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Agricultural Land Suitability Analysis for Rihand River Basin of Chhattisgarh State: Using Remote Sensing and Geographical Information System

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ABSTRACT:

The Land suitability analysis is one of the best techniques for the evaluation of soil quality for a particular study area. This technique was first developed by the Food and Agriculture Organization of the United Nations (UN-FAO). It is possible to evaluate the land based on different periodic conditions. The use of modern techniques, such as Remote Sensing and Geospatial Technique, helped the categorize land suitability assessments. In the present study, Rihand river basin areas were categorized according to the land suitability for defined land uses using the method of land suitability classification. The Land Suitability Analysis is one the most useful application for land use planning and sustainable resource management. The land suitability analysis of the Rihand river basin has been carried out in different classes to better understand land. The suitability of land has been categorized as S1 (highly suitable - no significant limitations), S2 (moderately suitable - having few limitations), S3 (marginally suitable - having most of the limitations), N1 (presently not suitable, but potentially is suitable for futures; uneconomical for land use), and N2 (permanently is not suitable). These suitability classes are refers to the effects of the individual land qualities on the engendering of the different crops.

Keywords: *Rihand River Basin, Soil Prosperities, Land Suitability, LULC.*

INTRODUCTION

The land Suitability is assessed considering the rational cropping system, for the evaluation of soil quality for a particular study area (FAO, 1976). The suitability is the function of soil quality assessments for different crop practices and land characteristics. This is one of the important measurements, of how well the soil qualities of a particular land unit match the

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requirements of land use (Mermut and Eswaran 2001; Yasrebi et al. 2008). Land suitability is the fitness of a given type of land for a defined use. The process of land suitability classification is the appraisal and grouping of a specific area of land in terms of its suitability for defined uses (Samian et al. 2015). For assessment of Land suitability, the soil is having main part. By soil survey, we can know about various soils, assess their potentiality, limitation and to predict their behavior for a specific purpose, and classify them (Alam and Olsthoorn 2011). The proper soil survey itself indicates the main hazard of soil and corrective measures required. All technical data regarding soil should be well known for profitable and suitable use of every piece of land according to Land capability (Sombroek et al.1982). For Land suitability analysis it is necessary to know soil characteristics such as soil texture, structure, infiltration, permeability, depth, color, and associated characteristics such as land slope, the extent of erosion, degree of wetness, salinity, frequency of flooding, etc for making proper evaluation (Kamali, F. P. et al. 2017). Changing the day-to-day environment conditions to assess the Land capability land use pattern is more important to sustainable development to achieve the terms, needs to assess the soil loss, land capability, slope aspect, land use and land cover information are more important in Land capability and sand use adjustment (Ziadat (2000). In order to define the land suitability of a particular study area for a specific land use practice, several criteria have to need to be evaluated (Bishop, T. F et. al. 2005). The local Farmers' communities assess to their farmland by using different consistent observations and collective experiences (Niemeijer 2003). However, for the rural communities, the knowledge usually used is insufficient for understanding the suitability conditions, and different strategies of management (Daigle, J. J. et al. 2005). Economic growth has been found all over the world and as the result is increased to meet the very high demand for new agricultural land, residential housing, recreation area, tourism, railway, highways and so many other human activities (Patel, N. N et al 2015). Those have expanded in the hills and their peripheries (Pramanik, M. K. 2016). The Land suitability analysis for hill area development is one of the planned land use systems. This may provide an adequate idea for solving urban environmental problems in growing cities (Miyamoto, S. et al 2005).

The modern Remote Sensing techniques, using sensors in the visible, thermal, and microwave region of the electromagnetic spectrum, have been found to be valuable tools in the evaluation, monitoring, and management of land, water, and crop resource (Albaji M, et

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al 2015; Surendran U. et al 2016). The launching of Indian remote sensing satellite 1RS- 1A, 1B, 1C, and 1D having sensors in the visible and infrared regions, has enhanced the capabilities for better utilization of this technology and significant progress has been made in soil and land cover mapping, land degradation studies, monitoring of wastelands, assessment of drought and crop condition (Abeysingha, N. S. et al. 2015), crop acreage and production. Multispectral satellite data viz., Landsat MSS, TM, IRS- LISS I, II, and III have been found to be small-scale soil resource and land use mapping using visual and digital techniques (Jyoti, N.A. et al. 2015). The utility Landsat TM and IRS LISS II & III data for soil and land use mapping and productivity assessment has been reviewed by (A. A. Mustafa. Et al. 2011). The task of gathering information on the soils has been greatly synergized by the enhanced speed and reliability with spatial and temporal information generated by Remote Sensing techniques (Somprasong, K. et al 2014; Sun, Y. et al 2010). Somehow GIS (Geographical Information System) is one of the most powerful tools to use input, store, analysis, and retrial of spatial and non-spatial data in a quicker way to calculate and compute for making a suitable decision and map making (Asres S.B. 2016; Kanlaya et al. 2009). A physiographic soil map for many large areas with a good level of accuracy can be prepared at a shorter time with less manpower and at a lower cost ground penetrating radar devices with soil penetration capacity ranging from approximately one meter in sandy soils can provide precise images to complete soil sequences for identification of sub-surface soil features and diagnostics horizon (Masuda, H. 2018; Zink.1990).

