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An Integrated Approach for Land Suitability Analysis for Agriculture through Remote Sensing and GIS - A Case Study of Seoni District (Madhya Pradesh), India

Sandeep Kumar[1], Utpal Biswas[2], Mobin Ahmad[3], Sheetal Kumari[4]
[1, 4]Centre for Land Resource Management, Central University of Jharkhand
[2]Project Assistant, Department of Natural Resource Modelling and Environment Management, CSIR Central Institute of Mining & Fuel Research, Dhanbad, Jharkhand, India.
[3]Scientist, Department of Natural Resource Modelling and Environment Management, CSIR Central Institute of Mining & Fuel Research, Dhanbad, Jharkhand, India.

Abstract: Land suitability is one of the most important aspect now a days for finding a suitable agricultural land. As seoni district is situated in the regions of plateaus, so a major area is covered with rocks or soil having mixture of rock particles. The record of famine in the district clearly shows that crop failures are common and recurring phenomenon. Thus, there is a need for land suitability analysis. Consequently, there is a need to develop an optimal method for mapping land suitability to identify which areas of the province could grow crops successfully. This study is for selecting suitable areas for crops using a multi-criteria evaluation using GIS tools and techniques. Remote sensing provided the satellite data which had been further used to delineate information like slope, land use/land cover. Different land quality parameters such as soil texture, slope, depth to water level, lithology, geomorphology, etc. had been integrated in the GIS environment. Weightage had been provided to each class of each parameters and weightage overlay had; been done to achieve suitability map. In the final suitability map, we found that total area of 352 sq. km (4%) and 2421 sq. km (27.6%) in the study area is very highly suitable and highly suitable respectively for agriculture. About 2985 sq. km (34.1%) of study area falls under moderately suitable zone. A large area of this district of about 2910 sq. km (33.2%) is least suitable for agriculture. In the least suitable zone agriculture practices is very difficult to do.
Keywords: Land Suitability Analysis; Multi-Criteria Decision Making; Remote Sensing & GIS.

I. INTRODUCTION

Agriculture is the most primary occupation of the civilized man. In these days our population on this earth is increasing rapidly. To feed the increasing population we have to produce the food more and more on the same land, since we have a limited land for agriculture. Here, suitability can be defined by matching the land characteristics with the crop requirements. So, “Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use” (*FAO*, 1976). The procedure for land suitability classification involves the evaluation and grouping of particular areas of land depending upon their suitability for a fixed crop (Prakash, 2003). Land suitability analysis is a multidisciplinary approach by including the information from various domains such as social science, crop science, soil science, meteorology, economics and management (Pareta and Jain, 1992). In order to determine land suitability for agriculture, a major decision should be taken at various levels such as choosing a major land use types, selection of criteria, organization of the criteria, deciding suitability limits for distinct class of the criteria, deciding the preferences both qualitative and quantitative. By using the concept of multi-criteria decision making, relative importance of all the factors can be well evaluated to determine the suitability (Perveen, Nagasawa and Uddin, 2007)(Ceballos-Silva and López-Blanco, 2003).

In terms of planning and management, land use suitability mapping and analysis is one of the most useful GIS application (Collins, Steiner and Rushman, 2001)(Hopkins, 1977). GIS gives us freedom to perform various tasks using both spatial and non-spatial data. Integrated GIS and remote sensing has been proved to locate potential new cropland sites (Liengsakul *et al.*, 1993).

Land suitability evaluation is done throughout the continents by researchers using different methods. Mesgaran *et al.*, (2017) used a parametric method to evaluate potential suitability and limitations of Iran’s land for crop production. Bagherzadeh and Gholizadeh (2016) used parametric and fuzzy approaches to evaluate qualitative land suitability for sugar beet crop in sabzevar plain, northeast of Iran. Chanhda *et al.* (2010) used AHP method in GIS based land suitability assessment along Laos- China border. Montgomery, Dragi and Dujmovi (2017) used soft computing logic and the logic scoring of preference method for agricultural land suitability evaluation.

MCDM had been used in many studies such as solid waste management (SURAJIT, MOBIN and PREET, 2018), sustainable energy planning (Pohekar and Ramachandran, 2004), land suitability (Bandyopadhyay *et al.*, 2009), urban , landslide susceptibility mapping (Shahabi and Hashim, 2015).

