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Digital Soil Mapping of Maniyari Basin for Sustainable Cultivation using Geospatial Techniques

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ABSTRACT: Digital Soil Mapping (DSM) now a days is very popular rather than conventional soil map, it is an important tool in soil survey and sustainable agriculture planning. The spatial distribution of per pixel soil information by the use of soil samples laboratory observations data. Ninety soil samples were collected at a depth of 0–50 cm from various Physiography land units in the Maniyari basin, Chhattisgarh, India. This Physiographic landscape unit was made with the help of on the basis of slope percentage and Landuse Landcover as well as Physiography. Sentinal 2 satellite data with 10 m. and Aster DEM with 30 m. resolution has been used to prepare the digital soil map. Mainly four Landuse Landcover classes have been accounted to incorporate with five topographic classes to prepare physiographic units. Soil samples were analyzed to determine the Macro (N, P, and K), Micro (Fe, Zn, Cu, Mn, S and Br) Nutrients and Some Physico (Texture, Bulk density, depth) Chemical Properties (pH, EC and OC). Six textural classes identified were sandy clay loam and sandy clay, clay, clay loam, loam, sandy loam. The bulk density, depth varied from 1.08 to 1.8 Mg m-3, 14 to 90 cm. respectively. The pH, EC, OC are varied from 5 to 8.36, 0.1 to 1.2 ds/m, 0.03 to 1.47 respectively. Nitrogen (N), Phosphorus (P), Potassium(K) varied from 125 to 476 kg/ha., 4.44 to 77.78 kg/ha, 79.6 to 504 kg/ha Respectively. The digital soil database along with all properties are called physiographic soil map. Spatial distribution mapping of all properties and nutrients has been prepared with the help of Kriging and Inverse distance weightage interpolation method and finally prepared a soil map which will help to selection crop and get best sustainable cultivation.

Keyword: Soil Nutrients, Digital soil map, Kriging interpolation, Geographical Information System.

INTRODUCTION

The compilation of geographically referenced soil databases based on quantitative correlations between spatially distributed environmental data which taken from the field and measurements made on laboratory, is referred to as digital soil mapping. (McBratney et al.,2003). The digital soil map is a raster based map which composed of 2-dimensional cells (grid) in which each pixel has a spatial location and contains soil physical and chemical parameter and nutrients. Digital soil maps illustrate the spatial distribution of soil classes or properties and can document the uncertainty of the soil prediction. Digital soil mapping better captures observed spatial variability and reduces the need to aggregate soil types based on a set mapping scale (Zhu et al.,

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2001) When Geospatial techniques used for the preparation of soil maps are known by the term "digital soil mapping" (DSM).The compilation of geographically referenced soil databases based on quantitative correlations between spatially distributed environmental data and measurements taken in the field and laboratory is referred to as digital soil mapping.(McBratney et al., 2003). The production and populating of spatial soil information systems through the application of field and laboratory observational methods paired with spatial and non-spatial soil inference systems.(Digital Soil Mapping: Introductory Perspective 2007). Geographic Information Systems (GIS), Global Positioning Systems (GPS), remotely sensed spectral data, topographic data produced from Digital Elevation Models (DEMs), prediction or inference models, and data analysis tools have significantly advanced the science and art of soil survey. Traditional soil mapping now includes field measurements Geo-referenced with GPS and digital elevation models shown in a GIS. The key difference between digital soil mapping and traditional soil mapping is that digital soil mapping use quantitative inference methods to provide predictions of soil classes or soil attributes in a geographic database (raster). Data mining, statistical analysis and machine learning models organize massive volumes of geographical data into meaningful clusters for spotting spatial patterns.

Soil maps basically two types one is conventional mapping and another one is Digital Soil Mapping, this idea develop in recent era due to its functional ability. In conventional mapping, there is no basic difference between two soil groups where as in Digital Sol Mapping this problem is resolved because in this case every pixel has their own soil information. Dsm Basically focal on those marginal areas. Digital soil maps demonstrate the spatial distribution of information (soil classes) which can help to uncertainty of the soil prediction.Digital soil mapping (DSM) can be used to create basic soil survey, corrected and refine the existing soil database, generate specific soil interpretations, and estimate the risk(Carré et al., 2007).