Therefore, land management is focusing on soil suitability for development mainly crop production. The idea of local land use and land cover conditions has become increasingly recognized its importance for sustainable land management (Shukla et al., 2006). Many of Geographic Information System (GIS) based land suitability analysis has been approached recently to develop the modeling for land suitability analysis. However, these approaches lack a well-defined mechanism for incorporating the decision maker's preferences into the GIS procedures (Nath, A.J. et al. 2012). Modern techniques like satellite remote sensing technologies and Geographic Information systems are monitoring crop practices and have the potential to establish timely assessments of changes in the growth and development of crops on regional scales (Rajitha et al. 2007). The Geographic Information System and Remote Sensing have played an important role throughout the world, and are

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greatly effective when used for determining the land suitable for agriculture management (Zabihi, H. et al. 2007). The main aim of this research is to Analysis the land suitability for sustainable land use in the Rihand river Basin of Chhattisgarh State.

LOCATION OF THE STUDY AREA

The present study has been carried out in the Rihand River basin. It is a part of the Son river basin, located in the Sarguja and Surajpur districts of Chhattisgarh state, India. A total of 3070.04 km2 areas are covered by the upper Rihand river basin mentioned in figure 1. The extension of the study is 22°37'23" N to 23°29'29" N latitude and 83°36'39" E to 83°23'27" E longitude. The maximum elevation of the river basin is more than 1100 m which is found on the Mainpat plateau and the minimum elevation is 345 m on the Rihand river bed.

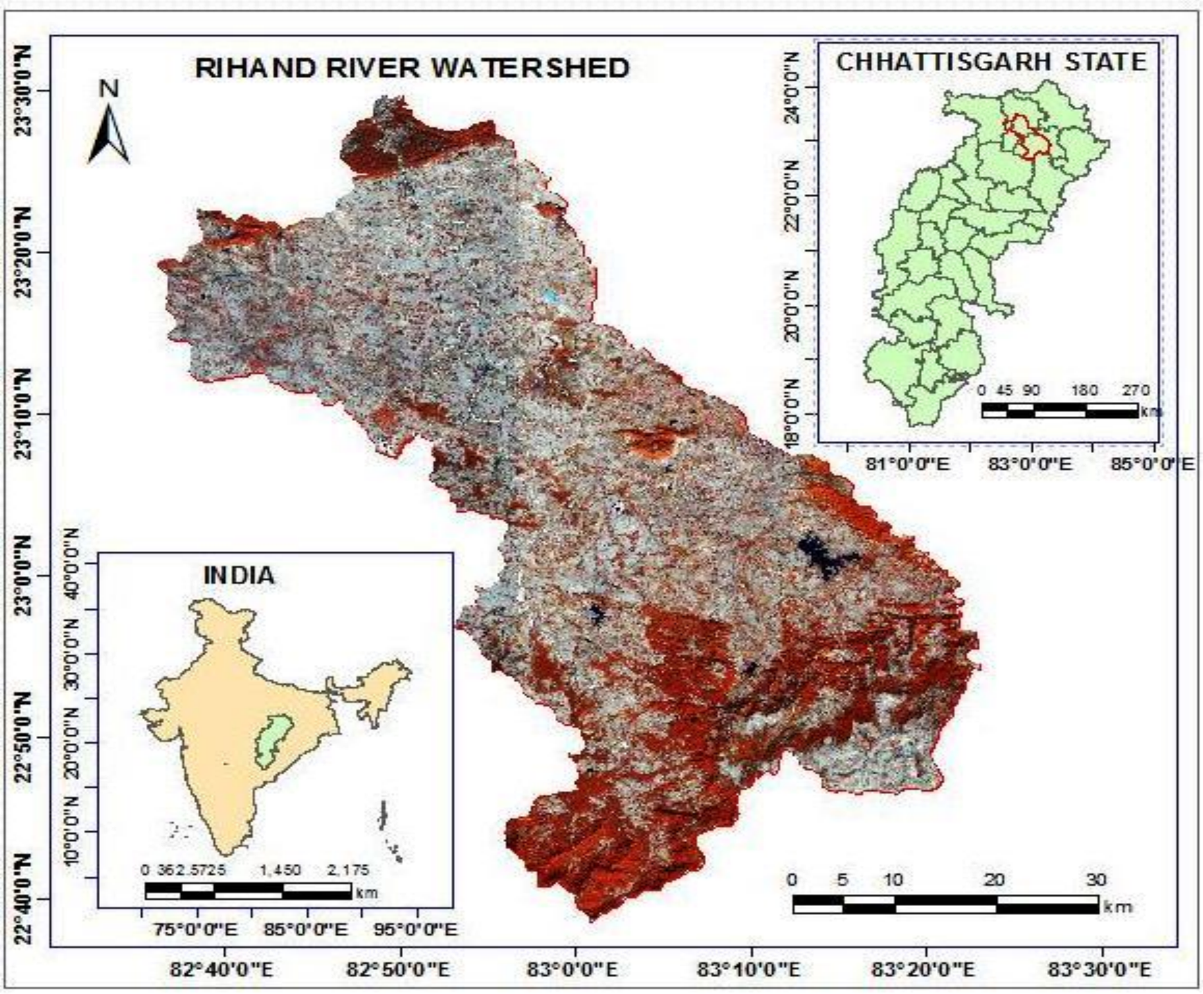

Figure 1: Location map of Rihand River Watershed.

