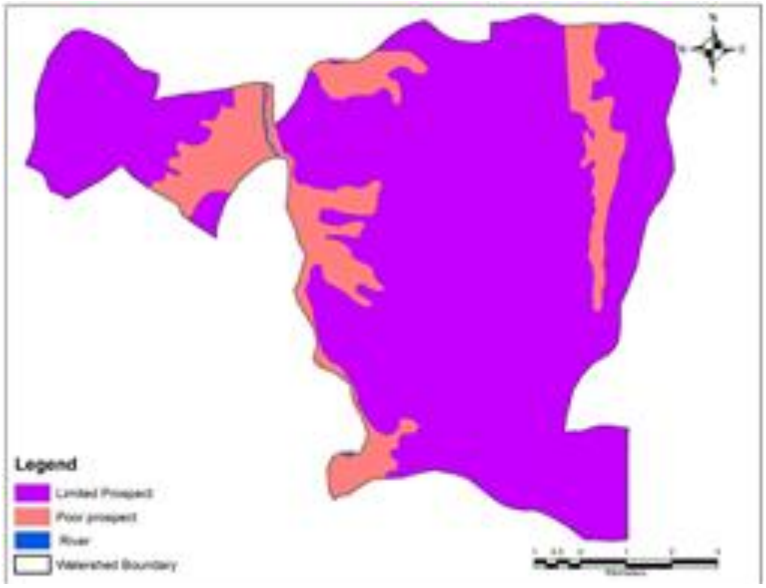


Fig. 4 Drainage Density Map

3. Ground Water Prospects Map

Various thematic maps were prepared under RGNDWM (Rajiv Gandhi National Drinking Water Mission) Phase-I project using satellite data with limited field surveys. Geological, geomorphological, structural and hydrological aspects have been studied to evaluate ground water prospects. The geological details like lithology/rock types and structural trend lines were delineated using geological maps and satellite data and incorporated on hydro-geomorphological maps to arrive at ground water potential zones. The ground water prospect map depicts zones which are Limited prospect and Poor prospect etc. In the project it has also indicates sites for recharging aquifers and water harvesting structures (Fig. 5).



Source: RSAC-UP

Fig. 5 Ground Water Prospect Map

4. Soil map

Ground truth of the entire study area is under taken to adjust the sample strips. Subsequently, in each sample strip, soil profiles, mini pits, auger bores etc., are studied along with morphological characteristics, existing land use/terrain parameters [3]. The information recorded systematically by noting the place of observation, topographic conditions, existing land use/land cover, geology of the area, physiographic unit, natural vegetation occurring in the area and morphological characteristics of the soils. The soil samples are collected from soil profile horizons with proper labeling to determine various soil properties later in the laboratory (Fig 5).

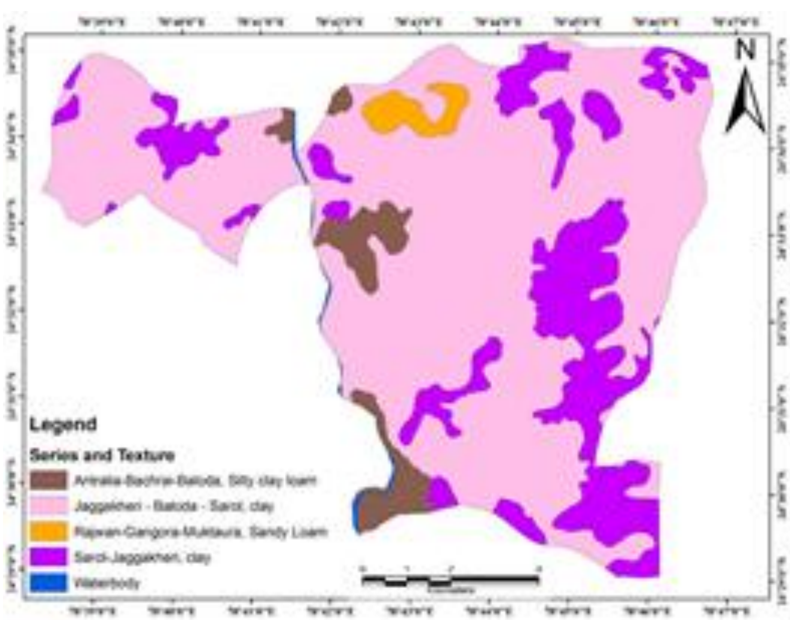
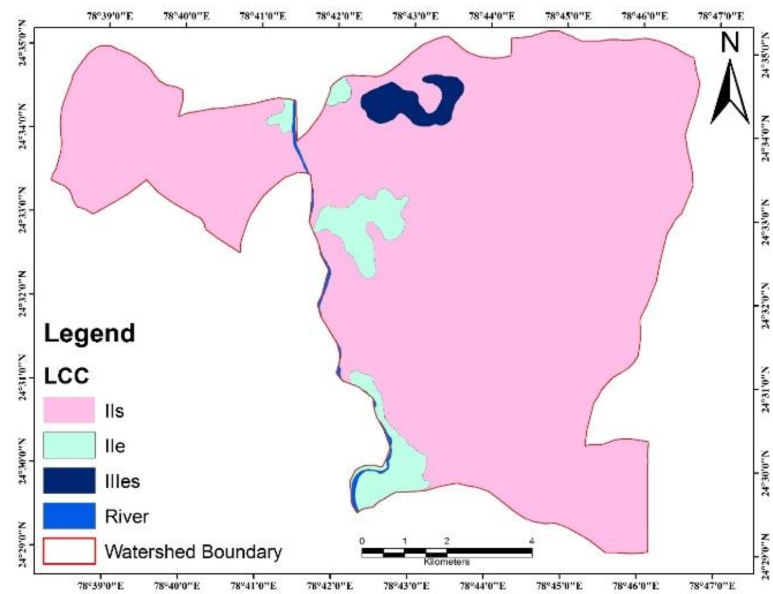