STUDY AREA

The Maniyari River basin is a part of Shivnath catchment which is also a tributary of Mahanadi River. The river maniyari rises from Satpura Maikal hill, in the North West of the Central plateau of India. So, the Maniyari River flows through all the three ideal stages of fluvial cycle like hilly, plateau and plain. That's why this basin represents whole Chhattisgarh although the geological formation is different but the Physiography and land facets have a strong phenomenon to represent the entire state.

The study area covered three districts namely Kabirdham, Mungeli and Bilaspur. Latitude and Longitude of the study area 21°55' 0" N to 22° 32'0" N and 81°15' 0" E to 82° 5' 0" E. Total area of the study region approximately 3794 sq. km. with the total population of near about 10 lakhs. The Achanakmar-Amarkantak Biosphere Reserve is a biosphere reserve in India that extends across the states of Madhya Pradesh and Chhattisgarh. The northern part of maniyari basin (Lormi plateau) comes under the Achankamar biosphere reserve .

Summer temperatures peak at 43º C, with a mild winter temperature of 11ºC. And the average annual rainfall is 1128.34 mm, which is less than the 1292 mm average rainfall in Chhattisgarh. (**Figure 1**)

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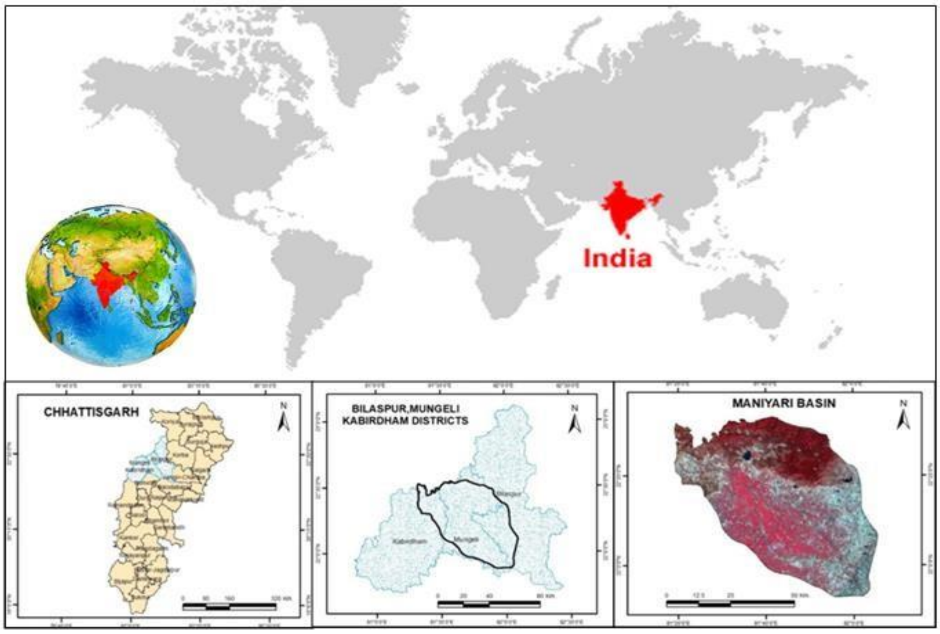

Figure 1: Location map of the study area

MATERIAL AND METHODS

Data base is one of the prime raw materials to finish a work. Both primary and secondary database has been used to prepared soil productivity and to find out the best productive way to find out the crop. And secondary data like topographical sheet, Sentinal 2 satellite imagery with the resolution of 10 m. and Aster DEM has been collected from survey of India and USGS Earth Explorer respectively. All of the primary and secondary data sources are included in Table 1.