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METHODOLOGY:

The present study involves the application of remote sensing techniques in soil resource surveys and land evaluation of the area. Its aim was to interpret, identify, classify, and map analytical studies of characteristics and integrate all these attributes for soil suitability evaluation with respect to different land utilization types for better land use planning. The survey of India toposheet and LISS IV satellite imagery (5m Resolution) has been used for the study. The Slope, aspect map, is prepared by the use of CARTO DEM (30m Resolution). The IRS-P6 LISS IV standard geocoded false color composites in 1:50000 scales generated from band 2, 3, and 4 was used to delineate the broad physiographic unit used for the study of the area. Delineation of the major landforms was done mono-scopically and each landform was identified and mapped based on the physiographic variation. Each landform was further subdivided based on the combination of color, tone, land type, texture, pattern, slope, land use, etc. By these combinations, features were recognized and boundaries of different homogeneous area interpretation keys have been prepared. For the preparation of land use and physiographic soil map following points were considered.

Fieldwork was carried out to collect ground information on the study area. A rapid reconnaissance survey of the study area was undertaken prior to detailed field checking to understand the broad landforms, land use, and their relationship with soil properties. Then ground verification process was started by selecting sample strips, to cover the area of maximum physiographic units for traversing and locating observation points in imagery, topographical map of the 1:50000 scale of the study area was used. For each mapping unit representative soil profile, auger bores were studied and noted on the field notebook containing detailed profile site and morphological characteristics.

Altogether sixty-seven soil profiles and a number of augers bore observations were taken. The soil samples of the master horizons were selected for each mapping unit for detailed laboratory analysis. The soil suitability classification was carried out according to the FAO framework (1976) and each mapping unit was rated for the suitability of onion, sugarcane, wheat, and grape crops (Tercan E. et al 2020). The soil survey data which describes the land qualities of the physiographic units e.g., texture, drainage class, slope, relief, salinity hazards, erosion hazards, and water logging hazards parameters (Sys et al.

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1991) was crossed with the land requirement of Land utilization types (LUT' s) for evaluating site suitability of each unit for sustainable land use planning. The model has been created in Arc GIS 10.3 software to perform overlay analysis. The below-mentined equation (1) has been used for land suitability classification.

$$LS = SLOPE \times SOIL\ TETURE \times SOIL\ DEPTH \times pH \times EC \times OC \times LULC$$

Where, LS is the land suitability for the basin area. The slope, soil texture, and soil depth are the physical properties of soils. The pH, Electric Conductivity (EC), and Organic Carbon (OC) are the chemical properties of soils, and LULC is the land use and land cover of the study area.

RESULT AND DISCUSSION

It involves the interpretation of basic survey data for specific land use. It appraises the suitability of different types of land for particular use assuming that all other environmental conditions are optimum. For this purpose, relevant soil and land characteristics such as texture, drainage, gravelliness/stoniness, slope, soil -depth, erosion hazards, and risk of flooding are taken into account which provides a sound basis for rating the land. Suggested land use and cropping may not only curb the misutilization of the land but also lead to sustained yields and ultimately will improve the socio-economic conditions of the inhabitants.

River and Water Bodies

The area falls within the drainage basin of the Upper Rihand river and forms part of the Son River. The area can be broadly covered by the Gungata and Rather river which are sub-tributary of the Rihand river in figure 2. The rivers are flowing in the northern and north-western directions. More than thousands of water bodies have been identified in the study area. Most of the water bodies are located in the northern side's plain area but in the hilly area, only a few of them have been identified. Mainly reservoirs, tanks, ponds, and a few large dams have come under these water bodies. Gungata dam is the largest of them (Mandal B. et al. 2022). These are played a significant role in irrigation purposes.

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Physiography

The lithological structures of the study area are consisting of mainly sandstone, granite, and basaltic rocks. The sandstone cover nearly 61%, granite 24%, basaltic 6.5%, and laterite 4.3% respectively, and the remaining are schist and quartzites. Physiographically about 29% area has come under high hills which are mostly found in the southern part and a few of them in the northern parts. The middle part of the study area is covered by a piedmont and plain surface. The maximum height of topography is 1106 and the minimum is 345 m. The relative height of the study is 760 m mentioned in figure 3. it represents the topographical diversification.

