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Remote sensing and GIS based land use / land cover, soil and land capability analysis for agricultural resource management in Sagar district of Madhya Pradesh (India)

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ABSTRACT
The concept of remote sensing and GIS based land capability analysis for agricultural development is incorporated into the study to find out what best use the land can be allocated to. Land capability is done by finding the appropriate-ness of the relative benefit to be derived from the use a land is assigned to. It may be considered the opposite of land use conflicts. Land capability should be viewed as a means of attaining the highest and best use of land. By achieving this goal, a sound overall structure and economic vitality is created and preserved. Land use is categorized as developable and none developable, and urban sable and none urban sable land. There are certain parcels of land which are not appropriate for cultivation due to its limitations and neither it is feasible to develop for any other land use. This kind of land is mostly waste land or vulnerable areas where development does not hold any prospects. They are not economical for development but have a high ecological value. Such lands are best when kept for biodiversity and ecosystem conservation. They increase the value of land by conserving it as special environmental area, and biodiversity conservation area. By understanding their characteristics and best use for it such lands are categorized as a land conservation area. Apart from this it is import to have an inventory of erosion wastelands as they have a tendency to increase in spread owing to the presence of the natural forces responsible. Thus an inventory will help in better implementation of erosion resisting strategies and will provide benefit in long run.

Keywords: Land use, agricultural development, land capability analysis, remote sensing and GIS

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1. INTRODUCTION

A sustainable approach seems to be a modern jargon but it is the basic principle behind long term successful ventures. It gets more focus in current times when the human population doubled in past 50 years, increasing pressure on natural resources. This was compensated by intensification and expansion of agricultural land. Because land is a limited resource by nature and law, intensification of agricultural practices was the main tool to combat increasing demand. This lead to either depletion of the resource or it became economically unviable. This calls for understand and identifying constraints and using proper land use planning by means of Land capability studies for sustainable optimum use of land resource. Land capability study classifies a piece of land into classes depicting their potential for a particular land use activity (Alshuwaikhat, & Nasef, 1996). The term "land capability" was found to be used in a number of land classification systems especially that of the Soil Conservation Service of the U.S. Department of Agriculture (Helms, & Douglas, 1992). It was for the first time also implemented in USA and since then being replicated in many countries at various scales keeping in view the characteristics of local land use activities (Choudhary et al., 1962). The specific objectives of land use mapping and land capability assessment are to: obtain up-to-date information about current land use activities; assess the existing land resource base for the study area; assess the physical constraints like soil, slope, geology, slope, drainage density, and physiography; relate these to land capability to facilitate and improve planning; to evaluate the land capability classes based on physical constraint and information about the resource base in a weighted multi-criteria evaluation environment.