II. STUDY AREA AND DATASETS

A. Study Area

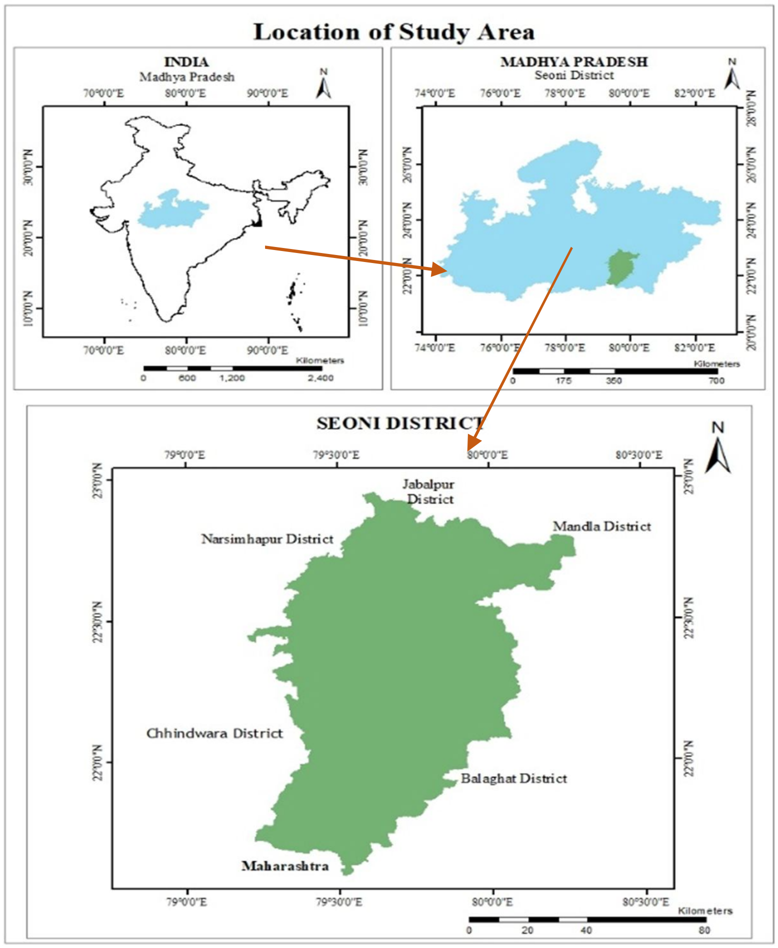

Figure 1: Location Map

The study area selected for this case study is Seoni district (a district in Madhya Pradesh).

The Seoni district falls on a section of the Satpura plateau. The total geographical area of this district is approx. 8754 sq. km covering total 25 toposheets of 1:50000 scale. It is located between 21º35′ to 22º58′ N latitude and 79º12′ to 80º18′ E longitude.

This district is mainly covered by black cotton soil, sandy loam soil, loamy soil and morand soil. It has two major river systems: The Narmada, and the Wainganga.

B. Datasets

Data used for present study comprises of 25 SOI toposheet of scale 1:50000, the standard MODIS land cover type data product (MCD12Q1) of year 2013, Cartosat DEM version-2 R1 of spatial resolution 30m, Soil data obtained from National Bureau of Soil Survey and Land Use Planning, lithology map and geomorphology map obtained from District Resource Map, Seoni district, Madhya Pradesh, and Water level map obtained from Ministry of Water Resources, Central Ground Water Board, North Central Region, Government of India.

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III. METHODOLOGY

The Methodology adopted for the present study is shown in Figure 2. The LULC map was prepared using the standard MODIS land cover type data product (MCD12Q1) of spatial resolution 500m, downloaded from USGS Earrthdata. The Slope map was prepared from Cartosat DEM of spatial resolution 30m downloaded from Bhuvan, using spatial analyst tool in ArcGIS 10.4.