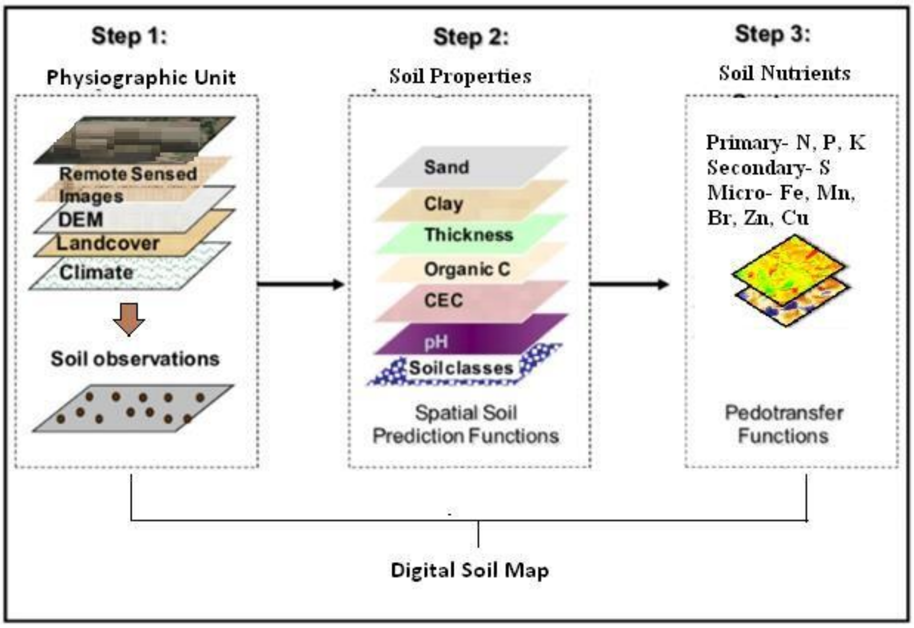

Figure 2: Flow chart methodology for Digital soil map

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Table 1: Sources of data

Data types	Data sources	Details
Soil Sample	Field Survey	Top soil up to 20 cm.
Topo sheet	Survey of India	64F-06 to 16, 64F16,64G13, 64J03,64J04, 64K01
Satellite imageries	NRSC, ISRO	Sentinal 2 (30 m)

3. RESULTS

SLOPE AND PHYSIOGRAPHY

Slope map has been prepared with the help of Aster Digital elevation Model (DEM) with a resolution of 30 m. there are five classes of slope category has been accounted for the preparation of physiographic unit map. The elevation range of this study area found from 135 m. to 1015 m. Fives Physiography classes has been estimated on the basis of relief features as well as elevation. A soil sample has been collected with the help of physiographic unit map.

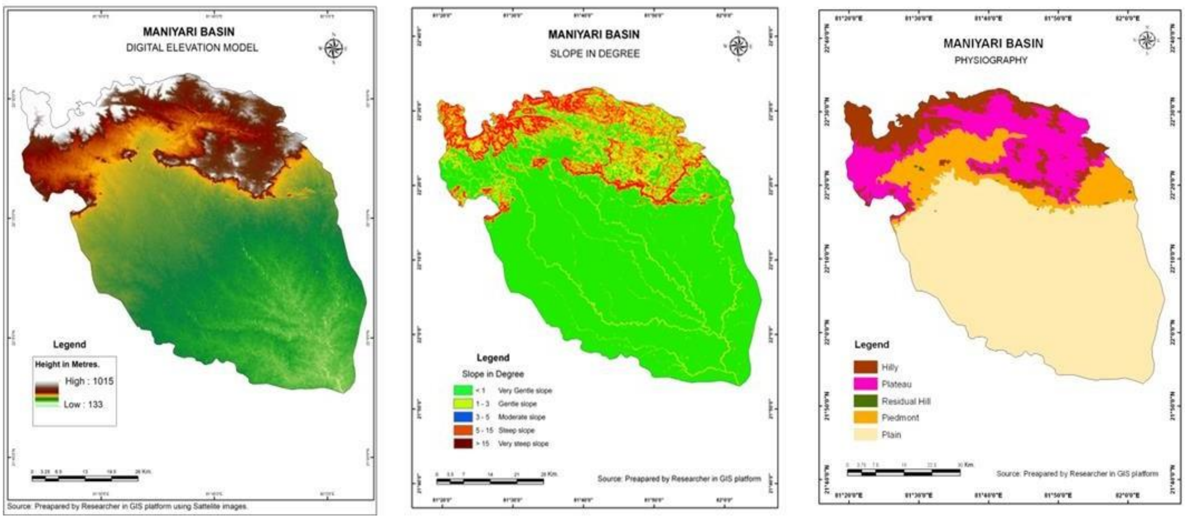

Figure 3: Digital Elevation Model, Slope and Topography

LANDUSE LAND COVER

LULC map has been prepared with the help of visual image interpretation technique. Ground truth verification has been completed to verify the doubtful areas. Accuracy abasement has been done using 50 Ground control point with the help of GPS. The area of the LULC is varies from one land use to another. In the study area there are 12 Landuse land cover classes has been identified. Agriculture land covered the 60.13 %, forest 27.66%, Open scrub 3.16 %, Built-up rural 2.96 % area of the total Geographical area. Landuse Landcover is depicted in Figure 2 and Table 2.

