Available online at https://jonass.meybod.iau.ir/

Journal of Nature and Spatial Sciences

Journal homepage: https://jonass.meybod.iau.ir/


**Research Article**

# Digital soil mapping of Maniyari basin using geospatial techniques

**Dipak Bej[a,*], Naresh Kumar Baghmar[b]**

[a]*Ph.D. Scholar, Pt. Ravishankar Shukla University, Raipur*
[b]*Professor, Pt. Ravishankar Shukla University, Raipur*

ARTICLE INFO

*Article history:*
Receive Date: 14 October 2022
Revise Date: 20 January 2023
Accept Date: 25 January 2023

Keywords:
Digital soil map, Geographical Information System, IDW interpolation, Soil Nutrients

ABSTRACT

**Background and objective:** Remote sensing image data are often used as input in digital soil mapping (DSM). DSM nowadays is very popular rather than conventional soil maps it is an important tool in soil survey and sustainable agriculture planning. Spatial distribution of soil information in each pixel using laboratory observation data of soil samples plays an important role. The purpose of this study is to prepare a digital soil map using remote sensing.
**Materials and methods:** Ninety soil samples were collected at a depth of up to 50 cm from various Physiography land units made with the help of the basis of slope and Land use Land cover (LULC) as well as physiography. Sentinel 2 satellite data (10 m.) and Aster DEM (30 m.) have been used to prepare the digital soil map. 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).
**Results and conclusion:** Six textural classes identified were sandy clay loam and sandy clay, clay, clay loam, loam, and sandy loam. The bulk density, and the depth varied from 1.08 to 1.8 Mg m-3, and 14 to 90 cm. respectively. The pH, EC, and OC are varied from 5 to 8.36, 0.1 to 1.2 ds/m, and 0.03 to 1.47 respectively. Nitrogen (N), Phosphorus (P), and Potassium(K) varied from 125 to 476 kg/ha., 4.44 to 77.78 kg/ha, and 79.6 to 504 kg/ha respectively. The digital soil database along with all its properties called a physiographic soil map which has been prepared with the help of the inverse distance weightage (IDW) interpolation method, which will help to select crops and get the best sustainable cultivation.

## 1. Introduction

The compilation of geographically referenced soil databases based on quantitative correlations between spatially distributed environmental data taken from the field and measurements made in a laboratory is referred to as digital soil mapping (Dharumarajan et al., 2019; McBratney et al., 2003). The digital soil map is a raster-based map composed of 2-dimensional cells (grid) in which each

* *Corresponding author.* Tel.: +9399038309
E-mail address: bejdipak@gmail.com, ORCID: 0000-0002-4152-0171
Peer review under responsibility of Meybod Branch, Islamic Azad University

DOI: https://dx.doi.org/10.30495/jonass.2023.1967749.1058

pixel has a spatial location and contains soil physical and chemical parameters and nutrients.

Digital soil maps illustrate the spatial distribution of soil classes or properties and can document the uncertainty of soil prediction. Digital soil mapping better captures observed spatial variability and reduces the need to aggregate soil types based on a set mapping scale (Minasny & McBratney 2016; Zhu et al., 2001). The use of geospatial techniques for mapping soils is broadly covered by the term "digital soil mapping" (DSM). Digital soil mapping is defined as the creation of geographically referenced soil databases based on quantitative relationships between spatially explicit environmental data and measurements made in the field and laboratory (McBratney et al., 2003).

Creation and population of a geo-referenced soil database using field and laboratory observation methods combined with environmental data produced through quantitative relationships of the International Working Group on Digital Soil Mapping (WG-DSM).

"Production of soil class or property maps using GIS and/or Remote Sensing software" – anonymous Digital soil mapping (DSM) represents "the creation and population of spatial soil information systems by the use of field and laboratory observational methods coupled with spatial and non-spatial soil inference systems" (Digital Soil Mapping: An Introductory Perspective 2007). The availability and accessibility of geographic information systems (GIS), global positioning systems (GPS), remotely sensed spectral data, topographic data derived from digital elevation models (DEMs), predictive or inference models, and software for data analysis have greatly advanced the science and art of soil survey.