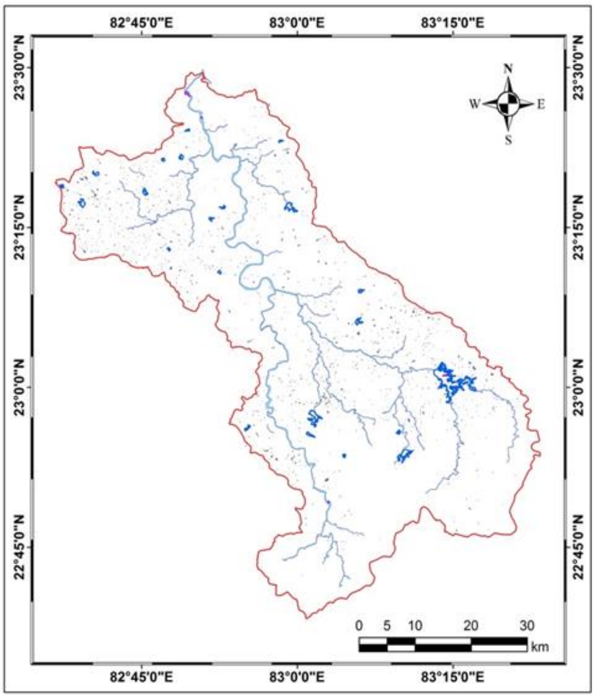

Figure 2: River and water bodies map

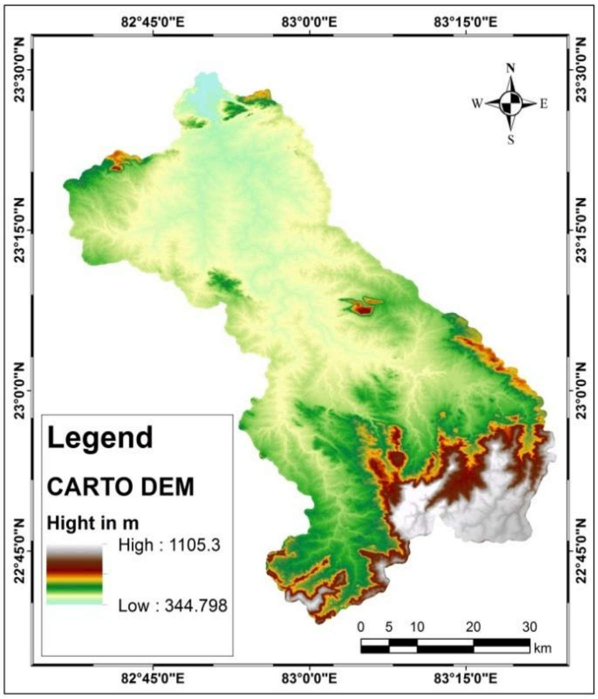

Figure 3: Digital Elevation Model (DEM)

Slope

The dominant slope categories in the Rihand river basin are nearly level (< 1 %), very gentle slope (1-3 %), and gentle slope (3-5 %). These areas are close to rivers and streams have flown on the plain surface area. However moderate slopes 5-10% to Mod. to the steep slope (15-35 %) are found mainly on piedmont and foot hillsides of hilly areas. Steep slope (35-50 %), Very Steep slope (50-70 %), and Escarpment (> 70 %) are found in the hilly part of the

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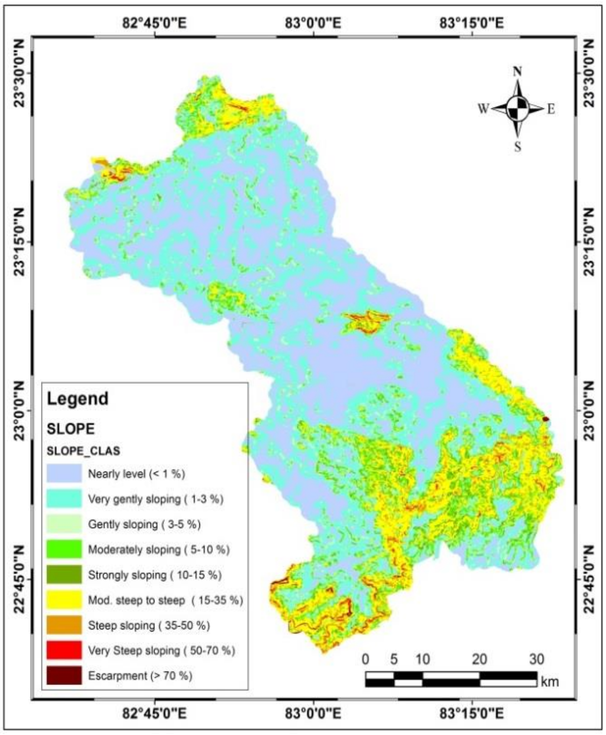
study (table 1 and figure 4). The slope is, directly and indirectly, implication on-various land use land covers. The areas with fewer than 10 % of slopes are mostly river valleys, plain is influenced by agricultural practices.