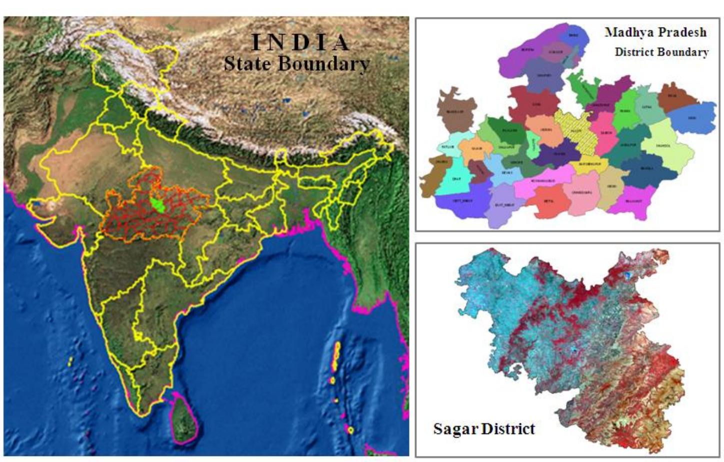

Figure 1
Location Map of the Study Area

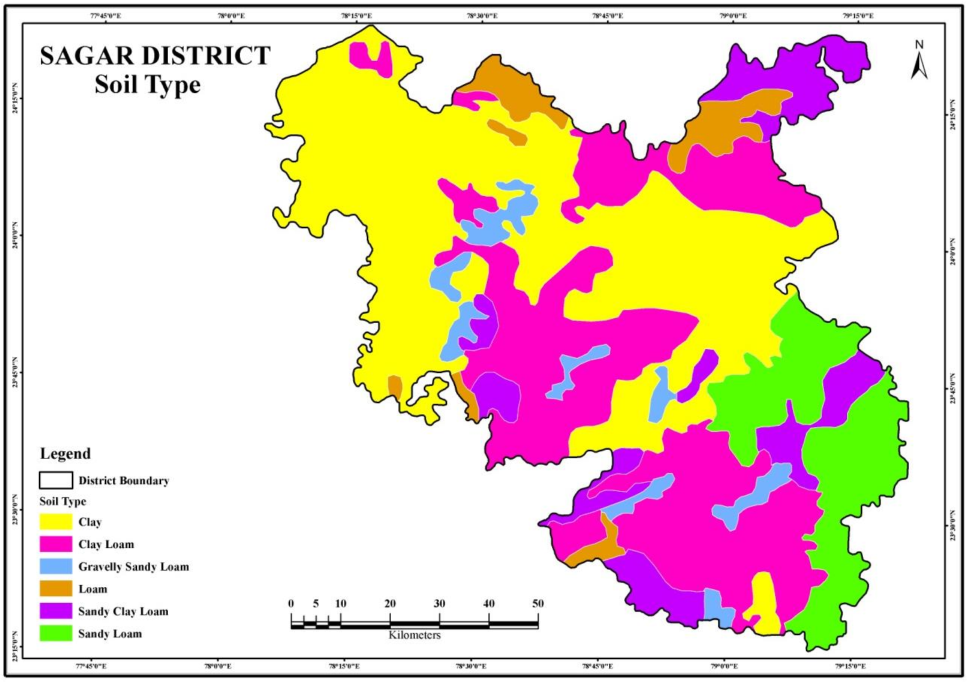

Figure 2

Soil Type

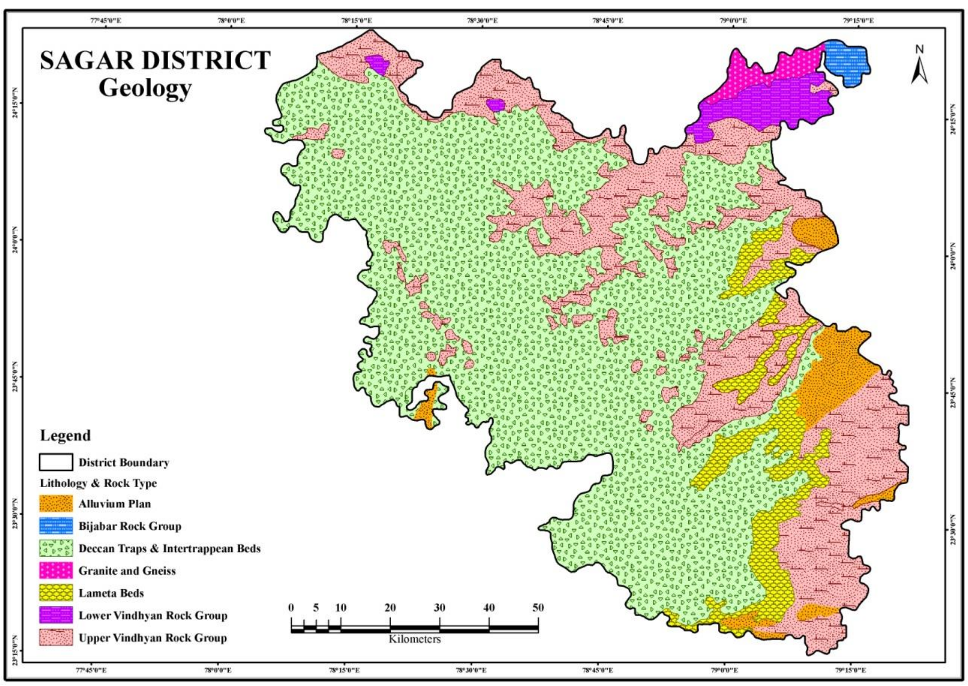

Figure 3

Geology

2. ABOUT THE STUDY AREA

The Sagar district covered 10,252 Sq Kms and situated between 23^0 10' to 24^0 27' N latitude, and between 78^0 04' to 79^0 21' E longitude, the district has a truly central location in the country (Figure 1). The topic of cancer passes through the southern part of the district. The district is divided into nine tehsils, viz, Sagar, Banda, Khurai, Rehli, Garhakota, Bina, Rahatgarh, Kesli and Deori. The main occupation of the district is agriculture and wheat, soghum and oilseeds are the chief grown crops. Sagar district has several fine tourist spots including the archaeological site near Eran and Sagar Lake (DIET - Sagar, 2013).

2.1. Soil Type

The soil map was generated in GIS environment using soil map collected from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur and were updated using LANDSAT-7 ETM$^+$ (30m) & ResourceSAT-2 LISS-IV Mx (5.8m) multi-spectral satellite imagery. The soil map obtained from the NBSS&LUP was geo-metrically registered to the base data to match Landsat & IRS satellite imageries. The geo-referenced soil map was used to assist in visual classification of satellite imagery for obtaining soil categories. The final vector map was stored in a geo-database which is amenable to spatial analyze (Figure 2). Major soil type of the study area (MoWR-CGWB, 2009) is clay loam, sandy clay loam, and sandy loam.

2.2. General Geology

The general geology of the study area has been mapped by Medlicott (1859, 1860), Blanford (1869), Durge (1970), West (1964-81), Dixit & Das (1971), Babu (1967), Choubey (1967), Mishra (1970), Gandhe (1970), Dixit (1970), Durge (1970), Subramanyan (1972, 81), Pascoe (1975), Rajrajan (1978), Alexander (1979), Wadia (1981), Krishan (1982), and Pareta (2004). They recorded the principal rock formations namely Bundelkhand granite (quartz veins, basic dyke), Bijawar (white quartzite, red shales & lime stone), vindhyan (the vindhyan supergroup has been divided into two litho-stratigraphic group viz. the lower vindhyan and upper vindhyan groups (Medlicott, 1859) separated by a well-marked erosional unconformity), Deccan traps and Intertrappean beds, and alluvium and laterite. geological map of the Sagar district has been collected from Geological Survey of India, after that it has modified by using satellite remote sensing imagery i.e. LANDSAT-7 ETM$^+$ & ResourceSAT-2 LISS-IV Mx (Pareta, 2004). The final geological map of the study area is shown in Figure 3.