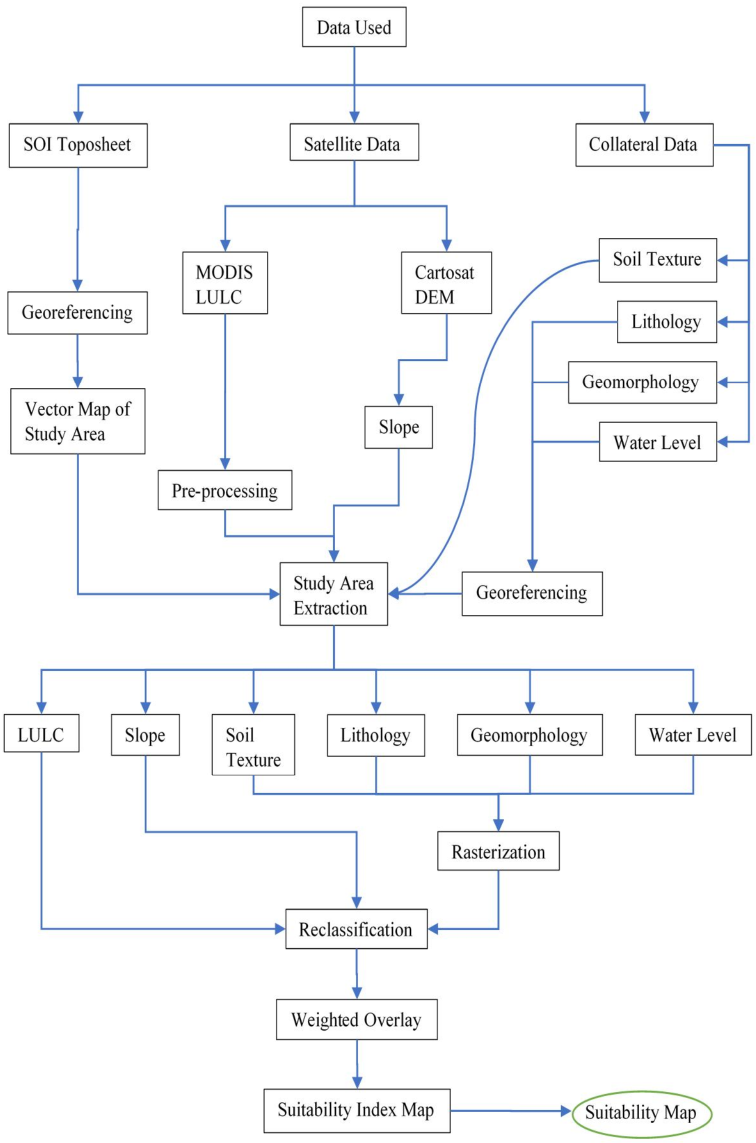

Figure 2: Flowchart

Soil texture map was prepared using the soil data from National Bureau of Soil Survey and Land Use Planning. Lithology and Geomorphology map was prepared based on District Resource Map of Seoni district. Water level map was prepared using map from District Ground Water Information Booklet (2013) of Seoni district provided by Ministry of water resources, Central Ground Water Board, North Central Region, Government of India.

All the prepared maps were geocoded with UTM 44 projection. All the vectors map was converted into raster using To Raster toolset in ArcGIS 10.4. Then, all the raster maps were resampled into a common spatial resolution of 30m using resample tool.

All the maps were reclassified according to the suitability rank given to each class of each parameter layers. Final suitability map for agriculture were obtained by overlaying all the thematic layers using weighted overlay method in spatial analyst tool. During weighted overlay analysis, the theme weightage to each layer were assigned according to multi-influencing factor of that layer on suitability analysis.

A. LULC Map

The LULC map prepared is shown in different colour for different land use classes. The colour assigned for each land cover class is based on the standard colour code for land cover classes. Area for all the land cover classes is given in the Table 1. Rank assigned for each land cover classes was based on the its suitability for the agriculture. Maximum rank was given to the agricultural class, since this is the most preferred class for agriculture. Grass land and shrub land were ranked fairly, since it is not currently used but it can be used as agriculture. Waste land was ranked lower than the scrub land since waste land may not be used as agriculture in some region but in scrubland, scrub vegetation promotes percolation which makes land potential for agriculture. Forest lies in the good agricultural zone, but it is not allowed to cultivate in these areas. So, it is also assigned poor rank (Bandyopadhyay *et al.*, 2009). Water bodies and built-up land were assigned least rank.