Fig. 5 Soil Map

5. Land Capability Classification Map

The land capability classification has been carried out by applying parameters like soil depth, soil texture, land use /land cover and slope of land. This information is used as a basis for placing lands in capability classes and subclasses. The information related with soil depth and soil texture about study region has been used from National bureau and soil survey and land use planning (NBSS and LUP) and thematic maps of the study region are created in Arc GIS software (Fig. 6).



Source: RSAC UP

Fig. 6 Land Capability Classification Map

6. LAND USE/ LAND COVER

Landuse/Landcover map is one of the most important input in integration process. To suggest any development activity, it is imperative to know the existing use and spatial distribution of that particular land. Landuse/landcover maps up to level III classification have been prepared using IRS LISS III satellite images of two different seasons especially for agricultural landuse. Kharif and rabi season imageries of October 2013 and February 2012 have been used to map the kharif and rabi crops respectively in the watershed. Standard image characteristic, i.e. colour hue, size, shape, texture, pattern, location, association etc. have been utilized to interpretation and field checks after interpretation were also carried out.

Major landuse/landcover categories identified and mapped in watershed are: built-up land, agriculture, forest, wasteland and water bodies. A digramatic representation of various landuse classes show in fig. 8. Brief descriptions of the different landuse/landcover categories are given as under:

Table- 1 Various Landuse/Landcover Categories

SI.No.	Landuse/Landcover	Area (Km^2)	Percent (%)
1	Barren Rocky/Stony waste land	0.11746565	0.135846308
2	Fallow Land	2.069526	2.393351841
3	Kharif	8.546271	9.883535377
4	Rabi+Kharif (Double Crop)	7.873848	9.10589604
5	Land with Scrub	5.995019	6.933080241
6	Rabi	59.448921	68.75109758
7	Reservoir	1.130104	1.3
8	River	0.366364	0.597633555
9	Scrub Forest	0.853862	0.302090799
10	Settlement	0.410081	0.050723013
11	**Total**	**86.469777**	**100**