The greater part of the study area is situated on the rocks of Vindhyan system and Deccan trap volcanic series, the latter covering about 2/3 of the study area. In the extreme north-east corner of the study area, around Shahgarh and Hirapur, there occur the very ancient Bundelkhand granite, and rocks of the Bijawar series, while to the east and south-east of Sagar Lameta series fringes the district. The Archaeans are the oldest rocks in the study area. These are succeeded by the Bijawars which rest with non-conformity on the Archaeans. Overlaying the Bijawars unconformably is the Vindhyan. There are two divisions in the Vindhyan, the lower Vindhyan and the upper Vindhyan. The Semri series constituting the lower-Vindhyan comprises only sandstones and shales in the study area. The upper Vindhyan (Kaimur series, Rewah Series, and Bhander series) consists largely of sandstone forming extensive plateaus and scarps. The Deccan trap constitutes the major part of the study area. It consists of ten or more horizontal flows of light gray and dark gray basalt. The volcanic flows of the Deccan

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Table 1
Data Used and Sources

S.No.	Data Layer Used	Sources and Methodology
1.	Remote Sensing Data	IRS ResourceSAT-2 LISS-IV Mx Satellite Imagery with 5.8 m Spatial Resolution, Dated: April 16, 2013 LANDSAT-7 ETM+ Satellite Imagery with 30 m Spatial Resolution, Dated: 02 December, 2007 Elevation Data: ASTER (DEM) with 30 m Spatial Resolution, Dated: 22 August, 2006
2.	Topographical Map	1:250,000 Scale - 54/L, 54/P, 55/I, and 55/M 1:50,000 Scale - 54L/3, 4, 7, 8, 11, 12, 15, 16; 54P/3, 4, 7; 55I/5, 6, 9, 10, 11, 13, 14, 15, 16; and 55M/1, 2, 3, 4, 5, 6, 7
3.	Soil Map	Soil map of Sagar district has been collected from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur and updated through satellite remote sensing data i.e. IRS ResourceSAT-2 LISS-IV Mx and LANDSAT-7 ETM+ Data with limited field check
4.	Geological Map	Sagar District Geological Map has been collected from Geological Survey of India, Bhopal, and updated through satellite remote sensing data i.e. LISS-IV Mx Data with limited field check
5.	Drainage and Slope Map	Drainage network has been generated in GIS environment using ASTER DEM data & ArcHydro Tool in ArcGIS 10.2. Slope map has been created using Spatial Analyst Extension in ArcGIS 10.2, and DEM data with 30 m spatial resolution
6.	Land Use and Land Cover Mapping	Digitally land use and land cover map and forest map have been prepared using knowledge classification method in ERDAS IMAGINE 2013, and satellite remote sensing data i.e. LISS-IV Mx Data, and also verified through limited field check

Table 2
Land Use and Land Cover Classes and its Area (2013)

S. No.	Landuse Class	Area in Sq. Kms.	Area in %
1.	Crop Land / Agricultural Land	1009.39	09.85
2.	Built-up / Settlement (Rural / Urban)	80.75	00.79
3.	Dense Vegetation / Sparse Vegetation	1654.68	16.14
4.	Fallow Land / Open Land	5112.81	49.87
5.	Dense Forest / Sparse Forest	2329.20	22.72
6.	River / River Beds	40.04	00.39
7.	Water Bodies (Tanks, Ponds, Reservoir)	25.12	00.25
	Total Area	10252.00	100.00

Table 3
Land Capability Class and its Description

Capability Class	Description
Class I	Land is the best and the most easily farmed land. It has few limitations that restrict its use
Class II	Land has moderate limitations that reduce the choice of crops. It needs simple soil and water conservation practices and requires some attention to soils management
Class III	Land has severe limitations for use; hence it needs intense soil and water conservation treatment and requires careful soil management. Graded terraces are made on moderate slopes
Class IV	Land is generally suitable for very low to moderate impact land uses. Includes some of the best grazing in the area
Class V	Land is generally suitable for moderate to low intensity grazing. Significant limitation for high impact land uses. Suitable for very low to moderate impact land uses such as direct drill cropping and grazing
Class VI	Not Capable of Supporting high or medium impact land uses due to extreme difficulty in removing or reversing degradation and associated off-site impacts. Low productivity agricultural land capable of light grazing or natural conservation
Class VII	Land should remain under native vegetation due to high soil erosion hazard and extreme site limitation. The land is best utilized under forest and native vegetation
Class VIII	Other lands not suitable for any type of land use apart from native timber (commercial plant) and nature conservation due to soil and landforms limitation, and restrict their use to recreation, wildlife or water supply or to esthetical purpose. Examples: rock out crops, sandy beaches, marshes, deserts, land along river banks, mine tailings etc., which do not give any economical return

trap erupted at the close of the cretaceous. Subsequent erosion has removed a large part of the Deccan trap, exposing to view once more the old Vindhyan topography.

2.3. Topography

The average level over much of the district varies between 457.2 m to 533.4 m above mean sea level though extreme values ranges from 353.5 m in the extreme north (Dhasan river bed) to 683.3 m in the south-west (Naharmou peak). Nevertheless, the grain of the country trends is SW-NE direction (Pareta, 2004). Recently a major source of elevation information for the whole world was SRTM providing digital elevation model of the world at a spatial resolution of 90 m. While fortunately by the time this study was conducted global coverage of ASTER based digital elevation model (DEM) is released. This DEM has a spatial resolution of 30m which makes it captures more detailed information then SRTM base DEM (Figure 4). A slope map of the study area was generated using 3D analyst and spatial analyst extension in ArcGIS 10.2.

