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Characterization and delineation of farming situations of Durg district

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Abstract
The soil is the most vital and precious natural resource that sustains life on the earth. The native ability of soils to supply sufficient nutrients has decreased with higher plant productivity levels, associated with increased human demand for food. The study area is an increase in soil depth, water holding capacity, cation exchange capacity and preponderance of calcium and magnesium ions. Land and water both are the limiting resources of living thing so that it is required to understand their importance and efficient use. Remote sensing and GIS is the advance tool to investigate the land resources and make plan by policy makers for its better utilization. Farming situation tells about the land suitability for cultivation. The Multi Criteria Evaluation (MCE) approach is used for the characterization of farming situation. Various thematic maps such as NDSI, slope, LULC and texture map was used for the characterization and delineation of farming situation. Multi Criteria Evaluation (MCE) approach was applied to estimate different farming situation through assigning the weights of indicators and sub-indicators into account their influences in selecting suitable farming situation. Based on that the four orders of farming situation were categorized such as *Bhata*, *Matasi*, *Dorsa* and *Kanhar*. The area under *Matasi* is highest 1028.20 sq km (43.59%) among all of them followed by *Dorsa* 957.92 sq km (40.61%) and *Kanhar* 214.39 sq km (9.09%). Whereas *Bhata* having least area 120.97 sq km (5.13%). Another class of water body was also separately classified and it was found that 37.18 sq km (1.58%), in the study area.

Keywords: Farming situation, NDSI, MCE, overlay analysis, physiochemical properties

Introduction
Soil is the most important economic industry for the millions of people in rural areas. For decades, soil has been associated with the production of vital crops, herbs, raw materials and variety of human needs for sustainable development (Brady and Weil, 2007). Crop production depends fully on quality of soil and its fertility (Lal, 1998). It is the highest priority of soil science to improve and promote the understanding of soil and it function for economic crop production (Brady and Weil, 2007). The achievable objective is providing adequate and reliable soil information on how to protect, restore and manage soil resources on agricultural land for high and healthy crop yield, globally. Hence, the role of soil and its applied science is of utmost important for sustainable crop production and economic development.
Land use maps should be prepared, and land classes should be determined so as to decrease the negative effects of human activities on nature. Satellite images are important in these studies. Analysing satellite images on computers with GIS program, and determining the condition of the land is important process for land classification (Panhalkar, 2011). Land classes, and locations of agricultural activities, settlement conditions, irrigation possibilities, industrial activities are chosen according to these land classes (Clawson and Stewart, 1965; Burley, 1961; Anderson *et al.* 1972; Jahantigh and Efe, 2010).

Materials and Methods
Details of the study area
Chhattisgarh is located in the centre-east of the country, and stretches across the latitudinal expanse of 17°46' to 23°15' North on one hand to the longitudinal meridian of 80°30' to 84°23' East on the other. The climate of Chhattisgarh is tropical. It is hot and humid because of its proximity to the Tropic of Cancer and its dependence on the monsoons for rains. Durg is the part of the state. The monsoon season is from late June to October and is a welcome respite from the heat. Chhattisgarh receives an average of 1,292 millimetres of rain. Area of Durg district is 2356.6 sq km. location map of the study area is shown in Fig. 1.