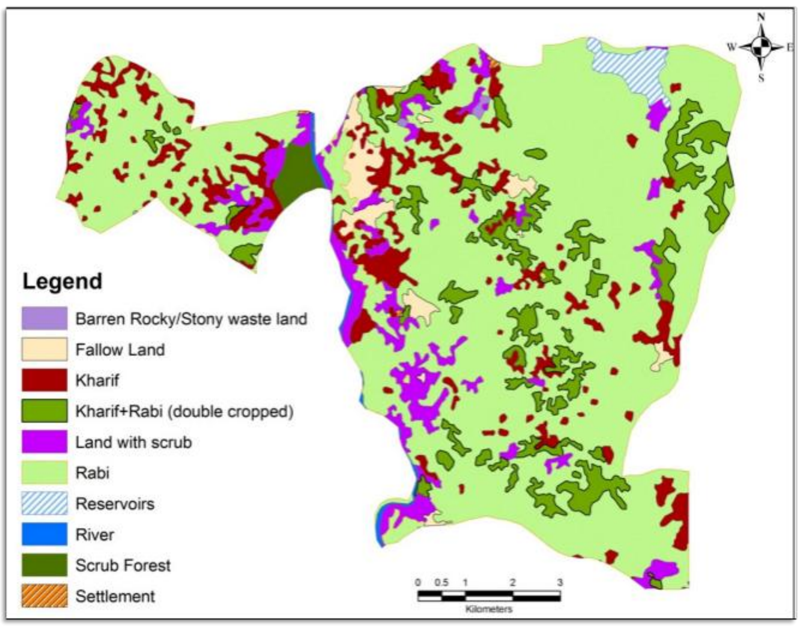


Fig. 7 Landuse/ Landcover Map

7. Contour Map

A contour line is an imaginary line which connects points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area. The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant.

They're useful because they illustrate the shape of the land surface topography on the map. It is most common to create a contour dataset from an elevation dataset. The base contour is the value from which to begin generating contours. Contours are generated above and below this value as needed to cover the entire value range of the grid. The contour interval specifies the distance between contour polylines (Fig. 8).

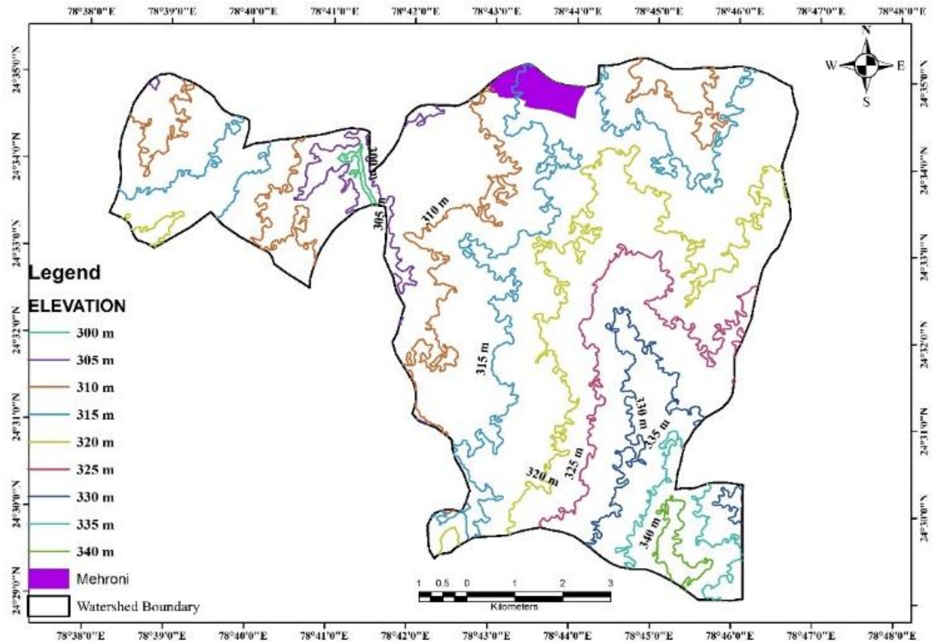


Fig. 8 Contour Map

8. Slope Map

Slope map and altitude are the important terrain parameters which are explained by horizontal spacing of the contour. This parameter used for land capability and irrigability assessment, formulating soil and water conservation measures etc. The map has been prepared based on the cartoDEM data.

The output measurement units for slope can be in degrees or percentages. The slope values were grouped into 6 classes viz. Nearly level (0-1%), gently sloping (1-3%), moderate slope (3-5%), moderately to steep sloping (5-10%), strongly sloping (10-15%) and steep (15-35%).

In general, in the vector form closely spaced contours represent steeper slopes and sparse contours exhibit gentle slope whereas in the elevation output raster every cell has a slope value. Here, the lower slope values indicate the flatter terrain (gentle slope) and higher slope values correspond to steeper slope of the terrain. In the elevation raster, slope is measured by the identification of maximum rate of change in value from each cell to neighboring cells. The entire slope map is divided intosix categories as in Table – 2. The slope values are calculated either in percentage or degrees in both vector and raster forms, (Fig.9).