Conventional soil mapping now incorporates point observations in the field that are geo-referenced with GPS and digital elevation models visualized in a GIS. However, the important distinction between digital soil mapping and conventional soil mapping is that digital soil mapping utilizes quantitative inference models to generate predictions of soil classes or soil properties in a geographic database (raster). Models based on data mining, statistical analysis, and machine learning organize vast amounts of geospatial data into meaningful clusters for recognizing spatial patterns.

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

## 2. Material and Methods

### *2.1. Study area*

The Maniyari River basin is a part of Shivnath catchment (Part of Mahanadi). The river maniyari rises from Satpura Maikal hill, in the North West of the Central plateau. So, the Maniyari River flows through all the three ideal stages of the life cycle hilly, plateau, and plain. The study area covered three districts namely Kabirdham, Mungeli, and Bilaspur.

The latitude and Longitude of the study area are 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 is approximately 3790 sq. km. with a total of population of near about10 lakhs. 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 depicts the study area.

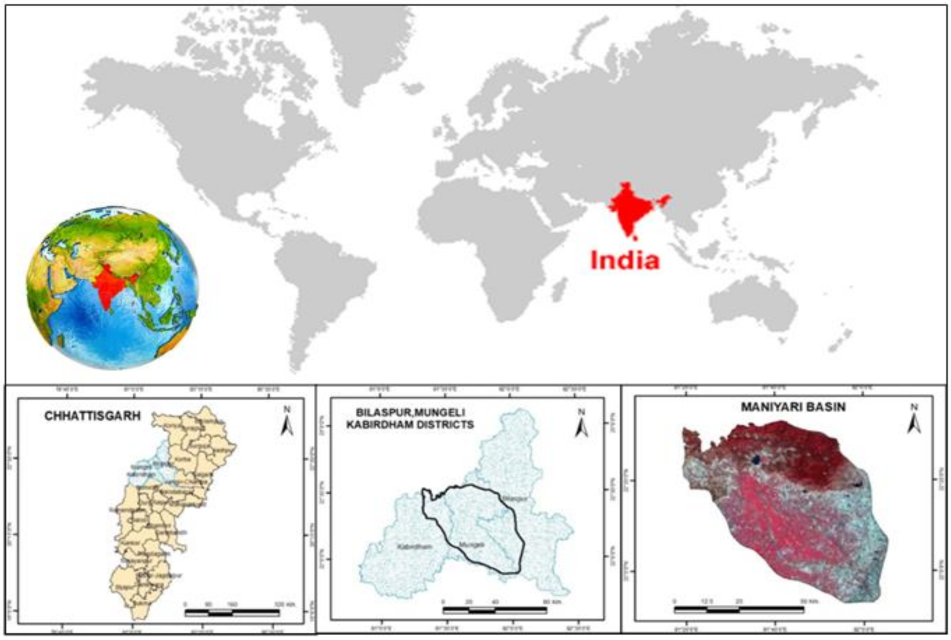



**Figure 1- Location map of the study area**

## *2.2. Data collection and research methods*

The database is one of the prime raw materials to finish a work. Both primary and secondary database has been used to prepare soil productivity and to find out the best productive way to find out the crop. And secondary data like topographical sheet, Sentinel 2 satellite imagery with the resolution of 10 m., and Aster DEM have been collected from a survey of India and USGS Earth Explorer respectively. Figure 2 shows the process of digital soil methodology map and all of the primary and secondary data sources are included in Table 1.