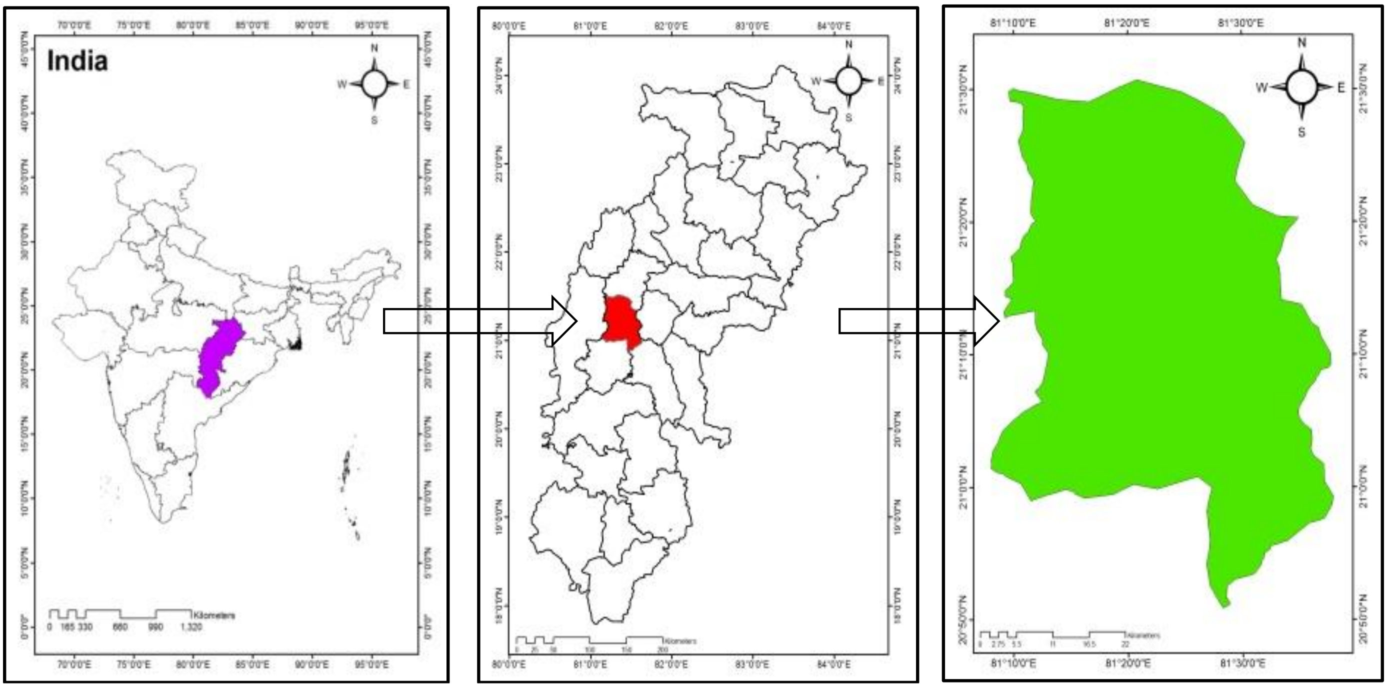

Fig 1: Location map of the study area

Soil characteristics

Soils of durg mainly developed by the action and interactions of relief, parent material and climate. Biotic features, mainly the natural vegetation follows the climatic patterns. Area of Durg comes under the soil orders of *Entisol, Inceptisols, Alfisols*, and *Vertisols*. The local studies as per the farmers understanding are known as *Bhata, Matasi, Dorsa* and *Kanhar* respectively.

Land use pattern

Rice and wheat are the major crops of the state of Chhattisgarh with yield of 1455 and 1024 kg/ha which is less than the National average of respective crops. Though the productivity level of al1 food grains in the state is lower than the National average, but the total production of food grains in the state is more than the State's requirement.

Data Acquisition

As a part of this project, various data were acquired from different sources as mentioned below:

- Soil data: Field survey, soil health card portal & GIS Cell, Chhattisgarh State Watershed Management Agency, Govt. of C.G., Raipur.
- Water quality data: Central Ground Water Board, NCCR, Raipur.
- Satellite data: https://www.usgs.gov

Soil data

For evaluation of the soil fertility status of study area, random soil sampling points based on four class distribution of satellite data using unsupervised classification technique was carried out. Surface 0-30 (cm depth) soil samples were collected from the different parts of Durg district of Chhattisgarh Plains using GPS (Global Positioning System) marked locations.

Digital Elevation Model

Digital Elevation Model (DEM) is sampled array of elevations (z) that are spaced at regular intervals in the x and y directions. The digital elevation data was downloaded from the website of United States Geological Survey (USGS) and shown in Fig.2. The Shuttle Radar Topography Mission (SRTM) data was available as 1 arc second (approx. 30m resolution) DEMs for the study area. Before using the downloaded DEM, it is required to apply the geometric correction. Therefore, the SRTM DEM was re-projected to Universal Transverse Mercator (UTM) co-ordinate system with Datum WGS 1984 (Zone-44) with spatial resolution of 30 m.