2.4. Drainage Pattern

In the Sagar district, the drainage pattern reflects the influence of slope, lithology and structure (Jeganathan, 2000). The drainage of the district is directed between towards the north and north-east. The five notable rivers of the district viz., the Dhasan, the Bewas, the Bina, the Sonar, and Bamner are all perennial rivers, which are joined by a number of small tributaries, mostly the wet-weather rills coming down the intervening ridges and joining the main streams at an acute. This gives a typical dendritic character to the drainage pattern of the district (Nayak et al, 2003). The 'Rajghat Pariyojna' on the dam of the river Bewas is very helpful for drinking water facility in the Sagar city. ASTER DEM was used to delineate a drainage network using ESRI ArcGIS platform based ArcHydro tool.

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Table 4
Rank, Weightage, and Score for Land Capability Analysis

Rank	Data Layer	Weightage	Score
A	**Land Use / Land Cover Classes**		
9	Crop Land / Agricultural Land	9	81
1	Built-up / Settlement (Rural / Urban)	1	1
7	Dense Vegetation / Sparse Vegetation	8	56
8	Fallow Land / Open Land	9	72
5	Dense Forest / Sparse Forest	6	30
1	River / River Beds	1	1
1	Water Bodies (Tanks, Ponds, Reservoir)	1	1
B	**Soil Type**		
8	Gravelly Sandy Loam	9	72
7	Sandy Loam	8	56
5	Sandy Clay Loam	7	35
4	Loam	6	24
3	Clay Loam	4	12
1	Clay	3	3
C	**Lithology / Rock Type**		
9	Alluvium and Laterite	9	81
7	Deccan Traps & Intertrappean Beds	8	56
6	Upper Vindhyan Rock Group	7	42
6	Lower Vindhyan Rock Group	7	42
2	Bijawar Rock Group	3	6
2	Lameta Beds	4	8
4	Bundelkhand Granite	5	20
D	**Slope Type**		
9	Plan Area	9	81
7	Low Slope	8	56
6	Low-Moderate Slope	7	42
5	Moderate Slope	6	30
4	High-Moderate Slope	4	16
3	High Slope	2	6
1	Very High Slope	1	1
E	**Drainage Density**		
9	Very Low	9	81
8	Low	7	56
5	Moderate	4	20
3	High	2	6
1	Very High	1	1

Note: The high value of rank, weightage, and score are showing the most capable land for agricultural uses.

Table 5
Land Capability Classes with Area

S. No.	Land Capability Class	Area (Sq. Kms)	Area (%)
1	Class - I	1086.98	10.60
2	Class - II	327.61	3.20
3	Class - III	268.48	2.62
4	Class - IV	1897.76	18.51
5	Class - V	4782.70	46.65
6	Class - VI	1428.26	13.93
7	Class - VII	130.33	1.27
8	Class - VIII	329.87	3.22
	Total	10252.00	100.00

3. DATA USED AND METHODOLOGY

The methodology for remote sensing and GIS based land use / land cover, soil, and land capability analysis for agricultural resource management in Sagar district of Madhya Pradesh (INDIA) involves the succeeding steps shown in Table 1.

4. RESULT AND DISCUSSION

4.1. Land Use and Land Cover Mapping

Land is the most important natural resource, which embodies soil, water and associated flora and fauna involving the total ecosystem (Rao et al, 1991). A remote sensor records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses the elements of tone, texture, pattern, shape, size, shadow, site and association to derive information about land use activities, which is also the basic information about land cover (Colwell, 1997). A Land Use classification is usually performed at various levels, where a level 1 classification will discriminate the overall land use types a level 2 classification subdivide them further. Level 3 classifications usually contain species information. The levels of detail that can be obtained in a land cover or land use classification depends on number of factors including first the quality of the satellite images, defined by the spatial, spectral and radiometric resolution and second the nature of the land use classes being observed.

Digitally land use and land cover map and forest map have been prepared using supervised & knowledge classification method in ERDAS Imagine 2013, and satellite remote sensing data i.e. IRS ResourceSAT-2 LISS-IV Mx (5.8m) (Figure 5), and LANDSAT-7 ETM$^+$ (30m MSS & 15m PAN) (Figure 6) data. Land use of the study area (Figure 7) comprise mostly of agricultural land (crop land & fallow land) and forest. This initial observation is confirmed by the statistics shown in Table 2.

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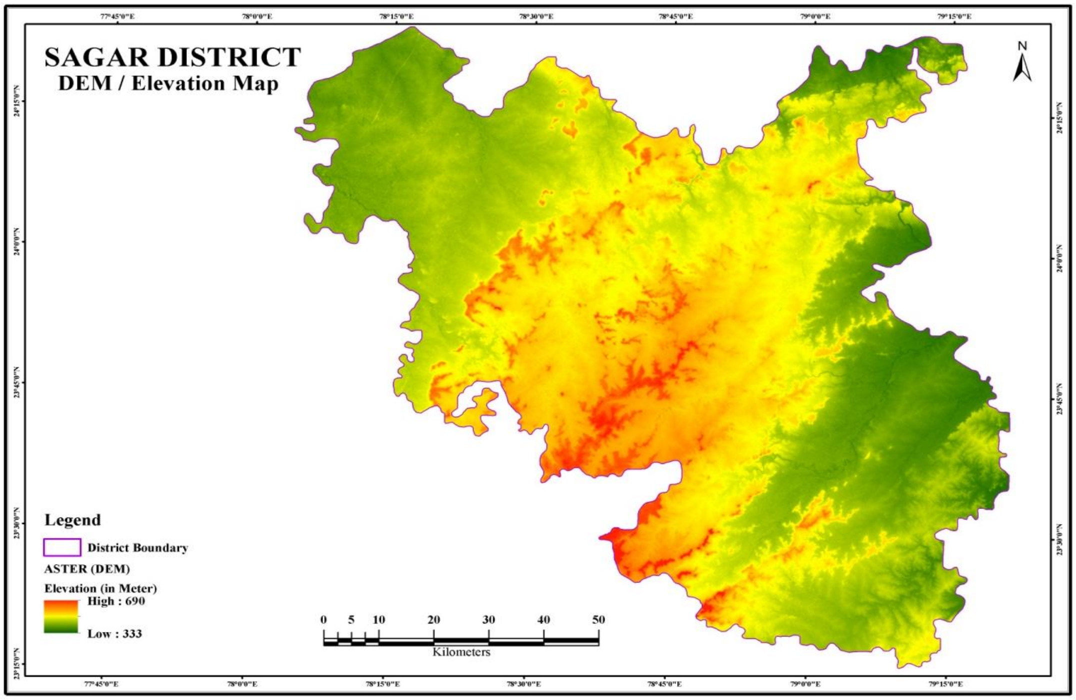