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Table 2 : Landuse Landcover Classes of the study area

LULC 2020	Area (sq. km)	Area (%)
Agriculture Cropland	2281.72	60.36
Barren Rocky	4.26	0.11
Forest	1051.45	27.82
Scrub Land	194.16	5.14
Water body	126.09	3.34
Built up	119.54	3.16

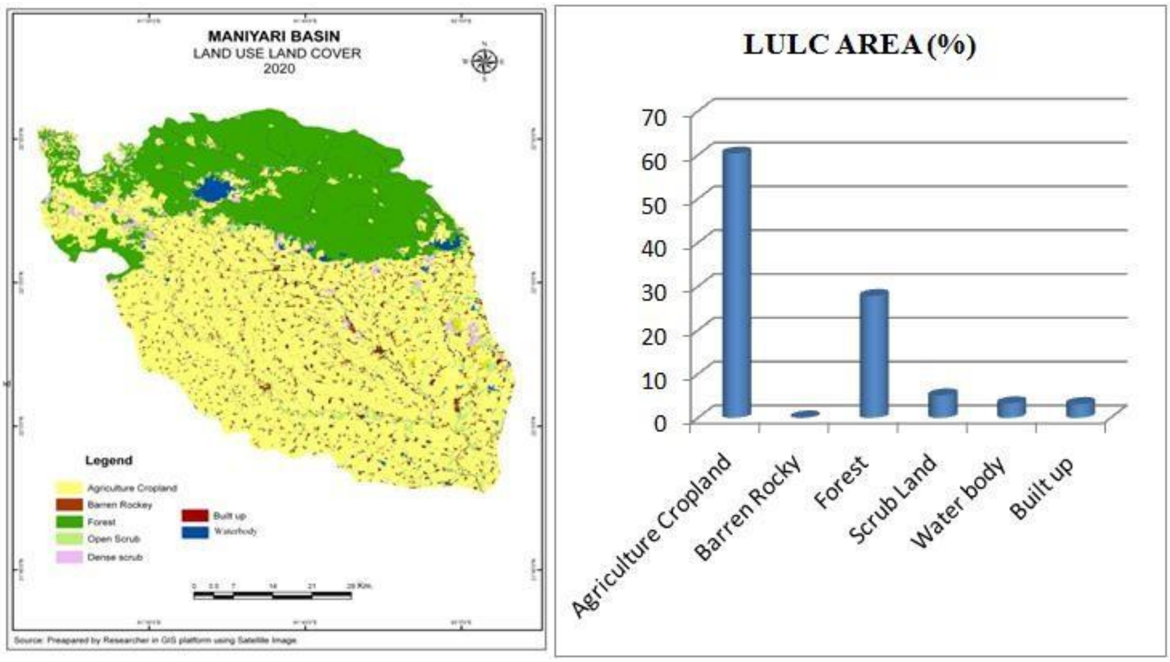

Figure 4: Landuse Landcover of Maniyari basin

PHYSIOGRAPHIC LAND UNIT

There are 19 primary physiographic land unit has been identified in the study area. The physiographic land facets has been prepared with the help Physiography, percentage of slope, geomorphology as well as landuse and land cover etc. Grid sampling method has been adopted to collect the soil samples. Ninety (90) soil samples has been collected according to the physiographic unit, some broad unit have contained more than one sample like PLS11 plain agriculture land have approximate 50 samples because of their soil textural differences as well as HLS12 hilly forest areas have more than ten samples to identified the soil nature. Physiographic unit details and maps are shown in Table no. 3, 4 and Figure 5, 6.