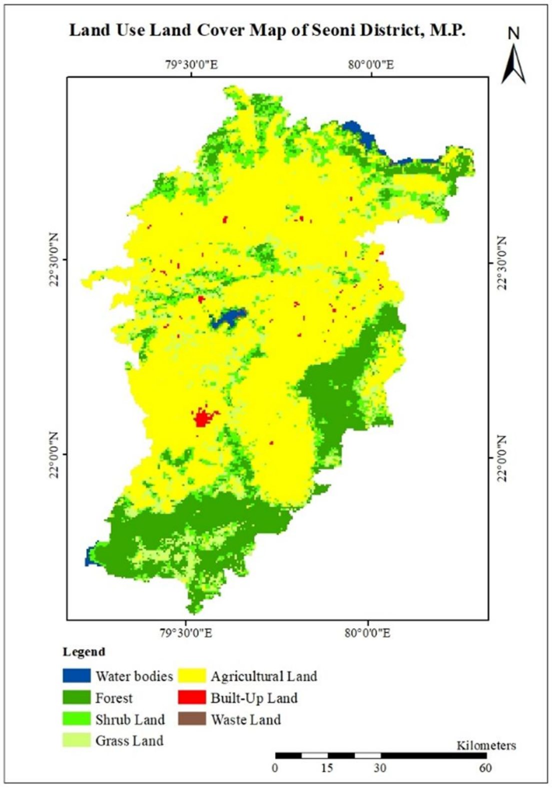

Figure 3: LULC Map

Table 1: Distribution of land under various LULC classes

Classes	Area (sq. km)	Percentage Area
Water bodies	73.3453	0.84
Forest	1668.9750	19.06
Shrub Land	914.6475	10.45
Grass Land	857.0090	9.79
Agricultural Land	5180.3243	59.17
Built-Up Land	44.3462	0.51
Waste Land	15.8092	0.18

Agricultural land covers about 59% of the study area. 19% of the study area is covered with forest. Shrub land and grass land together covers about 20% of the study area. Built-up land and water bodies are minor in the study area covering together about 1.4% of the study area, which is fully no cultivation zone.

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B. Slope Map

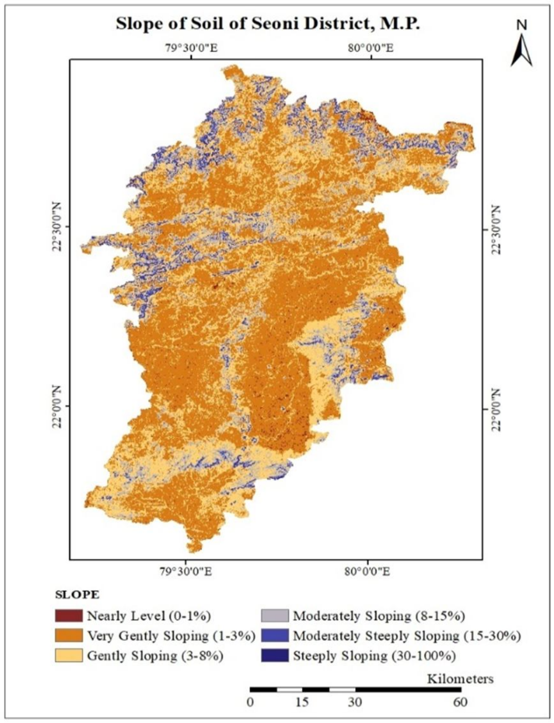

Figure 4: Slope Map

Slope map prepared is shown in Figure 4. Slope map is prepared from CartoDEM version-2 R1 of spatial resolution 30m using spatial analyst tool in ArcGIS software. Further on the basis of slope percentage, study area has been classified into six slope classes. The lower the slope value, the flatter the terrain and the higher the slope value, steeper the terrain. Class 1 having slope percentage of 0-1% was assigned maximum rank due to the flatness of the land. These types of land are excellent for agriculture. Class 2 having slope percentage of 1-3% was fairly ranked, since these lands are nearly flatter. Class 3 having slope percentage of 3-8% was average ranked. These regions are also called gently slope area. Class 4 having slope percentage of 8-15% which falls under moderately slope areas was poorly ranked due to relatively high runoff. Class 5 and 6 was assigned to be not suitable due to the presence of steeply sloping topography and high surface runoff.