Satellite data

Cloud Free Landsat satellite data of year 2017 of the study area was downloaded from the official website of USGS (www.earthexplorer.gov.in) and shown in Fig.3. All the data were pre-processed and projected to the Universal Transverse Mercator (UTM) projection system with WGS 84 datum (zone-44). The details of the satellite data collected and band designation are given in the Table. The spatial resolution of Landsat-8 is 30m (Visible, NIR, and SWIR); 100 meters (thermal); 15 meters (panchromatic) with 16 days of temporal resolution.

Table 1: Technical specification of satellite data

Date of acquisition	Satellite/Sensor	Reference system	Path/Row	Resolution (m)
November 2017	Landsat-8	World Wild Reference System –II (WRS-II)	142/45, 142/46, 143/45	30 m

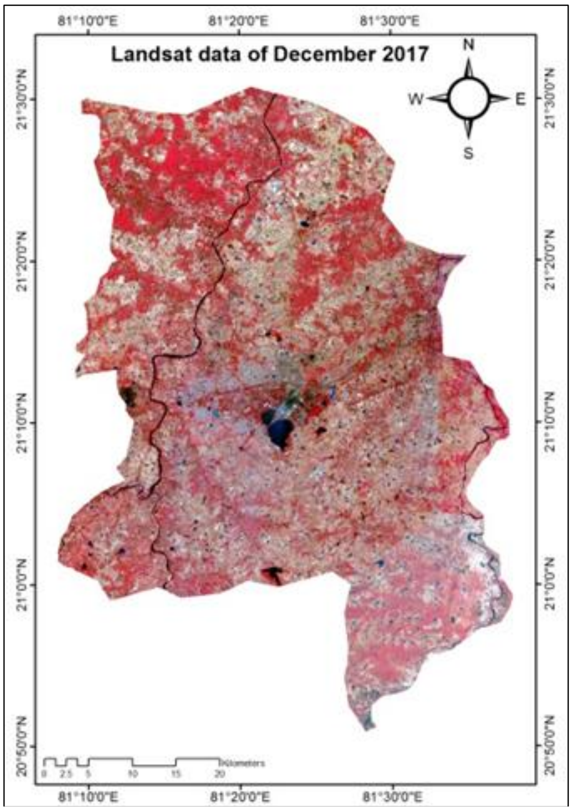

Fig 2: Digital Elevation Model of the study area

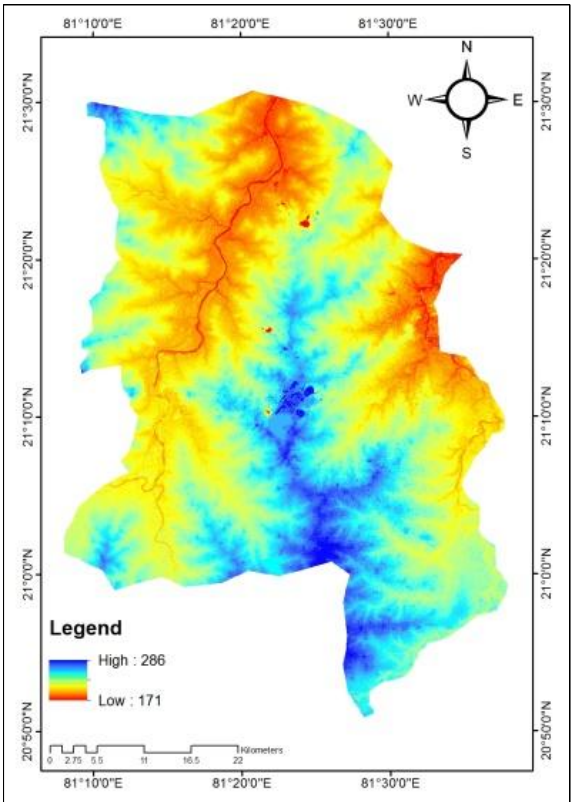

Fig 3: Landsat-8 (2017) Satellite imagery of the study area

Data Processing

Soil data

Creating a geodatabase for the study area from the point data based on field survey and soil health card. It comprises soil texture, soil depth and bulk density.