Figure 4
ASTER (DEM) / Elevation Map

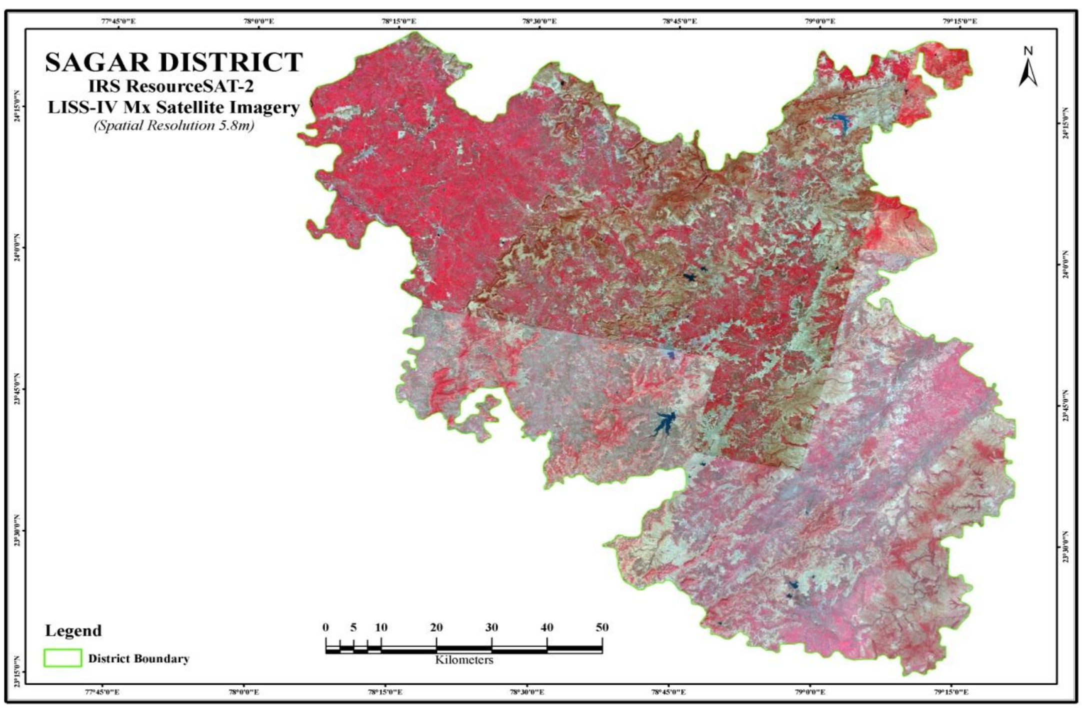

Figure 5
IRS ResourceSAT-2 LISS-IV Mx Satellite Imagery

The total area considered for study is 10,252 Sq. Kms. It is evident from the above table that built-up land or settlement accounts for 80.75 Sq Kms forming only 0.79% of the total area while water body accounts for 0.25%. River and river bed occupy 0.39%, while crop land accounts for 9.85% of the total study area. Other land use and land cover categories are dense vegetation and sparse vegetation with 16.14%, fallow land and open land with 49.87%. Dense forest and sparse forest accounts for 22.72%, which is the biggest share while agriculture land including crop land and fallow land accounts for 59.72% area in year 2013.