Table 2: Distribution of land under various classes of slope

Classes	Area (sq. km)	Percentage Area
Nearly Level (0-1%)	1151.18	13.15
Very Gently Sloping (1-3%)	3308.85	37.80
Gently Sloping (3-8%)	2935.14	33.53
Moderately Sloping (8-15%)	827.84	9.46
Moderately Steeply Sloping (15-30%)	460.82	5.26
Steeply Sloping (30-100%)	70.59	0.81

Most part of the study area is very gently sloping (1-3%) and gently sloping (3-8%). These two classes together cover more than 71% of the study area. Total of around 15% of the study area is falling under steeply sloping where agriculture is not possible.

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C. Soil Texture Map

The prepared soil texture map is shown in Figure 5. The soils of study area can be classified into the main type's i.e., clayey, clayey skeletal, coarse loamy, fine, fine loamy, fine silty, loamy, loamy skeletal, and sandy. Loamy soil constituted about 32.1% of the total soil in the study area. Clayey soil and fine soil together constituted about 40.2% of the total soil in the study area. These three soils cover almost 72.3% of the entire soil in the study area. Sandy soil is found to be minority in the study region constituting about only 0.003%.

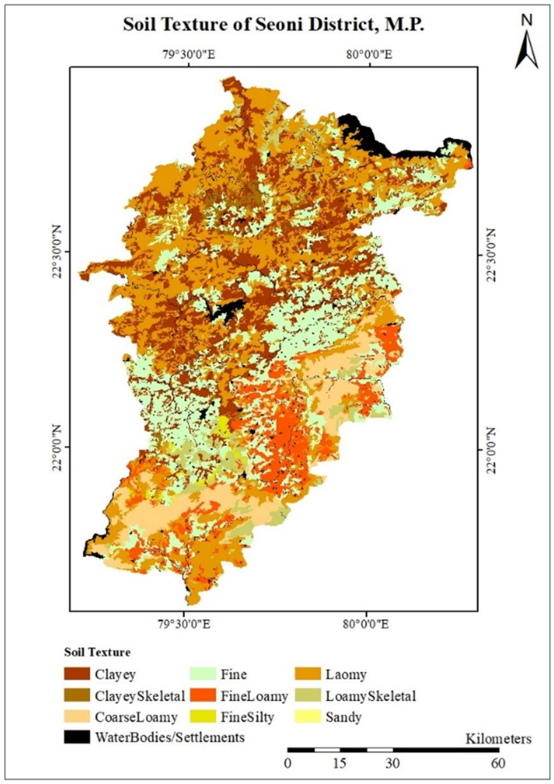

Figure 5: Soil Texture Map

Loamy soil was assigned maximum weightage, since this soil is best for agriculture. Followed by loamy soil, Fine loamy, coarse loamy and loamy skeletal were fairly ranked. Fine, fine silty, clayey skeletal and clayey soils were assigned average rank, depending upon their characteristics for the crop suitability. Sandy soil was ranked very poorly due to its high water drain capacity.

Table 3: Distribution of land under various soil types

Classes	Area (sq. km)	Percentage Area
Clayey	1679.8533	19.19
Clayey Skeletal	184.8379	2.11
Coarse Loamy	691.7900	7.90
Fine	1838.2652	21.00
Fine Loamy	711.0412	8.12
Fine Silty	53.9149	0.62
Loamy	2809.3552	32.09
Loamy Skeletal	428.2996	4.89
Sandy	0.2700	0.0031
Waterbodies/ Settlements	356.8292	4.08