Normalised Difference Soil Index (NDSI)

Soil water content or soil moisture is an important link between the exchange of water and energy at the soil-atmosphere interface (Richard *et al.* 2006). NDSI has the potential to detect soil water content because shortwave infrared wavelength can observe the moisture condition on the ground. Normally, the optical satellite image can detect the surface conditions, not underground condition, because it cannot penetrate through the objects. However, the results showed that NDSI has the best correlation with soil water content at 10 cm depth because it has the similar condition with the top soil surface layer. For soil water content at 5 cm depth, even it is closer to soil surface than 10 cm depth; it is the uncertain soil layer. Mostly, the water passes through this layer and starts to keep the water at 10 cm depth (Potithep *et al.* 2009).

Output of the NDSI method creates a single-band dataset that only shows Soil water content. Values close to zero represent rock and bare soil where negative values represent water, snow and clouds. Taking ratio or difference of two bands makes the vegetation growth signal differentiated from the background signal. By taking a ratio of two bands drop the values between -1 to +1. Forest has an NDSI value less than -0.1 and bare soils have NSDI between -0.1 and -5. Increase in the positive NDSI value means greater of soil moisture. The NDSI was calculated from reflectance measurements in the NIR and short wave infra-red (SWIR) portion of the spectrum with the help of Eq. 1(Potithep *et al.* 2009).

$$NDSI = \frac{SWIR - NIR}{SWIR + NIR} \quad (1)$$

Slope map

The slope map was prepared from Digital elevation model of 30 m resolution. The DEM was required to define the projection to WGS 84, Zone-44 datum system. After defining the projection of DEM, slope map was generated using this process: Toolboxes > Spatial Analyst Tools > Surface > Slope in per cent. The slope map was reclassified for further processing of generation of farming situation map.

Soil Texture map

Soil texture map was generated from the date of the texture analysis from department of soil science, IGKV, Raipur. The geodatabase of soil texture was created and map of soil texture was generated.

Land use/cover

Land use/cover classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. There are two ways to classify pixels into different categories. First technique i.e. supervised classification is more closely with the real values than unsupervised classification. In this process, pixels that represent patterns recognize or can identify with help from other sources. Knowledge of the data, the classes desired, and the algorithm to be used is required before selecting training samples. By identifying patterns in the imagery the computer system to identify pixels with similar characteristics. By setting priorities to these classes, supervise the classification of pixels as they are assigned to a class value. If the classification is accurate, then each resulting class corresponds to a pattern that you originally identified. The ERDAS IMAGINE 2016 software has been used for land use/cover classification in this study. Most common land use classification method "supervised classification" also known as pixel based classification was used. The land use classes found in the study area were forest, agriculture land, current fallow, barren land, settlement and water body.

Multi Criteria Evaluation (MCE)

The Characterization of farming situation map consists of three stages. In the first stage, Soil texture map have been converted to digital format by digitization. Remote sensing data already have in digital format. The second stage involves generation of thematic maps such as slope map and Land use/cover map from different sources. It involves digital image processing of remote sensing data. The third stage involves the integration and generation of the data in a GIS environment.

The ERDAS Imagine and ArcGIS software were used in different stages of the work. The weightages of individual themes and feature score were fixed and added to each layers depending on their suitability of farming. This process involves raster overlay analysis and is known as Multi Criteria Evaluation (MCE) techniques. Multi criteria based analysis has been adopted for categorization of land based on their suitability of farming. The generated soil texture map is in vector format, for Weighted Overlay Analysis (WOA) these format was to convert into raster format, which is known as “Rasterization”. The rasterization is performed for converting different lines and polygon coverage into raster data format. After this, reclassification of all the raster files is processed along with providing the scale value of each unit. The process of characterization of farming situations is given in Fig. 4. A scale value in the range 1 to 5 (5 was the highest weightage order and 1 was the lowest weightage order) is used. All the layers are given ranking based on their influence on the study, Normalized Difference Soil Index (NDSI) map was given 40% weightage, slope map was given 30% weightage, texture map was given 20% and Land use/cover (LULC) map was given 10% weightage. This weightage was given based on the importance of a particular layer (Table 3.5). Further, in the Spatial Analyst Tool, Weighted Overlay Function has been processed for delineate the farming situation. Based on the Weighted Overlay Function a farming situation map was given for the study area.