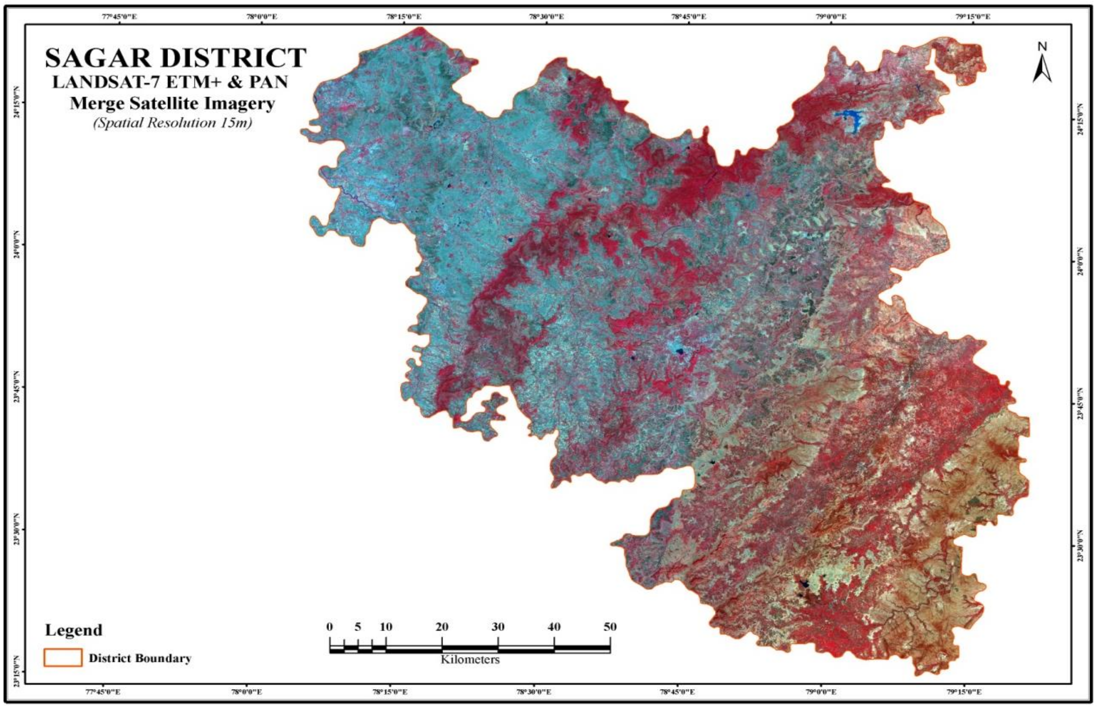

Figure 6

Landsat-7 ETM^{+} and PAN Merge Satellite Imagery

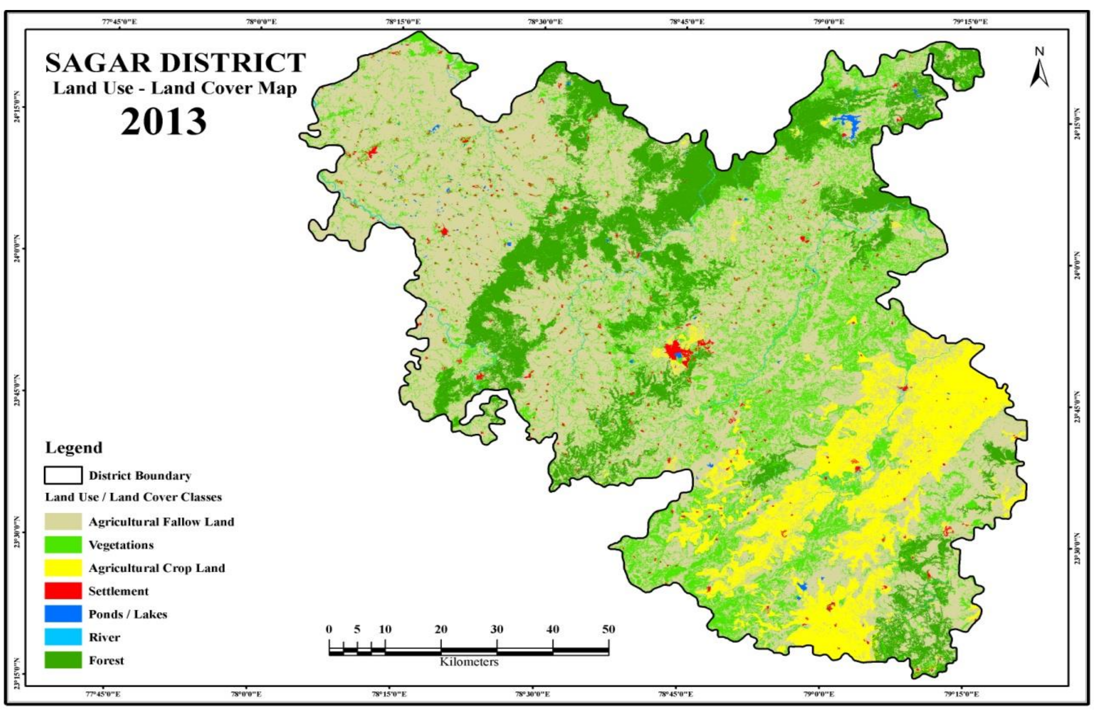

Figure 7

Land Use / Land Cover Map - 2013

4.2. Normalized Difference Vegetation Index (NDVI)

NDVI was first ascribed to by Rouse et al. (1974) though the concept was discussed by Kriegler et al, (1969); NDVI = (NIR - Red) / (NIR + Red). This is the most common VI and has a range of -1 to +1. NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light (Robert Simmon). The normalized difference vegetation index map of the Sagar district was generated using the IRS ResourceSAT-2 LISS-IV Mx satellite imagery (Figure 8) & ERDAS Imagine software.