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Table 3 Physiographic unit details and code

Sl. No.	Land Facets	Topography	Landuse Landcover	Unit code
1	Hill Surface (HLS)	Steep sloping (40-50%) Hilly (H)	Agriculture Land	HLS11
2			Forest	HLS12
3			Scrub Land	HLS13
4	Pleatue summit surface (PDS)	Moderate sloping (7-10%)	Agriculture Land	PDS11
5			Forest	PDS12
6			Scrub Land	PDS13
10	Pediment Fringe surface (PFS)	Gently sloping (2-7%)	Agriculture Land	PFS11
11			Forest	PFS12
12			Scrub Land	PFS13
13	Plain Surface (PLS)	Very gentle sloping (1-2%)	Agriculture Land	PLS11
14			Barren Land	PLS12
15			Forest	PLS13
16			Scrub Land	PLS14
17	Residual Hill (RH)	Moderate sloping (7-10%)	Agriculture Land	RH11
18			Forest	RH12
19			Scrub Land	RH13
20	Water Body (WB)	-	-	WB
21	Built Up and Industry (BI)	-	-	BI

The above physiographic land unit is the base of soil sample collect which express the same soil formation factors that may be the climate, geology, Physiography, slope etc. the entire soil sample has been analyzed in Labhandi soil testing laboratory (Raipur district soil testing laboratory, Labhandi, Raipur).

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Table 4: Physiographic unit and their area

Unit Code	Physiography	LULC	Area (Sq. Km.)	Area (%)
HLS11	Hill	Agriculture Land	31.49	0.83
HLS12	Hill	Forest	311.95	8.22
HLS13	Hill	Scrub Land	16.85	0.44
PDS11	Pleatue	Agriculture Land	92.87	2.44
PDS12	Pleatue	Forest	514.06	13.49
PDS13	Pleatue	Scrub Land	14.72	0.39
PFS11	Piedmont	Agriculture Land	146.13	3.85
PFS12	Piedmont	Forest	221.14	5.82
PFS13	Piedmont	Scrub Land	39.78	1.05
PLS11	Plain	Agriculture Land	2011.78	52.89
PLS12	Plain	Barren Land	10.73	0.28
PLS13	Plain	Forest	2.24	0.06
PLS14	Plain	Scrub Land	122.68	3.22
RH11	Residual Hill	Agriculture Land	0.51	0.01
RH12	Residual Hill	Forest	2.7	0.07
RH13	Residual Hill	Scrub Land	0.59	0.02
Water Bodies	Hill	Water Body	0.85	0.02
Built Up	Piedmont	Built Up And Industry	4.79	0.13