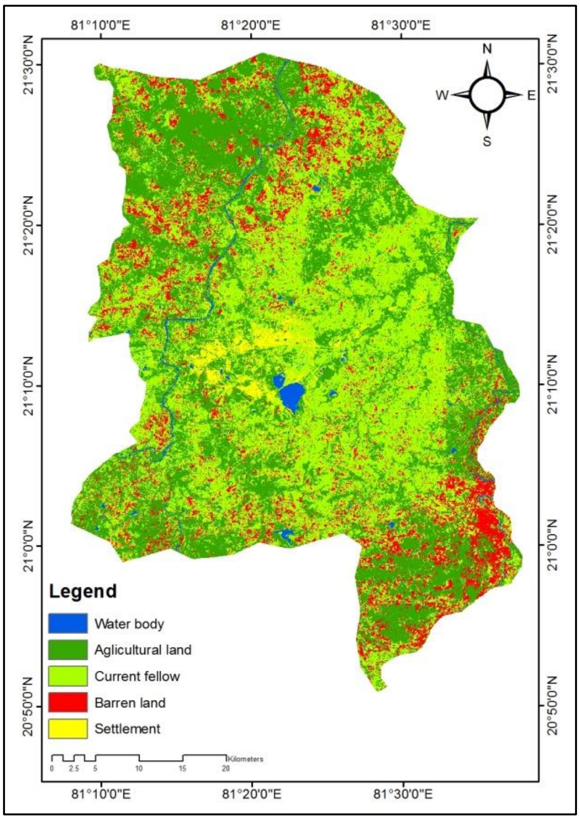

Fig 4: Land use/cover map

Table 2: Weightage criteria for calculating farming situation of Durg District

Raster	% Influence (Weighted Assigned)	Feature Classes	Feature Weighted Scale Value
NDSI	40	Very low	1
		Low	2
		Medium	3
		Moderately High	4
Slope	30	Level	4
		Level gently	3
		Undulating	2
		Rolling	1
Soil Texture Map	20	Silty loam	4
		Silty clay loam	4
		Sandy loam	1
		Sandy Clay Loam	1
		Loam	2
		Clay loam	3
		Clay	4
LULC	10	Water body	5
		Agriculture Land	4
		Current Fallow	3
		Barren Land	2
		Settlement	1