**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) |

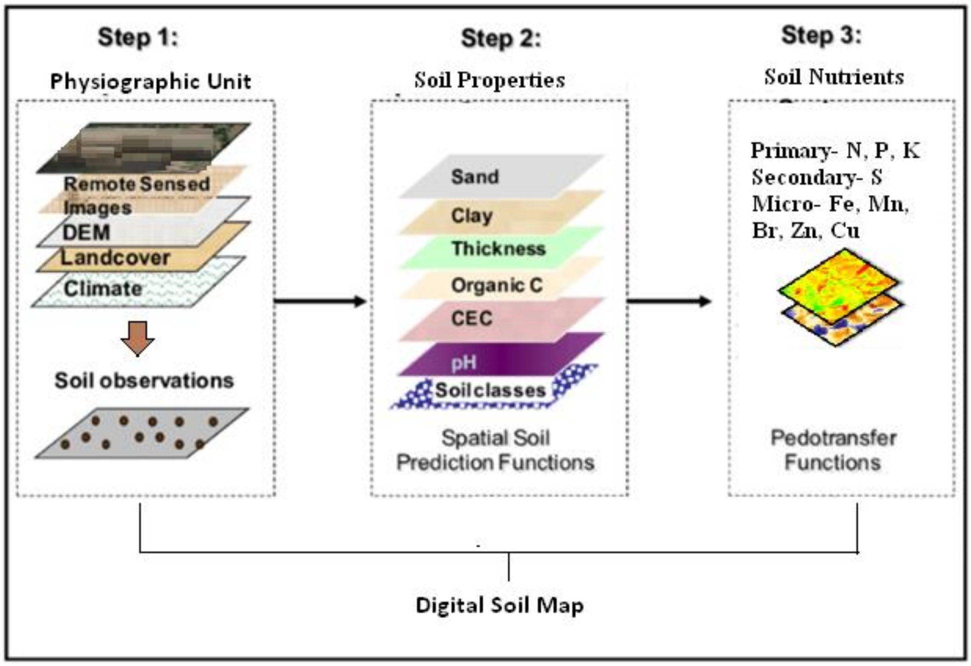



**Figure 2 - Flowchart methodology for digital soil map**

## 3. Results and discussion

### *3.1. Slope and Physiography*

A slope map has been prepared with the help of the Aster Digital Elevation Model (DEM) with a resolution of 30 m. there are five classes of slope category has been accounted for in the preparation of the physiographic unit map Figure 3.

The elevation range of this study area was found from 135 m. to 1015 m. Fives physiography classes have been estimated based on relief features as well as elevation. A soil sample has been collected with the help of the physiographic unit map.

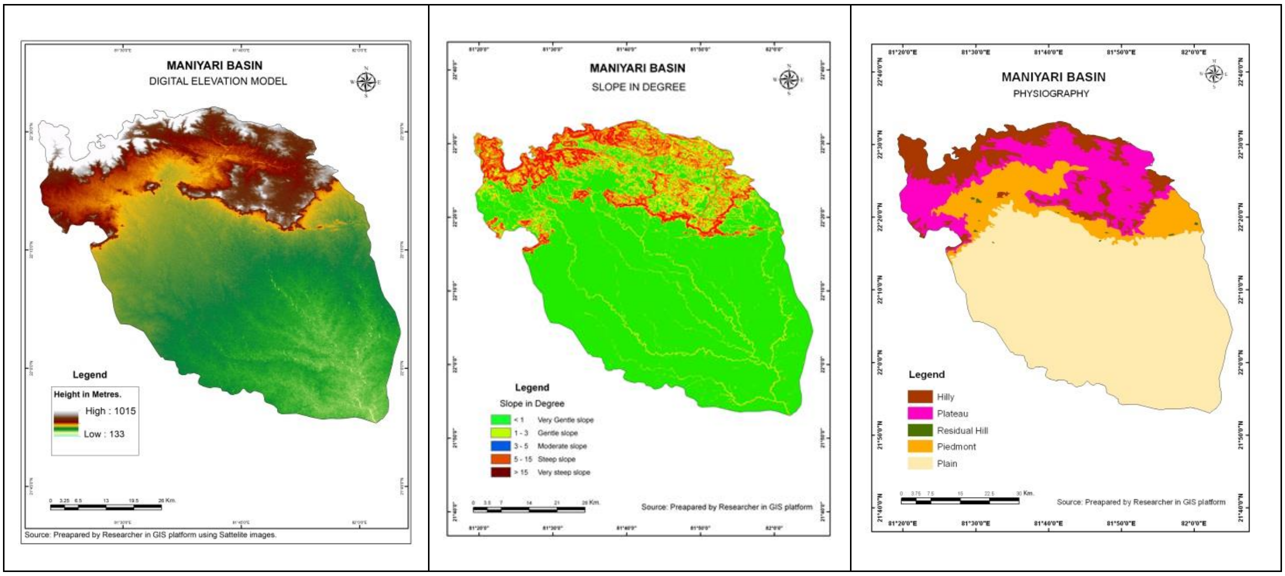



**Figure 3 - Digital elevation model, slope and topography**

## *3.2. Land use Land cover*

LULC map has been prepared with the help of the visual image interpretation technique. Ground truth verification has been completed to verify the doubtful areas. Accuracy abasement has been done using 50 Ground control points with the help of GPS. The area of the LULC varies from one land use to another. In the study area there are 12 LULC classes have been identified. Agriculture land covered 60.13 %, forest 27.66%, Open scrub 3.16 %, and Built-up rural 2.96 % area of the total Geographical area. LULC is depicted in Figure 4 and Table 2.