Table - 2 Soil slope categories in the study area

SI. No.	Soil Slope Classes	Area in Sq. km	Percentage (%)
1	Nearly Level	35.89981	41.98566242
2	Gently Slope	14.46001	16.91131787
3	Moderate Slope	10.109967	11.82384145
4	Moderate to Steep Sloping	1.45193	1.69806589
5	Strongly Sloping	5.620846	6.573710074
6	Steep	17.962364	21.0074023
7	**Total**	**85.504927**	**100**

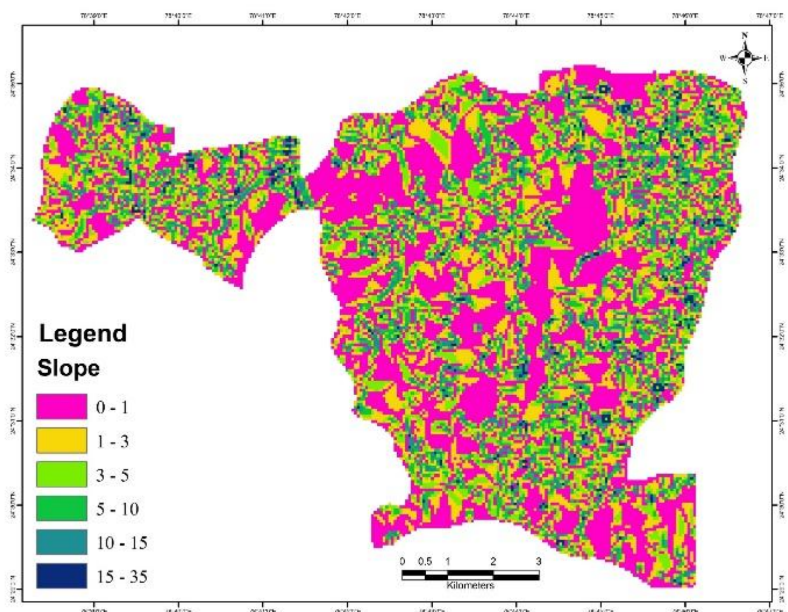


Fig. 9 Slope Map

INTEGRATION OF THEMATIC LAYERS USING GIS

One of the important aim of GIS application is to integrate the various information and its analysis, which will provide useful information about spatial and non-spatial data. The projected various thematic maps were made to a common UTM projection system so as to subsequently integrate the themes in ArcGIS using the weighted overlay method to derive the land and water prospective map which qualitatively defines the developing of land and water development plan. Thus, the land and water prospective area obtained for the watershed is represented in the Fig. 11. The integrated Land and Water Development map was obtained by integrating four thematic maps (Land capability classification), Ground water prospect, Landuse/Landcover, Drainage density) in terms of weighted overlay method using the spatial analysis tool in ArcGIS [4]. All the thematic maps were converted into raster format and they were assigned automatically a suitable value to each attribute of the respective theme.

During the weighted overlay technique, the ranks (scale value) have been given for each Attribute/Field of each theme. The weight (% influence) is also assigned to Attribute/Field according to the influence of the different parameters (Fig. 10). The weights and rank have been considered as per the real unit value of individual theme (Table-3).

Table-3 Assigned Scale value and (%)Influence

Sl. No.	Theme	Influence (%)
1	Land Capability	30
2	Land Use/ Land Cover	35
3	Groundwater Prospect	20
4	Drainage Density	15