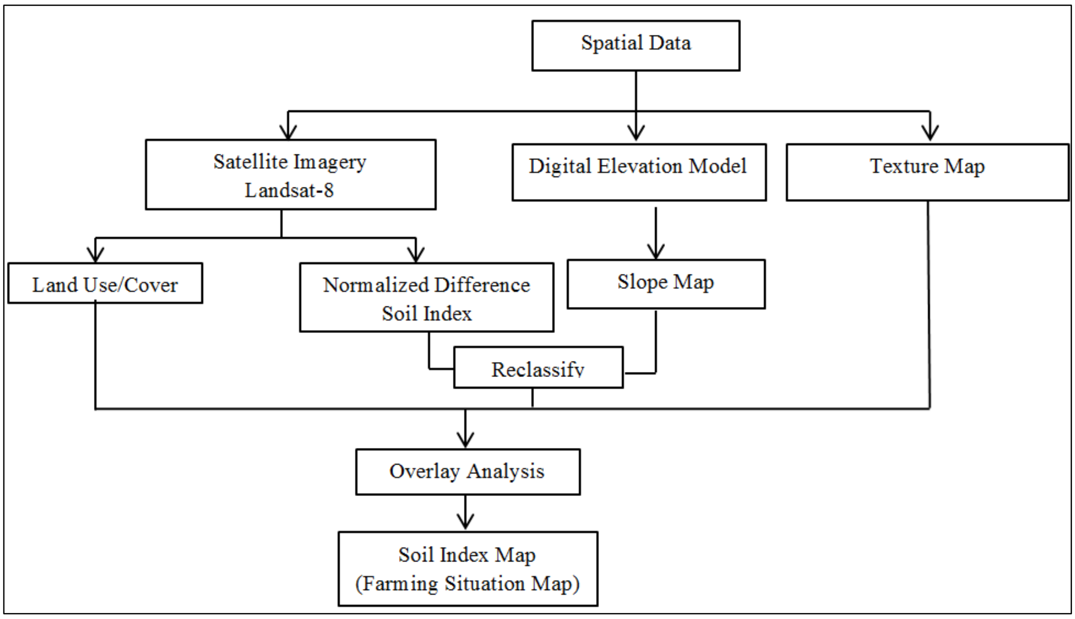

Fig 5: Process flow diagram for characterization of farming situation

Results and Discussion

Slope map

The elevation varies between 171 m to 286 m above MSL in the study area. The highest elevation recorded in the watershed is 286 m above MSL. Slope map of Durg as shown in Fig.6. The slope map played major role in delineating the farming situations. The land slope of an area is decides the suitability of farming. Slope map of Durg district is shown in Fig.6.

Normalized Difference Soil Index (NDSI) map

Normalized Difference Soil Index (NDSI) was calculated using ArcGIS software and reclassify to four classes shown in Table 4.26. The value ranges from -1 to -0.1 shows forest area and -0.1 to -0.05 shows bare soil. With increase in value of NDSI the soil moisture is also increase. The values greater than 0.02 is defines the highest soil moisture area. NDSI map of Durg Distric is given in Fig.7.

Table 3: NDSI classification range

S. No	Classes	NDSI Value range
1	Very Low	<-0.1
2	Low	-0.1 to -0.05
3	Moderately Low	-0.05 to 0
4	Medium	0 to 0.02
5	Moderately High	>0.02