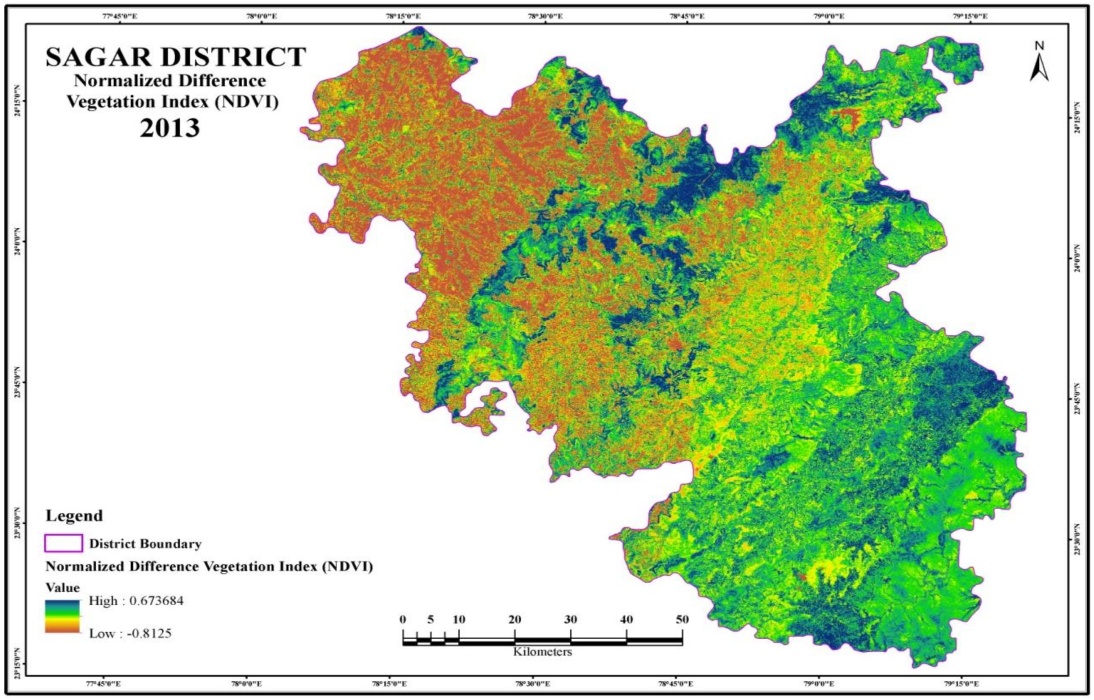

Figure 8

Normalized Difference Vegetation Index (NDVI) - 2013

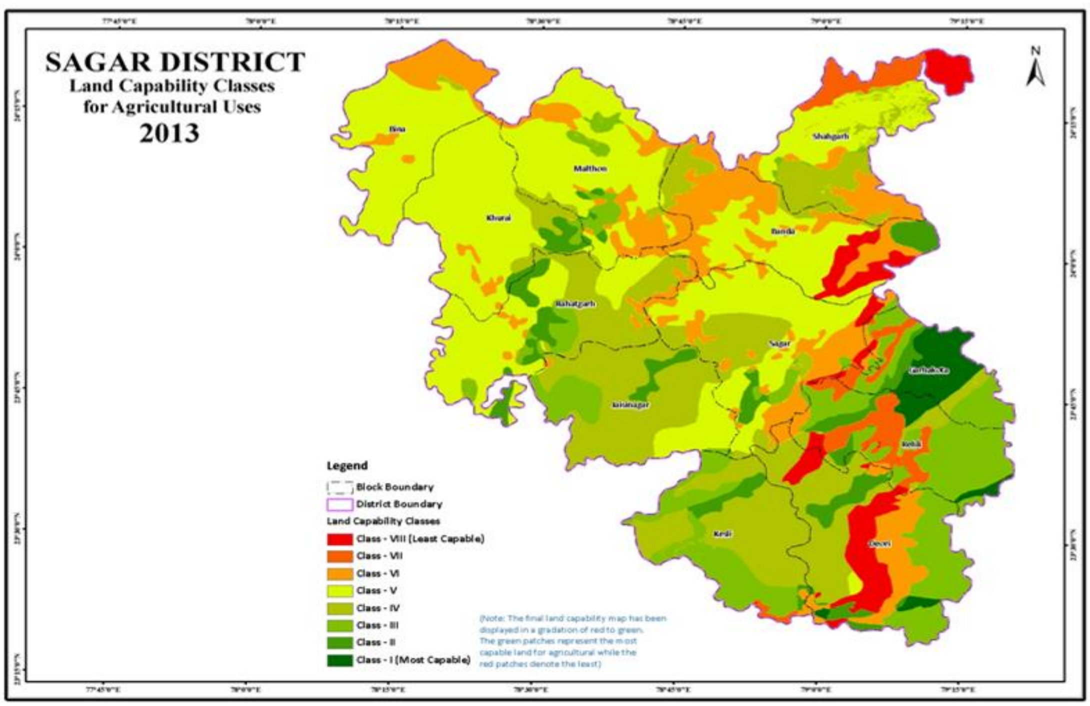

Figure 10

Land Capability Map - 2013

4.3. Methodology for Land Capability

Land capability classification is a systematic classification of land where each unit of land is classified according to what it is capable of producing and also according to the risk or damage that would result if they are mismanaged (NIH Report, 1999). This classification is made primarily for agricultural purposes and it enables the farmer to use the land ac-cording to its capabilities and to treat it according to its characteristics (Lynn et al., 2009). Land is arranged in various capability classes by considering a number of soil characteristics and associated land features (land use / land cover, soil and geology) & environmental factors (climate). The chief soil characteristics to be taken into ac-count are texture, depth, salinity and alkalinity of soil and subsoil. The important associated land features are slope of land, effect of past erosion, land use / land cover, slope, terrain, geology, geomorphology etc. By combining the thematic information generated in previous steps using a geographic information system (GIS) it is possible to handle multiple information layers and complex connections between