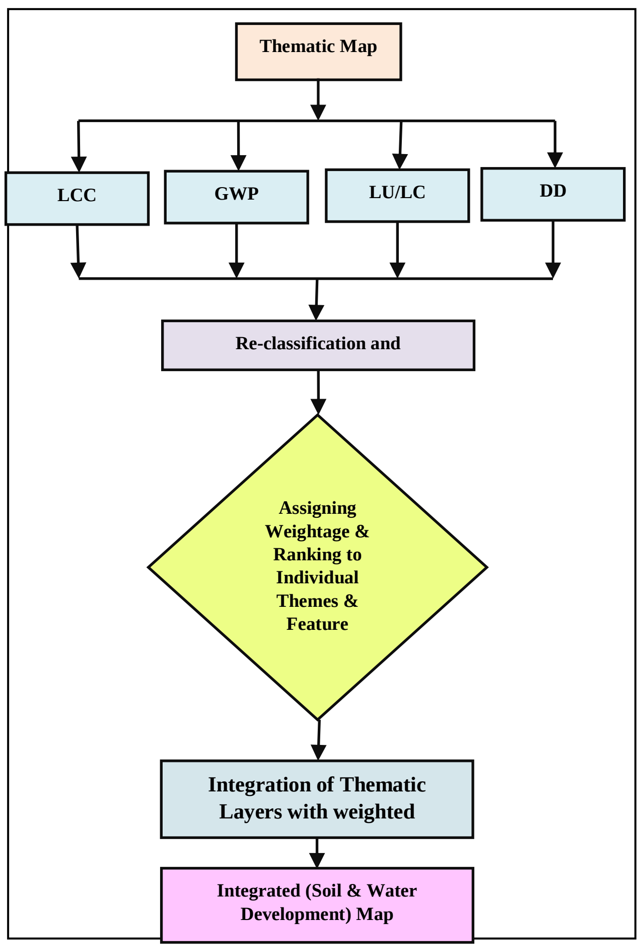


Fig. 10 Flow Chart of the Identification of Development Classes

Now all the raster maps were integrated using weighted overlay method to generate an integrated map. All these four themes are superimposed by weighted overlay method (rank and weight wise thematic maps and integrated with one another through GIS). For assigning the weight, the LCC assigned higher influence/weight, ground water prospect were assigned less influence/weight than LCC theme [5], whereas the landuse/landcover and drainage density were assigned lower influence/weight. In this process, the GIS layer on LCC, Ground water prospect, LU/LC and drainage density were visualized carefully and scale values were assigned to their attributes. The maximum value is given to the feature with more development land and more availability water potentiality and the minimum given to the less develop land and lowest water potential area. The higher rank factors are assigned to low drainage density because the low drainage density factor favors more infiltration than surface runoff. Lower value followed by higher drainage density. In LU/LC high rank is assigned to crop land and low value is assigned to barren land.

Using weighted overlay method an integrated map is generated. Depending on the attributes/Fields of four GIS coverage and their influence on the properties pertaining to the natural resource activity it was derived 6 category of classes. The categories have been classified (Table-4) according to the sum-weightage. Sum-weightage 5 has been considered as Class-6 as More developed land, Sum-weightage 4 has been considered as Class-5 as developed land, Sum-weightage 3 has been considered as Class-4 as Moderate developed land, Sum-weightage 2 has been considered as Class-3 as Poor developed land, Sum-weightage 1 has been considered as Class-2 as Very poor developed land and Sum-weightage 0 has been considered as Class-1 as which are Restricted as those areas are - water body/River, Forested area etc. These six distinct categories according to their NRM (Natural Resources Management) land activity potentiality are existed (Fig. 11)

Table –4Status of Sum-weightage for the categories

Class	**Category**	**Sum weightage**
Class - 6	More developed land	5
Class - 5	Developed land	4
Class - 4	Moderate developed land	3
Class - 3	Poor developed land	2
Class - 2	Very Poor development land	1
Class - 1	Restricted	0