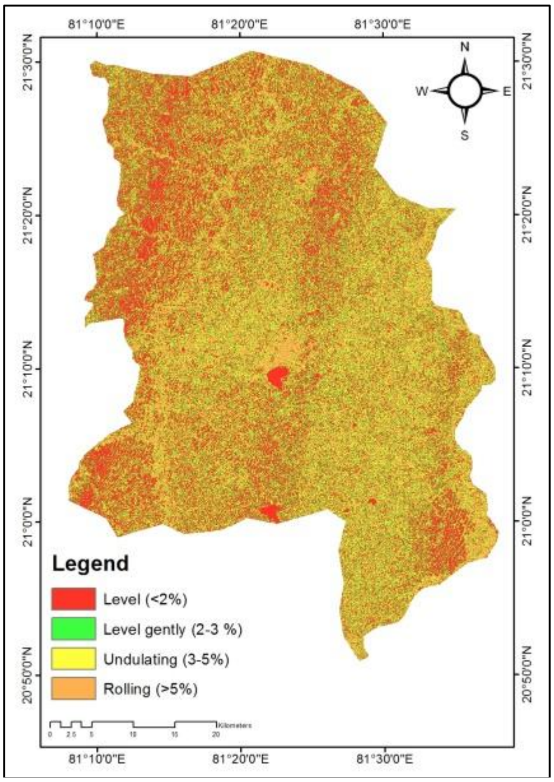

Fig 6: Slope map of the study area

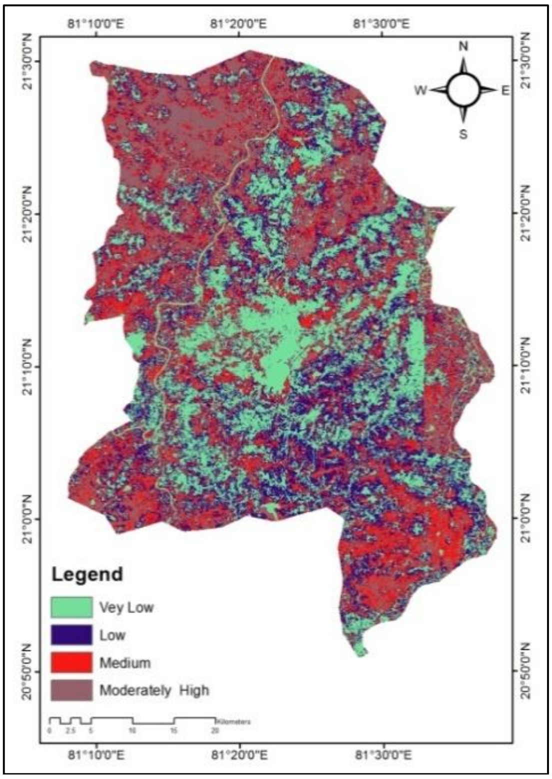

Fig 7: NDSI map

Land use/cover

The cloud free geocoded digital data of Landsat-8 was obtained from the USGS website. The imagery, which covers the watershed, was used in the study. Based on the result of image classification and image characteristics, the major land use/ cover classes were identified including forest (21.50%), agricultural land (30.27%), current fellow (27.79%), barren land (14.87%), settlement (4.11%) and water body (1.46%) (Fig. 8 & Table 4). The land use/cover map of Durg District was also prepared and shown in Fig. 8.

Table 4: Area covered in different LULC class

Class name	Area (sq km)	Area (%)
Forest	16138.64	21.50
Agriculture	22724.98	30.27
Current Fellow	20860.3	27.79
Barren Land	11163.79	14.87
Settlement	3084.253	4.11
Water Body	1098.57	1.46

Farming situation

Characterization of farming situation was based on the Multi Criteria Evaluation (MCE). Various map which is influence by the land suitability for farming or cultivation such as normalized difference soil index (NDSI), slope, soil texture and land use/cover map was overlay. Overlay was done based one weightage of each map on their influence over farming situation. A weighted criterion of overlay analysis for Durg District is shown in Table5. On the basis of that weighted criteria characterization of farming situation of whole Durg was prepared. Farming situation map of the Durg District is shown in Fig.9. Area under different farming situation of Durg is calculated and shown in Table5. The area under *Matasi* is highest 1028.20 sq km (43.59%) among all of them followed by *Dorsa* 957.92 sq km (40.61%) and *Kanhar* 214.39 sq km (9.09%). Whereas *Bhata* having least area 120.97 sq km (5.13%). Another class of water body was also separately classified and it was found that 37.18 sq km (1.58%), in the study area.