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D. Lithology Map

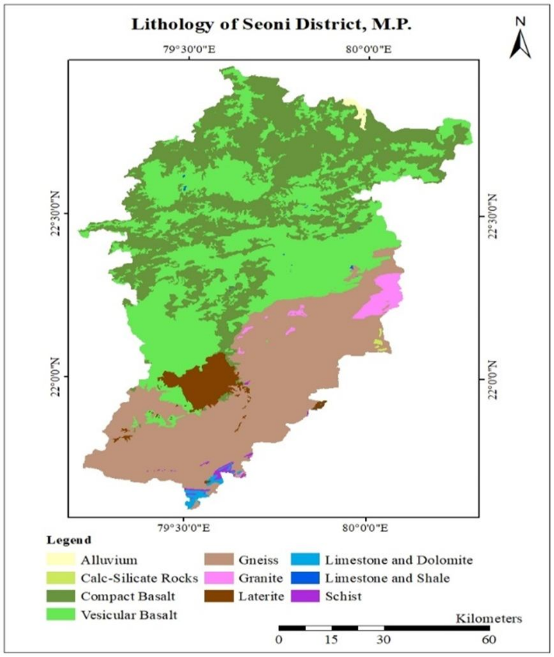

Figure 6: Lithology Map

The prepared lithology map is shown in Figure 6. The lithology of the study area can be assorted in the main type's viz., alluvium, calc-silicate rocks, compact basalt, gneiss, granite, laterite, limestone and dolomite, limestone and shale, schist, and vesicular basalt. Most part of the study area is covered together with compact basalt, vesicular basalt and gneiss. These three constitutes almost 95% of the study area. Vesicular basalt constitutes about 34.6% of the study area, this is the region where agriculture is highly suitable so, this was assigned maximum weightage. Compact basalt covers about 31.3% of the study area but in this region, agriculture cannot be done, so this was assigned least weightage. Alluvium is also good for agriculture, but it is available only in the water bodies in the northern part of the study area, where agriculture is not possible, so it was also assigned least rank. Laterite and limestone and shale were fairly ranked. Granite, gneiss and schist were averagely ranked. Calc-silicate rocks and limestone and dolomite were poorly ranked.

Table 4: Distribution of land under various lithology types

Classes	Area (sq. km)	Percentage Area
Alluvium	24.2784	0.28
Calc-Silicate Rocks	7.8048	0.09
Compact Basalt	2743.7355	31.34
Gneiss	2506.6890	28.63
Granite	129.6666	1.48
Laterite	250.6239	2.86
Limestone and Dolomite	34.9596	0.40
Limestone and Shale	4.3011	0.05
Schist	25.4907	0.29
Vesicular Basalt	3026.9070	34.58

E. Geomorphology Map

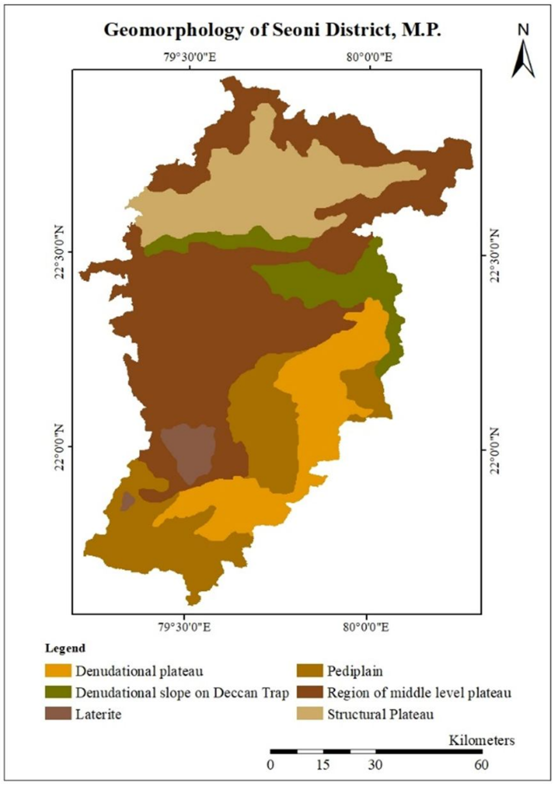

Figure 7: Geomorphology Map

The prepared Geomorphology map is shown in Figure 7. The geomorphology of the study area can be assorted in the main type's viz., denudational plateau, denudational slope on deccan trap, laterite, pediplain, region of middle level plateau, and structural plateau. Major part of the study area of about 43.3% is classified under region of middle level plateau. Pediplain, structural plateau and denudational plateau covers about 17.36%, 15.9%, 13.3% respectively.

Pediplain is best suitable for agriculture, so it was assigned maximum weightage. Region of middle level plateau was ranked fairly. Laterite was assigned average rank. Denudational slope on deccan trap and structural plateau were poorly ranked. Denudational plateau was ranked least from the agricultural point of view.