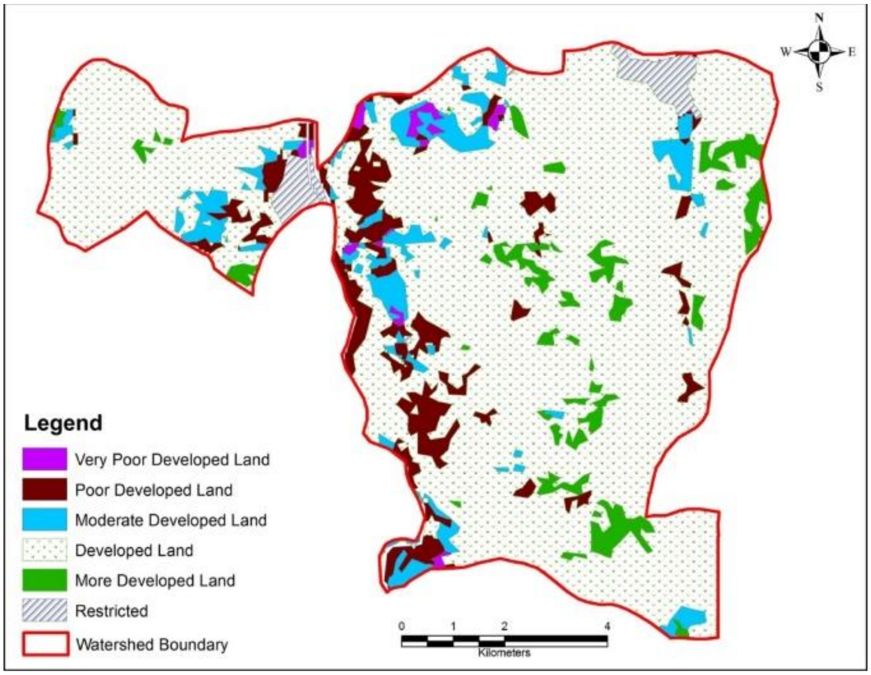


Fig. 11Integrated Land and Water Developed map

Overlay Analysis

The integration and results clearly show the usage of GIS in identification of the more developed and less developed land, which are responsible for various NRM activities. The integrated map is required to overlay on contour map of the same area which will decide the Priority classes within the watershed. In view of that the contour maps (Fig. 8) were overlaid on the integrated map (Fig. 11) to deciphered the priority classes (Table-5& Fig. 12). During the overlay of contour on integrated map it has given the emphasis that where ever Very Poor/ Poor developed land falls on high contour value (315-350m.) area those areas are to be picked for Priority-1 category (Fig. 13). Similarly, Moderate developed land falls on medium contourvalue (305-315m.) those areas are to be picked for Priority-2 category. Finally, developed land falls on low contour value (295-305m.) area those areas are to be picked for No priority category**.**

Table –5Status of Priority categories

Class	Category	Priority
Class - 6	More developed land	No Priority
Class - 5	Developed land	No Priority
Class - 4	Moderate developed land	Priority-2
Class - 3	Poor developed land	Priority-1
Class - 2	Very Poor development land	Priority-1
Class - 1	Restricted	

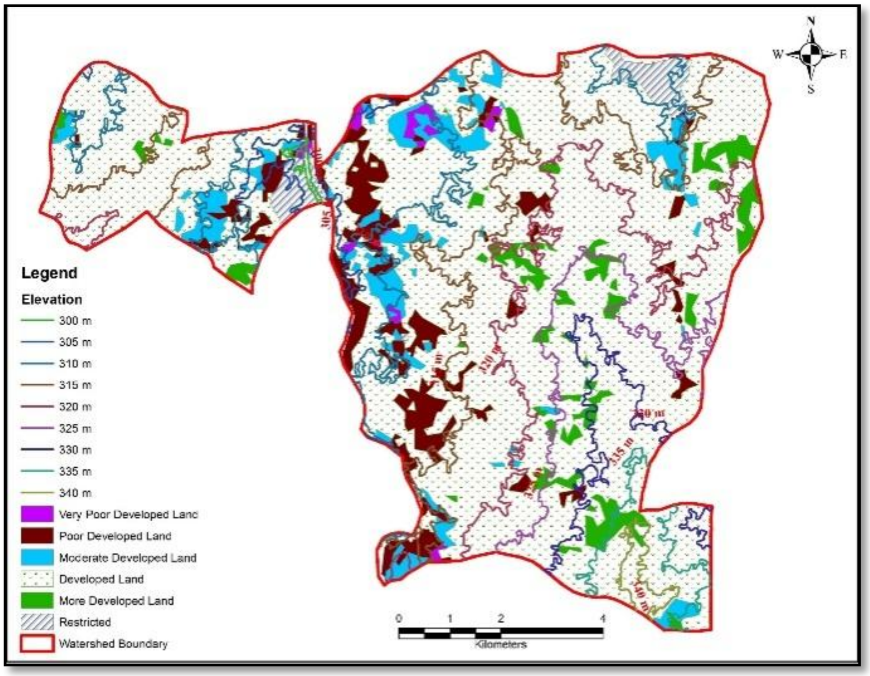


Fig.12 Contour map overlay on integrated map

Analysis were made in the prioritized categories map for different suggestive measure through geo-informatics for the structures such as contour bunds, check road bund, percolation tank, Agroforestry, Agrohorticulture etc. Thereafter the prioritized map were superimposed on seamless cadastral map for the selection of specific action plan on cadastral level.