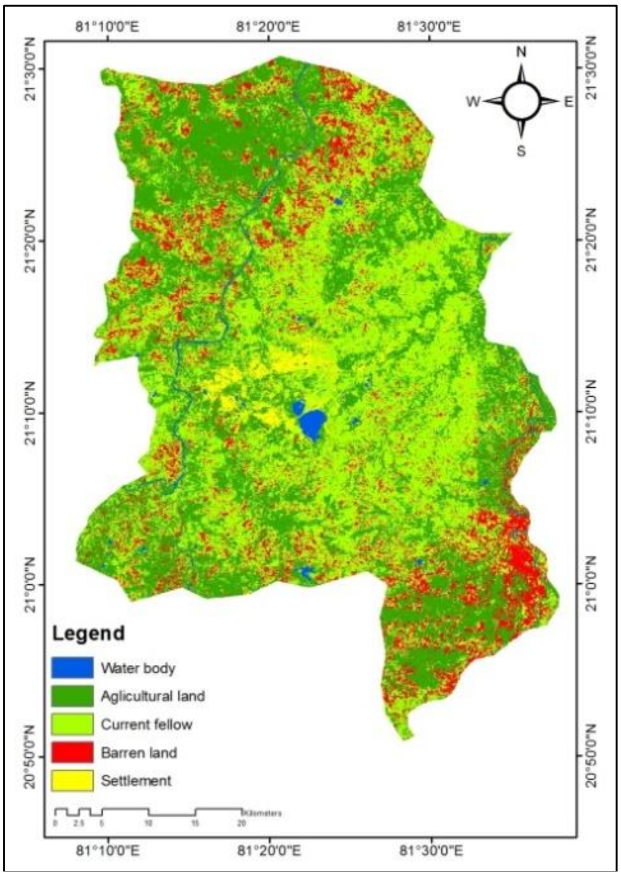

Fig 8: Land use/cover map

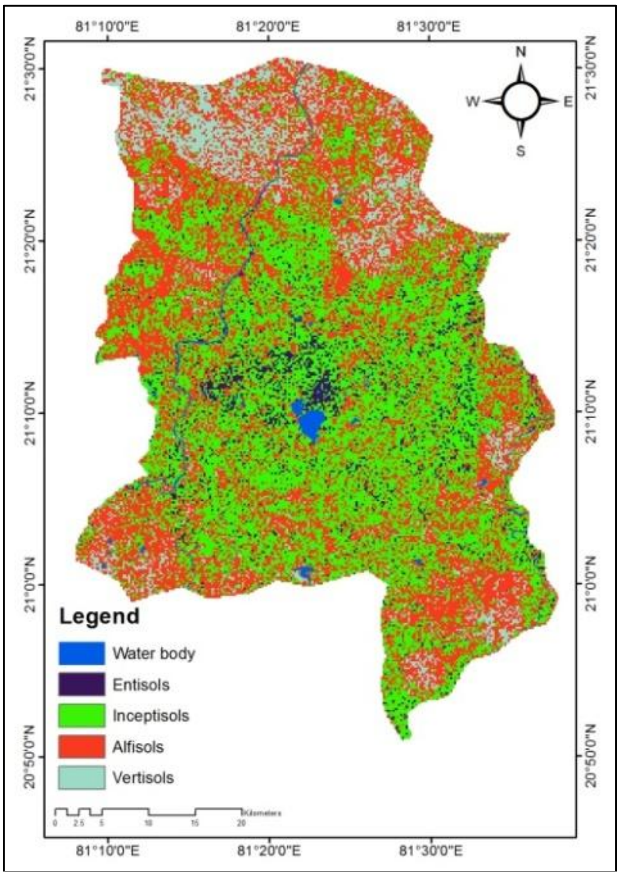

Fig 9: Farming situation map of the study area

Table 5: Area covered under different farming situation of Chhattisgarh Plains

Farming situation	Soil Order	Soil texture	Soil depth (cm)	Slope (%)	Bulk density (gm cm^{-3})	Area (sq km)	Area (%)
Bhata	*Entisols*	Loamy Fine Sand to Silt Loam	<30	5-8	1.71-1.85	120.97	5.13
Matasi	*Inceptisols*	Sandy Loam to Silt Loam	30-80	3-5	1.48-1.79	1028.20	43.63
Dorsa	*Alfisols*	Sandy Clay Loam to Clay Loam	80-150	2-3	1.28-1.62	955.88	40.56
Kanhar	*Vertisols*	Clay Loam to Clay	>150	<2	1.22-1.58	214.39	9.10
Water body	-	-	-	-	-	37.18	1.58

Conclusions

GIS technique for superimposition of various thematic maps including NDSI, land use/cover map, slope and texture map can be used for characterization of farming situation of Chhattisgarh Plains region. Various physical properties of soil was calculated, wherein the soil depth of *Entisols* is less than 30 cm, *Inceptisols* is 30 to 80 cm, *Alfisols* is 80 to 150 cm and *Vertisols* is more than 150 cm was found. Farming situations was delineated by overlapping of NDSI, slope, soil texture and LULC map. Multi Criteria Evaluation (MCE) approach is used for characterization of farming situation. The area under *Matasi* is highest 1028.20 sq km (43.59%) among all of them followed by *Dorsa* 957.92 sq km (40.61%) and *Kanhar* 214.39 sq km (9.09%). Whereas *Bhata* having least area 120.97 sq km (5.13%). Another class of water body was also separately classified and it was found that 37.18 sq km (1.58%), in the study area.

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