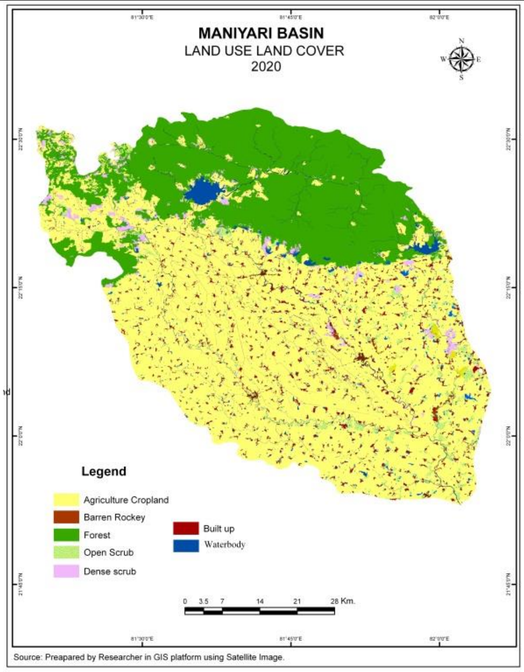
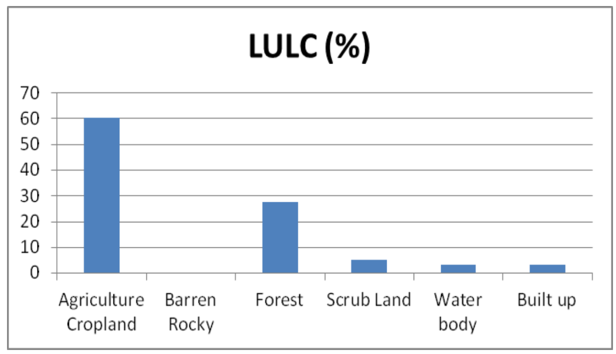



Figure 4 - LULC (2020)

**Table 2 - LULC Classes**

| 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 |




## *3.3. Physiographic land Unit*

There are 19 primary physiographic land units that have been identified with the combination of topography, slope, and LULC map. Ninety soil samples have been collected according to the physiographic unit, some broad unit has contained more than one sample like PLS11 plain agriculture land has approximately 50 samples because of their soil textural differences as well as HLS12 hilly forest areas have more than ten samples to identify the soil nature. Physiographic unit details and maps are shown in Tables 3, and 4 and Figures 5, and 6.

**Table 3 - Physiographic unit details and code**

| Sl. No. | Land Facets | Topography | LULC | 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 |