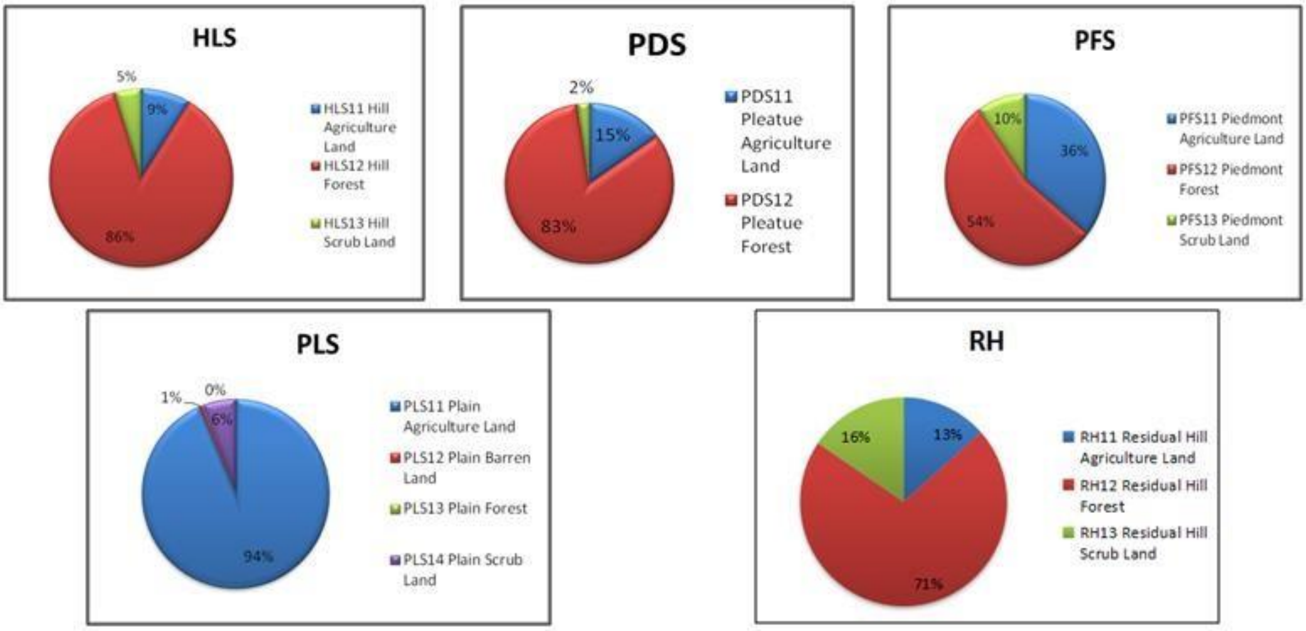

Figure 5: Physiographic unit wise land use Land cover Distribution (2020)

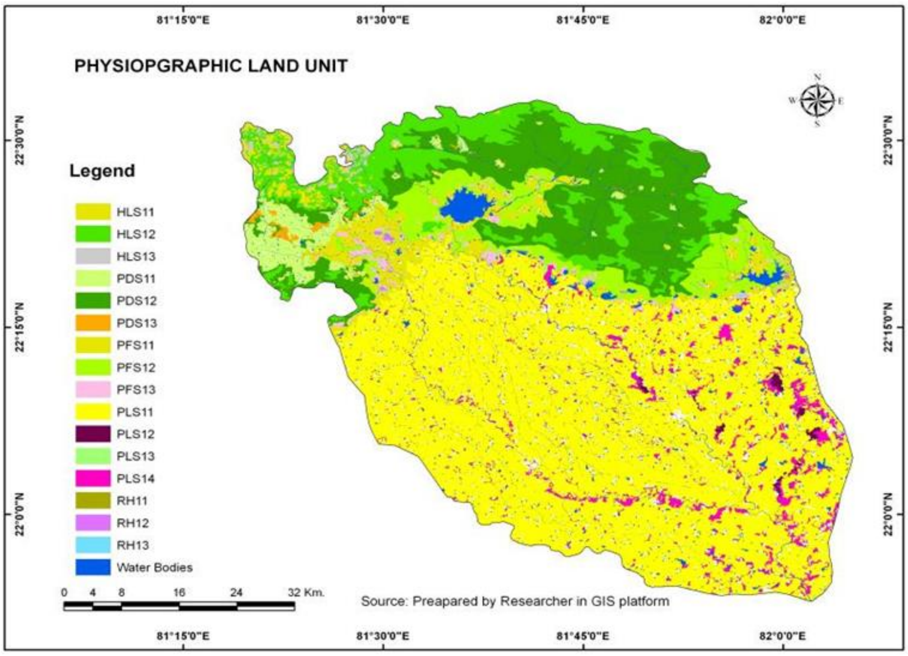

Figure 6: Physiographic Land Units of the study area

DIGITAL SOIL DATABASE

A database management system has been formulated on Arc GIS platform which contain soil physical properties (Texture, Bulk density, depth) Chemical Properties (pH, EC and OC), Macro (N, P, and K) and Micro (Fe, Zn, Cu, Mn, S and Br) Nutrients on the basis of physiographic landscape unit. This database gives a lot of information regarding soil health as well as the erosion. Soil sample size and the area or volume of representation should be considered when determining the location of field sampling sites and timing of measurements (Bouma et al., 1989; Mohanty and Mousli, 2000).