Table 1: Slope Classes

Sl no	Slope Classes	Area in km2	Percentage (%) in area
1	Nearly level (< 1 %)	1127.54	36.73
2	Very gently slope (1-3 %)	933.39	30.40
3	Gently slope (3-5 %)	194.24	6.33
4	Moderately slope (5-10 %)	232.29	7.57
5	Strongly slope (10-15 %)	89.26	2.91
6	Mod. to steep slope (15-35 %)	409.89	13.35
7	Steep slope (35-50 %)	66.29	2.16
8	Very Steep slope (50-70 %)	14.94	0.49
9	Escarpment (> 70 %)	2.26	0.07
	Total	3070.04	100.00



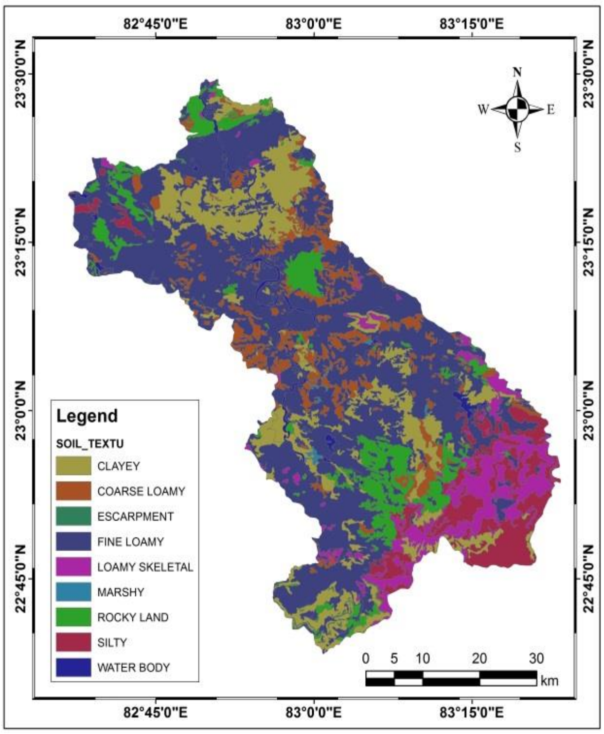


Figure 4: Slope map of the study Figure 5: Soil texture map

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Soil Prosperities

The Rihand river basin area has been classified into nine soil texture classes. The fine loamy soil covered about 50%, clayey 15.90%, Rocky land 8.96%, coarse loamy 8.74%, and loamy skeletal 7.4% respectively mentioned in figure 2. Fine loamy, clayey, and loamy soils are preferred for suitable land use purposes (figure 5). The most of areas are found on hill edges and plateaus in very shallow to shallow soil depth categories. The moderately, deep, and very deep soils are found on the foothill, plain, and river valley sides respectively mentioned in figure 6. The other soil parameters like Ph, EC, and organic carbon (OC) has been identified according to village wise and these are shown through maps unit in figure 7,8, and 9.

Land Use and Land Cover

The spatial information on present land use is a prerequisite for analyzing current demands /supply and assessing the sustainability of the area. In Rihand river basin terrain, the technique of remote sensing has maximum use especially when those areas are inaccessible due to high hilly and dense forest. Land use practices in this region are mainly controlled by topography, slope, soil, climate, human influence, and socio-economic needs. Agricultural land use is the most important in the study area. The Agricultural land, forest, forest plantation, scrubland, build-up area, mining, barren land, gullied, and water bodies are covered 56.6%, 21.8%, 0.07%, 12.8%, 4.78%, 0.04%, 8.7%, 1.9%, and 3.1% respectively (figure 10).

Land Suitability Classification

It involves the interpretation of basic survey data for specific land use. It appraises the suitability of different types of land for particular use assuming that all other environmental conditions are optimum. For this purpose, relevant soil and land characteristics such as texture, drainage, gravelliness/stoniness, slope, soil -depth, pH, organic carbon, and electric conductivity have been taken into account which provides a sound basis for rating the land suitability analysis. The resultant land Suitability orders are classified into five classes. The two more classes, settlement, and water bodies have been included in land suitability analysis to better understand the land use class but these are not fundamental classes of suitability. These classes reflect the land suitability viz, S for suitable and N for non-suitable.

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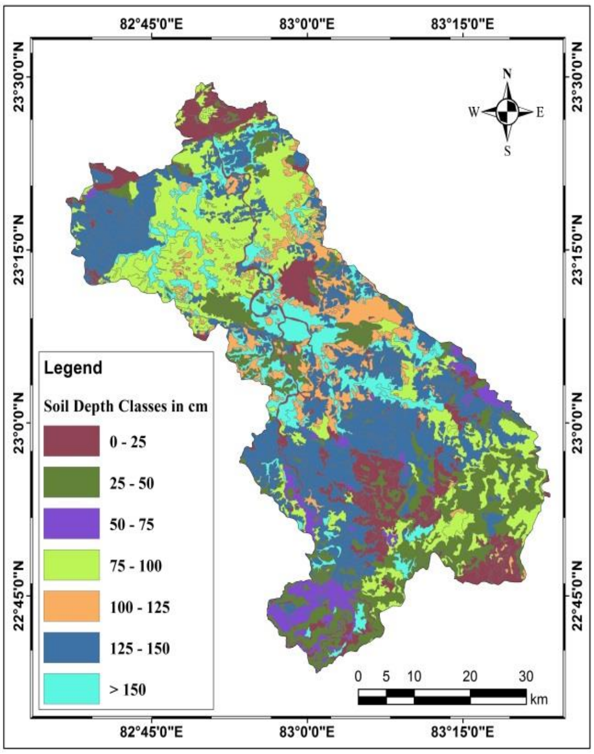