**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 |

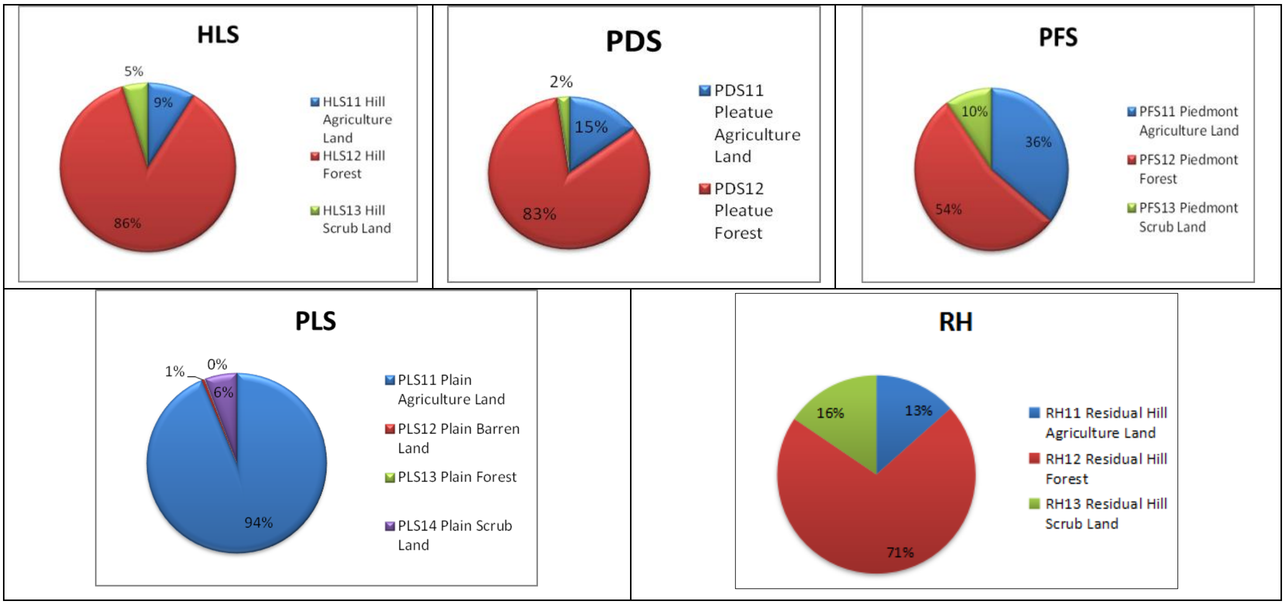



**Figure 5- Physiographic unit with LULC distribution (2020)**

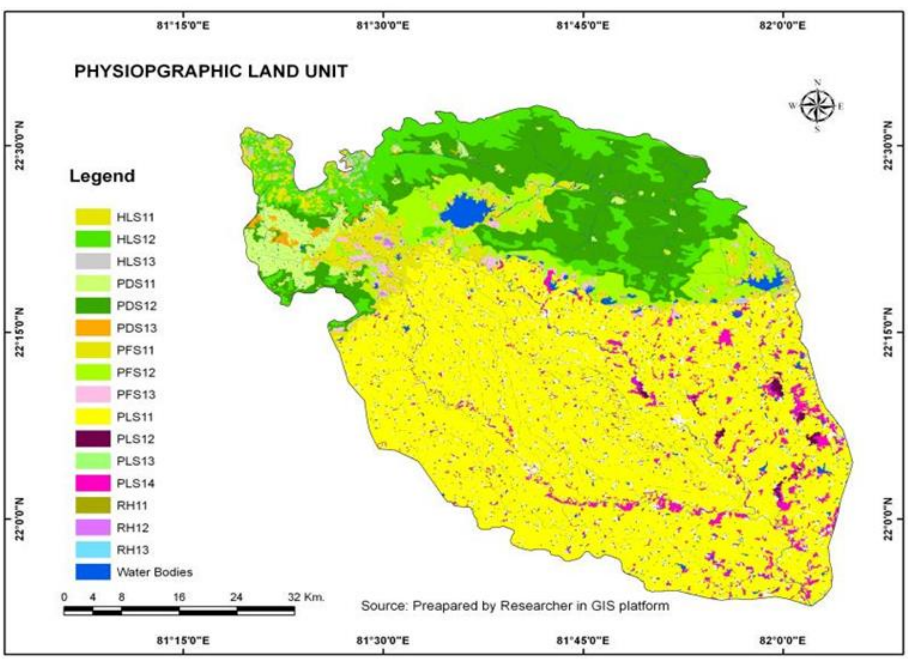



**Figure 6 - Physiographic land units of the study area**

## *3.4. Digital Soil Database*

A database management system has been formulated on the Arc GIS platform which contains 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 erosion Figure 7. Soil sample size and the area or volume of representation should be considered when determining the location of field sampling sites and the timing of measurements (Bouma et al., 1989; Mohanty & Mousli, 2000).