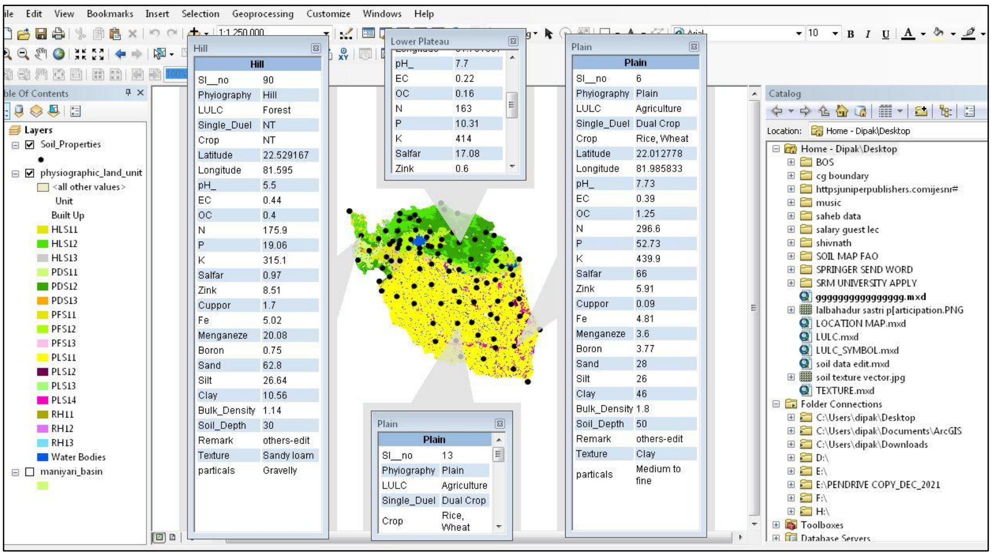

Figure 7: Physiographic soil map with database

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DIGITAL SOIL MAP (DSM)

The digital soil map is a raster-based map with 2-dimensional composed of cells (pixels) map organized into a grid in which each pixel has a specific geographic location and contains soil data. Digital soil maps depict the spatial distribution of soil classes or properties and can document soil prediction uncertainty. Digital soil mapping captures observed geographical variability more accurately and eliminates the requirement to combine soil types based on a fixed mapping scale.

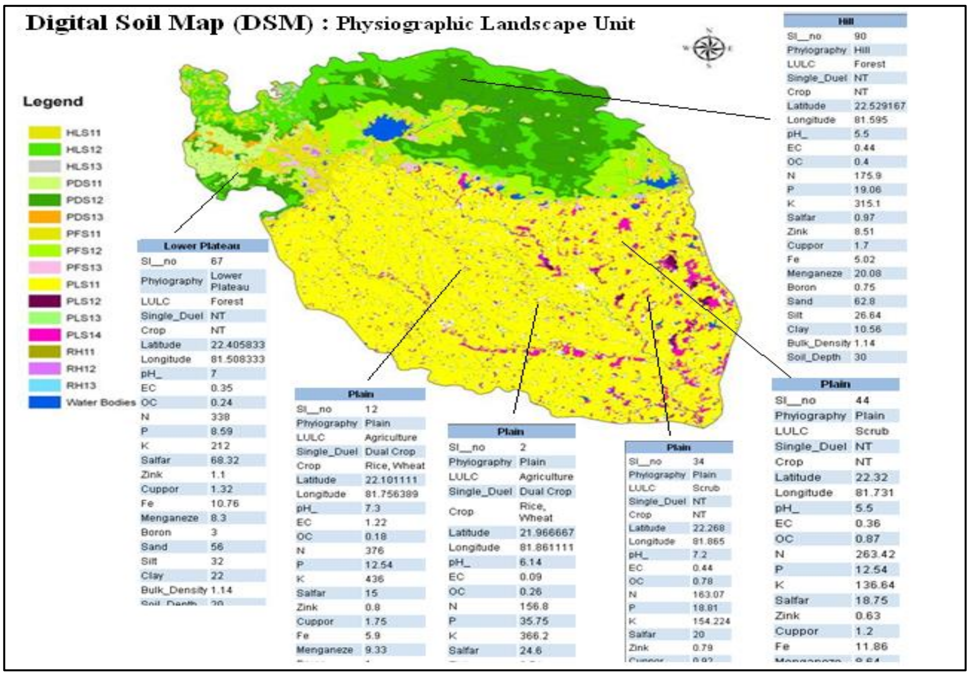

Figure 8: Digital soil Map

CONCLUSION

Digital soil maps are still not included in the discussion on soil degradation and sustainable management in India, nevertheless. It's not like India doesn't have any soil health information at all. Researchers have diligently gathered such information over the last several decades, in particular those at the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). This Digital soil database was created utilizing soil profile field data from 90 Georeference sites within the Maniyari basin.

Digital soil mapping would not only assist the study area (Maniyari basin) in making better use of its soils but also in preventing their degradation. In this present study, it has been observed that the area suffered from land degradation due to physical as well as anthropogenic activities. That's why it has been very necessary to manage the soil degradation as well as maintain the soil health. Soil profile data base helps to measure the soil health condition as well as to site suitability for crop selection.

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CONFLICT OF INTEREST: The authors declare no competing interests.

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