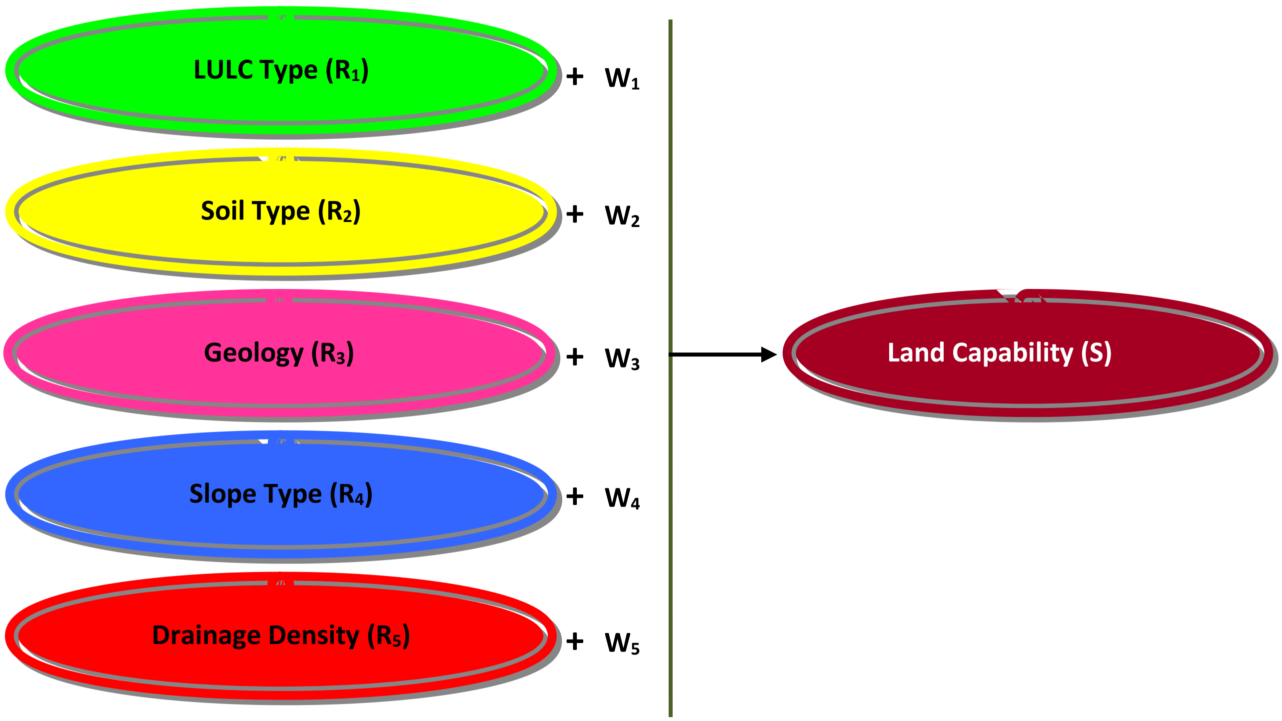

Figure 9

Schematic Illustration of Thematic Layers and Associated Weights (W) that Make up the Land Capability Analysis

these simultaneously. Figure 9 shows a schematic illustration of various input data layers that are each multiplied using a weighting factor and subsequently added together into a land capability measure. This methodology is commonly applied for agricultural land capability.

4.4. Land Capability Methods for the Study Area

The land is divided into eight capability classes, which are numbered in Roman numerals from I to VIII (Jacks, 1946). Each class assigned a standard color. These eight classes are grouped in two land use suitability groups viz., (i) “Land suited for cultivation and other uses” (class I to Class IV), and (ii) “Land not suited for cultivation, but suitable for other uses” (Class V to Class VIII) (Table 3). The land capability classes are based on the degree of erosion hazards and the intensity of limitations for use. Class I land is the best and the most easily farmed land and has no hazard or limitation for use, while in class VIII land nothing of economic value can be produced, and it may need protection and management to conserve other more valuable lands and watersheds.

The land capability information will enable an identification of development opportunities and over-developed areas. For instance, actual grassland areas located in areas of very high land capability can be considered as having development potential since they can support higher intensity agricultural use. On the other hand, agricultural land located in areas with severe land capability constraints can be considered as being over-developed. Data collected are categorized into static data, dynamic data and satellite data. Static data are those which do not change over time like soil data, surface, water resource, elevation / slope, geology and climate. Dynamic are those that changes over time; LULC, cropping pattern, and demographic are included in this category.

Using satellite imagery the land use / land cover map, soil map, geology map, slope map, drainage density map and physiography map were prepared. Using GIS tools land use / land cover map, soil map, geology map, slope map, drainage density map and physiography map were produced. Each map has a class category with a rank, weightage, and score on the basis of being most or least favorable for agricultural practice. The rank, weightage ranges from 1 to 10 and multiply the both to get the score of each category (Table 4), which are categorized into one major class from I to VIII. The score is simply the measurement of suitability for cultivation. The entire land was classified into classes of 8 according to the ability to support agriculture in the given land on the basis of soil characteristics, associated land features and environmental factor. The chief soil characteristics taken into consideration are texture. The important associated land features are slope, erosion, soil drainage and frequency of overflow. From the overlay of land use / land cover map, soil map, geology map, slope map, drainage density map and physiography map and the land capability map is produced. Land classes are shown with different colors indicating the intensity of suitability and non-suitability for cultivation. Land Capability of the study area comprise mostly of Class - I, IV, V and VI which are 10.6%, 18.5%, 46.6% and 14% respectively. The final land capability map (Figure 10) has been displayed in a gradation of red to green. The green patches represent the most capable land for agricultural while the red patches denote the least. This initial observation is confirmed by the statistics shown in Table 5.

5. CONCLUSION

In this study, we applied remote sensing (RS) and GIS techniques to identify capable areas for crop land. The results obtained from this study indicate that the integration of RS-GIS and application of multi-criteria evaluation could provide a superior database and guide map for decision makers considering crop land substitution in order to achieve better agricultural production. The study clearly brought out the spatial distribution of crop land derived from remote sensing data in conjunction

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with evaluation of biophysical variables of soil, geological, climatic, and topographic information in GIS context is helpful in crop land management options for intensification or diversification.

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