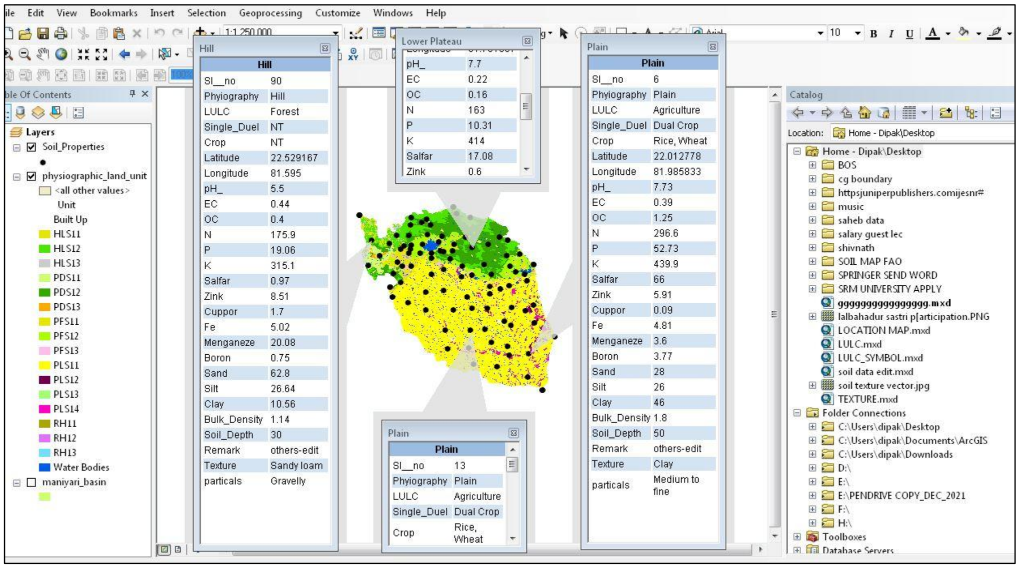



**Figure 7- Physiographic soil map with database**

## *3.5. Digital soil map*

The digital soil map is a raster-based map with a 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 eliminate the requirement to combine soil types based on a fixed mapping scale Figure 8.

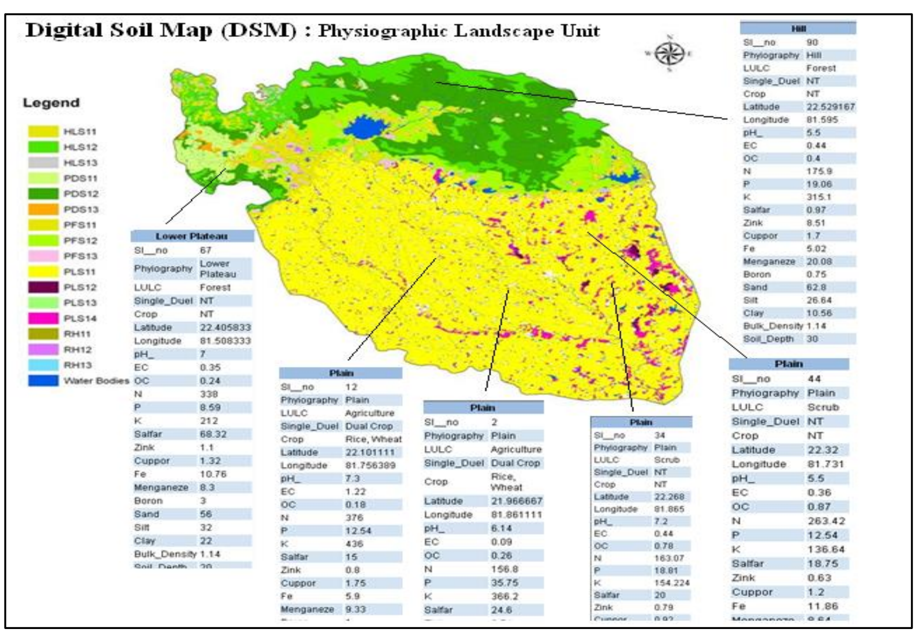



**Figure 8 - Digital soil map**

## 4. Conclusion

This study showed the high potential of using remote sensing data and land information to improve the accuracy of a digital soil map. The resolution of the DEM, slope category, and type of LULC play an important role in the accuracy of the digital soil map.

The results of this study showed that the majority of DSM studies that use remote sensing tools use the one-time remote sensing method and these one-time remote sensing variables are important predictors in DSM models. By combining topography, slope, and LULC map suitable land physiographic results were obtained. The soil sample size and area were also taken into consideration when determining the location of the sampling sites and the measurement time. The physical characteristics of the soil, chemical properties and nutrients of the soil based on the physiography of the land provided suitable information for the preparation of the digital soil map. Six soil textures were identified at different depths.

According to the texture and type of soil, pH, EC, OC, Nitrogen (N), Phosphorus (P), and Potassium (K) are variables, which can be considered as variables for the type of land use. Based on the results, the current research shows that many variables affect soil texture and LULC changes, so soil management and conditions to preserve natural and human resources require more attention from executive organizations and responsible experts. Therefore, paying attention to these changes and predicting the future leads to better decision-making and management, so considering all these factors leads to sustainable development and does not lead to destruction and pollution of the environment.