Figure 6: Soil depth map

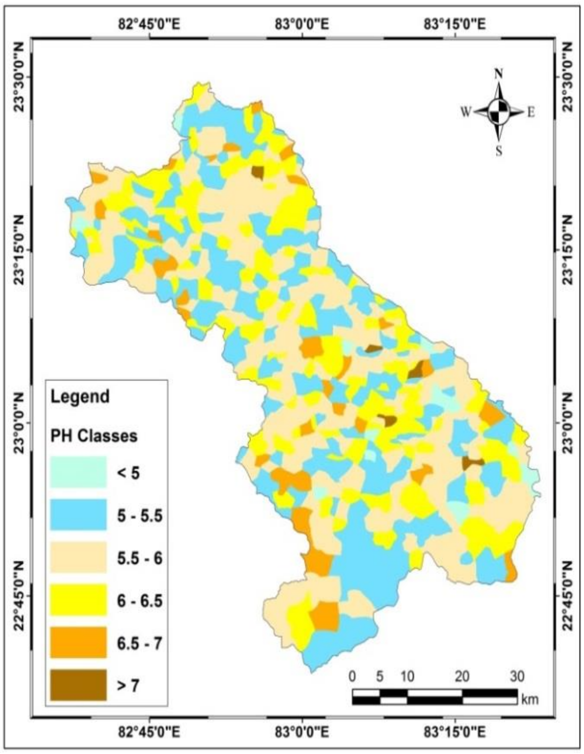

Figure 7: Soil pH map

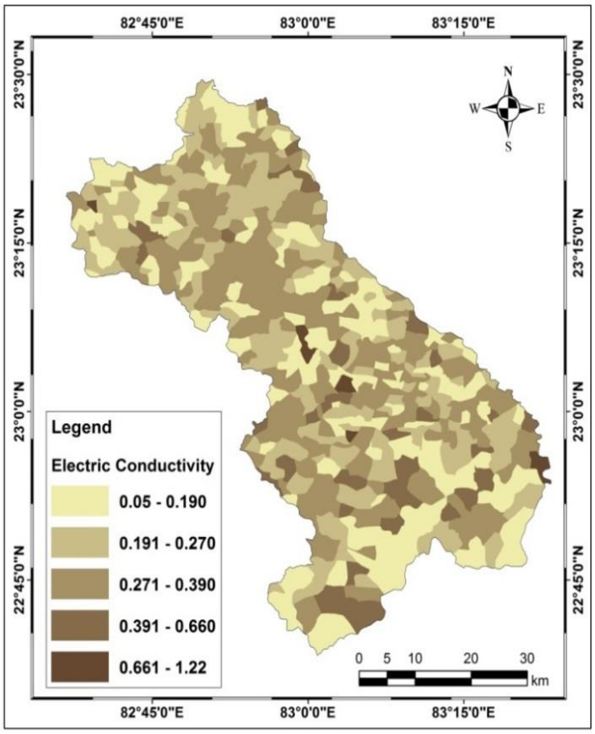

Figure 8: Soil electric conductivity map

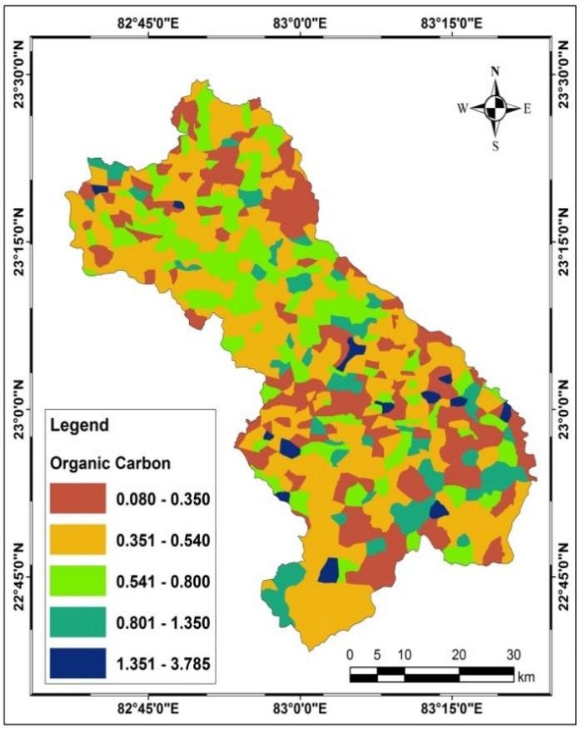

Figure 9: Soil Organic carbon map

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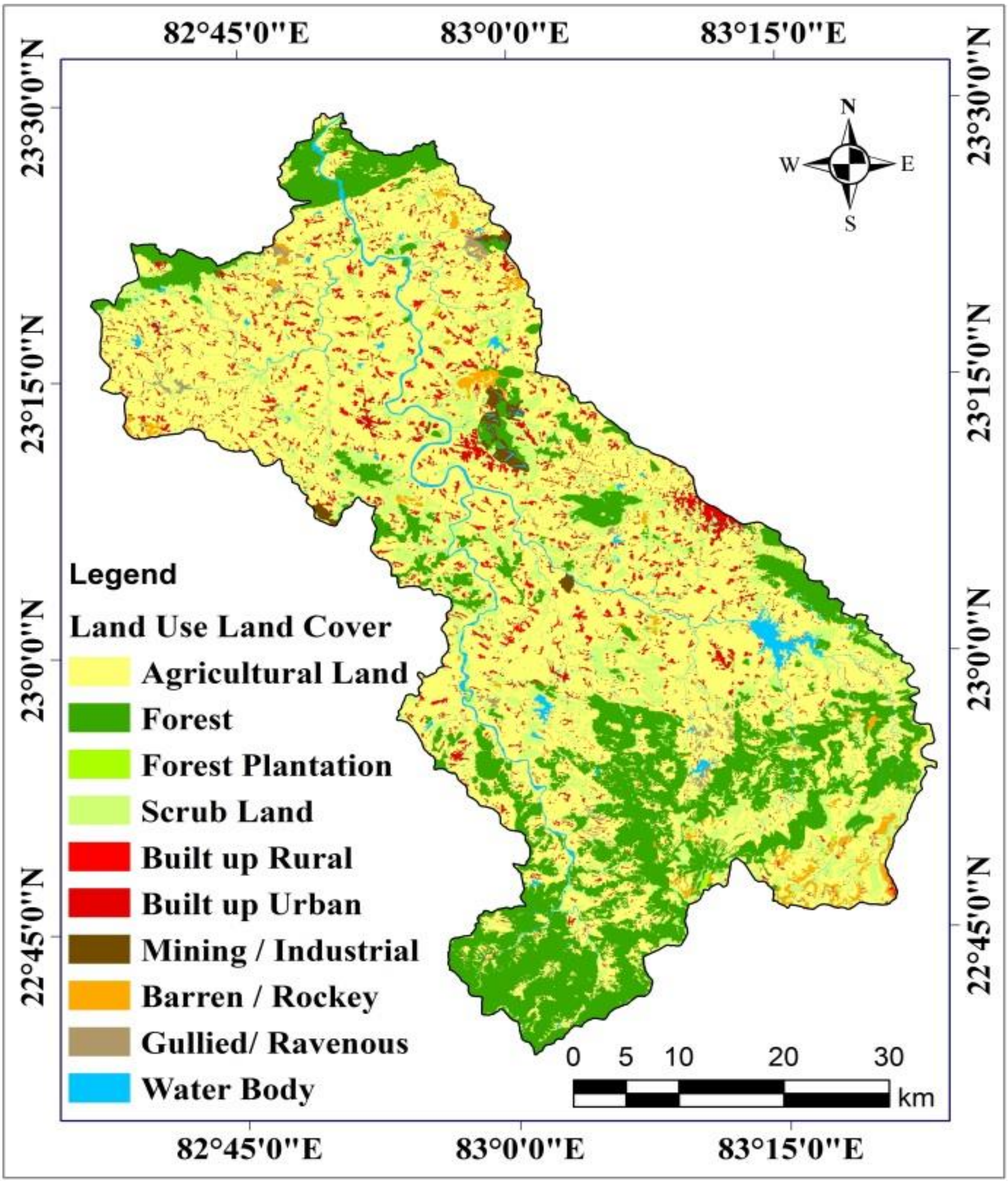

Figure 10: Land use and land cover map

Here the Suitable (S) is expected to yield benefit which justifies the inputs without unacceptable risk of resources and the non-suitable (N) is under limitations that appear to preclude sustained use of the like consideration. The suitability class has indicated the degree

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of suitability within the order. In all, there are four classes (S1, S2, S3, N1, and N2). Highly suitable (S1) is the land having no significant limitation to sustained application to a given use, or only minor limitations that will not significantly reduce productivity or benefits, and will not raise inputs above an acceptable level. The major part of the study 38.32% come under this suitability class. Moderately suitable (S2), the land has moderately severe limitations for sustained applications of a given use which reduces productivity or benefit or increases required inputs to the extent of obtaining optimum advantage from land. Mainly plain area and few flattened hilltops agricultural field nearly 29.88% of Rihand river basin have come in this class. Marginal suitable (S3), the land having limitations which in the aggregate are severe for sustained application of a given user and will so reduce productivity or benefit or increase required inputs, that this expenditure will be only marginally justified. Only a few parts (5.51 %) of land area are covered by this class. The N1, the land is presently not suitable, but potentially is suitable for futures; uneconomical for land use (11.30% area). Permanently unsuitable (N), the land has severe limitations which are indicating that there are no future possibilities of successful sustained use of the land for agricultural purpose in a given manner. Another 321.06 km^2 area (10.46%) has been classified in either N1 or N2 because these areas mostly match both types of land suitably class mentioned in table 2 and figure 11.