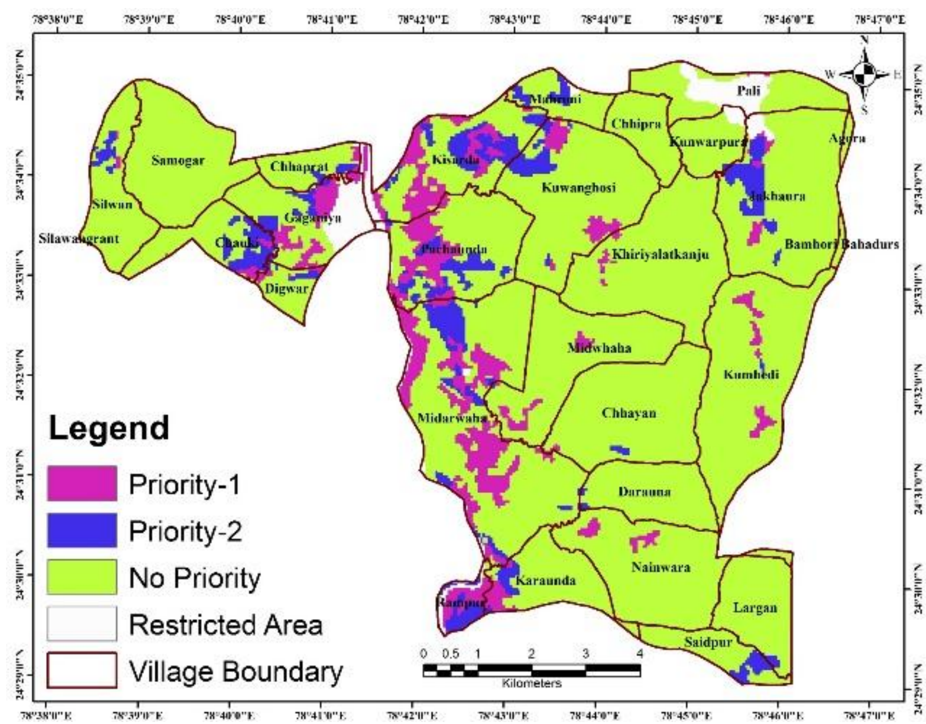


Fig. 13 Priority Class map within watershed

V. RESULTS AND DISCUSSIONS

The area is occupied by granite/granite gneiss associated with lineaments. The aquifer is of unconfined aquifer with poor ground water availability. The ground water is restricted to fractures and faults in the area.

The analysis of natural resources themes land use /land cover within the watershed are indicate that a major contingent of Rabi crop are existed and that is the major agriculture lands. Available wastelands are currently unproductive land and those could be used for horticulture and sericulture purposes. Land use / land cover map shows Kharif crop is the only crop being taken as rainfed crop.

GIS analysis has been carried out, land and water resource development plan has been generated. The activity of natural resources conservation measures have been divided into soil and water conservation measures. The water harvesting structures are recommended for the area based on the potentials of the natural resources and current cropping pattern.

VI. CONCLUSION

The work has been done on micro level for entire watershed for Identification of developmental plans. The approaches include both spatial and non-spatial data analysis. All the above results aim for optimum development of land and water resources and to meet the basic minimum needs of people there by improving their socio-economic conditions. The information generated from such studies can be applied by decision makers and planners for sustainable development at the watershed area.

Generated land and water resource development plan using remote sensing & GIS would resolve the natural resources issues. The activity of natural resources conservation measures have been suggested for soil & water conservation measures through specific measures in defined locations would hold substantial amount of water for utilization in the watershed.

High resolution satellite data provided very vital information for planning land and water conservation measures. GIS is helped in decision making towards developmental plan generation utilizing cadastral data base. The district authority and planners are needed to be involved in the planning process to identify need and resource based activities.

The soil within watershed is the black cotton soil which is very fertile but the area is deprived of ground water potentiality and lack of surface water facility. Therefore artificial Water harvesting measures to be adopted so that crop production could be achieved properly.

Remote sensing techniques will improve the efficiency of such surveys while speeding the process of resource evaluation and monitoring. Since the data is available in the digital form, it is amicable for computer processing for analyzing the resource and to integrate them using Geographic information System (GIS).

The present study illustrates the utility of remote sensing and GIS techniques as a practical and effective approach for monitoring soil erosion over large areas, especially a watershed. The identification of areas with high erosion potential is likely to help planners and conservationists for implementation of conservation plans for minimizing erosion thus saving time and resources.

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