**Acknowledgment:**

We want to thank local farmers as well as district soil survey lab Labhandi, Mungeli who continuously supported to data collection as well as testing. Soil science dept. of Indira Gandhi Krishi Vishwavidyalaya, Raipur also supported us to completion the work.

**Declarations**

**Funding Information** (Private funding by authors)

**Conflict of Interest /Competing interests** (The authors declare no competing interests.)

**Availability of Data and Material** (Data are available when requested)

**Consent to Publish** (Authors consent to publishing)

**Authors Contributions** (All co-authors contributed to the manuscript)

**Code availability** (Not applicable)

REFERENCES

Arianpour, M., & Jamali, A. A. (2014). Locating flood spreading suitable sites for groundwater recharging through multi criteria modeling in GIS (case study: Omidieh-Khuzestan). *Journal of Biodiversity and Environmental Sciences*, *5*, 119-127.

Bouma, J., Jongmans, A. G., Stein, A., & Peek, G. (1989). Characterizing spatially variable hydraulic properties of a boulder clay deposit in the Netherlands. *Geoderma*, *45*(1), 19-29. https://doi.org/10.1016/0016-7061(89)90054-2

Carré, F., McBratney, A. B., Mayr, T., & Montanarella, L. (2007). Digital soil assessments: Beyond DSM. *Geoderma*, *142*(1-2), 69-79. https://doi.org/10.1016/j.geoderma.2007.08.015

Dharumarajan, S., Hegde, R., Janani, N., & Singh, S. K. (2019). The need for digital soil mapping in India. *Geoderma Regional*, *16*, e00204. https://doi.org/10.1016/j.geodrs.2019.e00204

Ghane Ezabadi, N., Azhdar, S., & Jamali, A. A. (2021). Analysis of dust changes using satellite images in Giovanni NASA and Sentinel in Google Earth Engine in western Iran. *Journal of Nature and Spatial Sciences (JONASS)*, *1*(1), 17-26. https://doi.org/10.30495/jonass.2021.680327

He, S., Wang, D., Zhao, P., Li, Y., Lan, H., Chen, W., & Jamali, A. A. (2020). A review and prospects of debris flow waste-shoal land use in typical debris flow areas, China. *Land Use Policy*, *99*, 105064. https://doi.org/10.1016/j.landusepol.2020.105064

He, S., Wang, D., Li, Y., Zhao, P., Lan, H., Chen, W., ... & Chen, X. (2021). Social-ecological system resilience of debris flow alluvial fans in the Awang basin, China. *Journal of Environmental Management*, *286*, 112230. https://doi.org/10.1016/j.jenvman.2021.112230

Masoumi, H., Jamali, A. A., & Khabazi, M. (2014). Investigation of role of slope, aspect and geological formations of landslide occurrence using statistical methods and GIS in some watersheds in Chahar Mahal and Bakhtiari Province. *J. Appl. Environ. Biol. Sci*, *4*(9), 121-129.

McBratney, A. B., Santos, M. M., & Minasny, B. (2003). On digital soil mapping. *Geoderma*, *117*(1-2), 3-52. https://doi.org/10.1016/S0016-7061(03)00223-4

Minasny, B., & McBratney, A. B. (2016). Digital soil mapping: A brief history and some lessons. *Geoderma*, *264*, 301-311. https://doi.org/10.1016/j.geoderma.2015.07.017

Mohanty, B. P., & Mousli, Z. (2000). Saturated hydraulic conductivity and soil water retention properties across a soil-slope transition. *Water Resources Research*, *36*(11), 3311-3324. https://doi.org/10.1029/2000WR900216

Parsasyrat, L., & Jamali, A. A. (2015). The effects of impermeable surfaces on the flooding possibility in Zarrin-Shahr, Isfahan Municipal Watershed. *J Appl Environ Biol Sci*, *5*(1), 28-38.

Qanbari, V., & Jamali, A. A. (2015). The relationship between elevation, soil properties and vegetation cover in the Shorb-Ol-Ain watershed of Yazd. *J Biodivers Environ Sci (JBES)*, l.

Zhu, A. X., Hudson, B., Burt, J., Lubich, K., & Simonson, D. (2001). Soil mapping using GIS, expert knowledge, and fuzzy logic. *Soil Science Society of America Journal*, *65*(5), 1463-1472. https://doi.org/10.2136/sssaj2001.6551463x