Table 2: Land suitability classes

Suitability Class	Area in km^2	Percentage (%) of area
S1	1176.32	38.32
S2	917.28	29.88
S3	169.26	5.51
N1	83.08	2.71
N2	347.04	11.30
N1/N2	321.06	10.46
Settlement	10.07	0.33
water bodies	45.94	1.50
Total	3070.04	100.00

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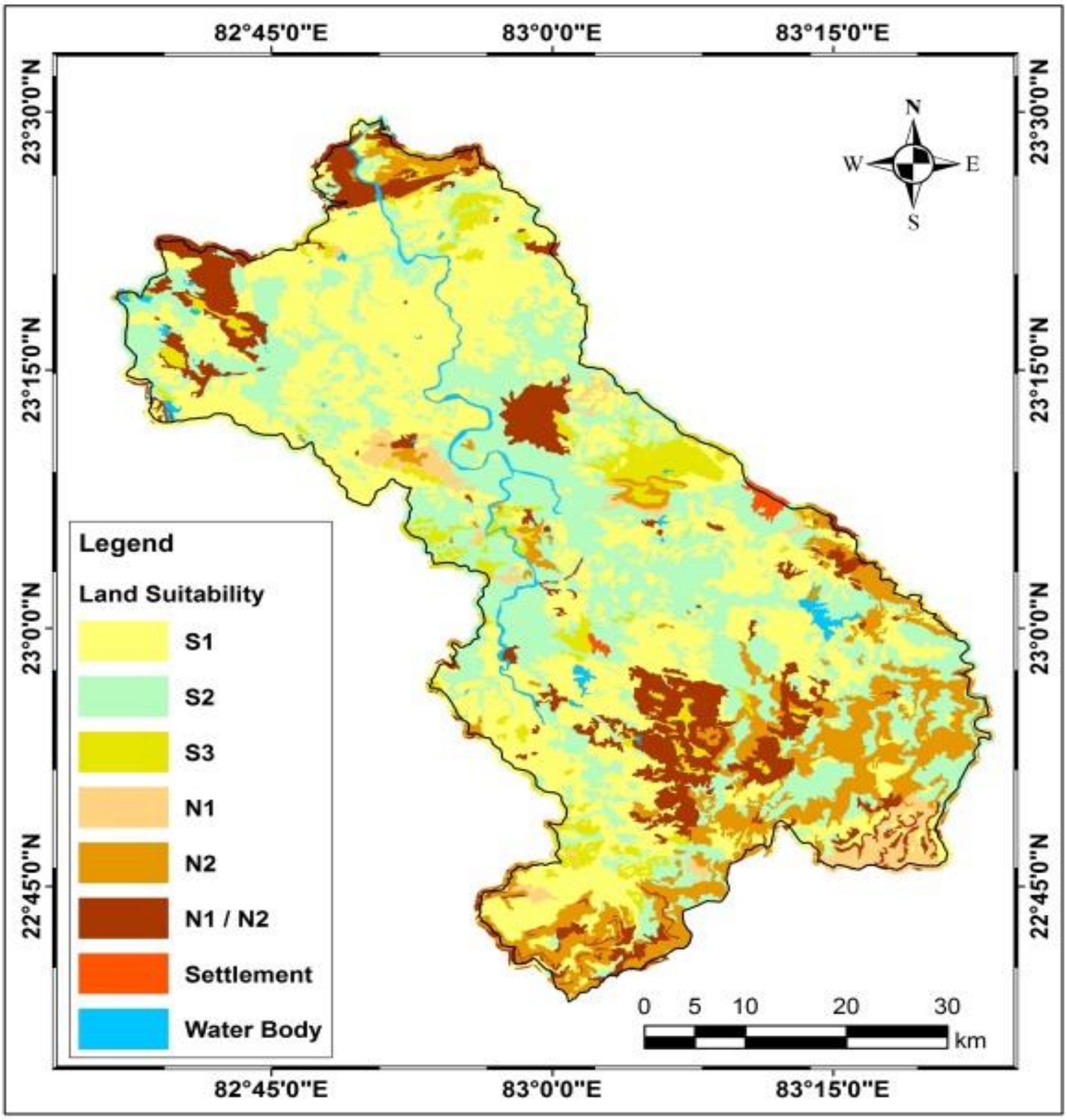

Figure 11: Land suitably map

CONCLUSION

Various digital enhancement techniques have been applied to extract the information about physical and chemical prosperities of soil. Soil samples are analyzed in a soil laboratory and carried out important information regarding this research work. Modern techniques like remote sensing and Geographic information system (GIS) analysis carried out for land suit

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abilities shows that it is a useful tool for handling the spatial and non-spatial data obtained from field survey and can be used to prepare the following interpretation map. These maps were found to be of great use for preparing soil resource management planning in the study area. After the land suitability classification, the resultant table shows that S1 and S2 suitability classes cover 68.2% of the study area which are the agricultural land use mostly preferred. A total of 24.47% area of the Rihand river basin come under either N1 or N2 classes due to highly hilly, undulating land surface and gullied ravine eroded land. There is very limited opportunity for agricultural land use practices for N1 but no opportunities for N2 class. The knowledge sharing in the concluding line is that this land suitability class may help to understand the potentiality of land for the study area for better management and land use practices for agricultural practices.

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