Table 5: Distribution of land under various geomorphology types

Classes	Area (sq. km)	Percentage Area
Denudational plateau	1165.8888	13.32
Denudational slope on Deccan Trap	690.1047	7.88
Laterite	194.8581	2.23
Pediplain	1520.0370	17.36
Region of middle level plateau	3791.7369	43.31
Structural Plateau	1391.8311	15.90

F. Depth to Water Level Map

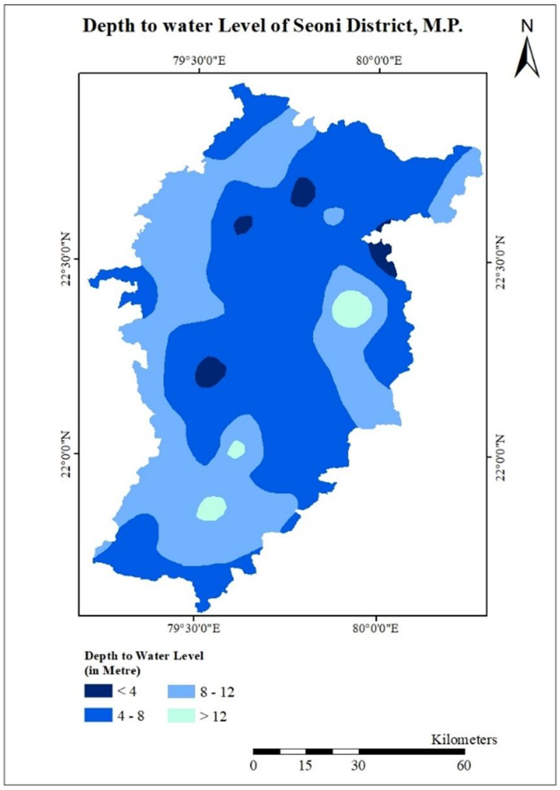

Figure 8: Water Level Map

The prepared depth to water level map is shown in Figure 8. The study area has been divided into four zones based on the water level of the region. About 58% of the study area has good water level of 4 to 8 m below the surface. About 38.2% of the study area has moderate water level of 8 to 12 m below the surface. Only 2% of the study area falls under the category of excellent water level. About 1.8% of the study area has very poor water level. All the four zones are ranked depending upon the availability of the water, i.e., deeper the water level rank will be lower.

Table 6: Distribution of land under various water level classes

Classes (m)	Area (sq. km)	Percentage Area
< 4	176.3541	2.01
4 to 8	5071.7682	57.93
8 to 12	3348.5049	38.25
> 12	157.8294	1.80

G. Weighted Overlay

Weighted overlay applies a common measurement scale of values to dissimilar inputs to create an integrated output.
The working formula for this method is:
Output layer = $\sum$ (Input layer * Weight assigned/100)
Where, sum of weights of all input layers = 100
The weightage overlay table is shown in

Table 8.

IV. RESULTS AND DISCUSSIONS

The final land suitability map for agriculture is shown in Figure 9. This suitability map is prepared using six thematic layers namely LULC, slope, soil texture, lithology, geomorphology, and water level which have been discussed earlier. All of these six layers was assigned theme weightage on the basis of its influence on the suitability map. Then Weightage overlay has been performed to achieve the suitability index map. Further reclassification of suitability index map has been performed to obtain suitability map. Suitability map has five classes namely very highly suitable, highly suitable, moderately suitable, least suitable, and not suitable. Very highly suitable land constitutes only about 4% of the study area. This area constitutes mainly in the north-west to middle part of the seoni block. Highly suitable land covers about 27.7% of the study area. This area covers western part of Barghat block, through-out Seoni block except some middle part, north-west and north-east parts of Keolari block, and some patches in southern part of Ghansaur block. Moderately suitable land constitutes about 34.1% of the study area. This area covers southern middle part of Lakhnadaun block, North-west and south-east part of Kuri block, major part of Dhanaura block, and South-east part of Keolari block. Least suitable land constitutes about 33.24% of the study area. This area covers major part of Ghansaur, Lakhnadaun, chhapara, Kuri, and some part of Keolari and Barghat blocks. Not suitable zone constitutes about 1% of the study area. This zone can be seen in the form of small patches in the suitability map mainly in middle part of Kuri block and south-west part of Keolari block.

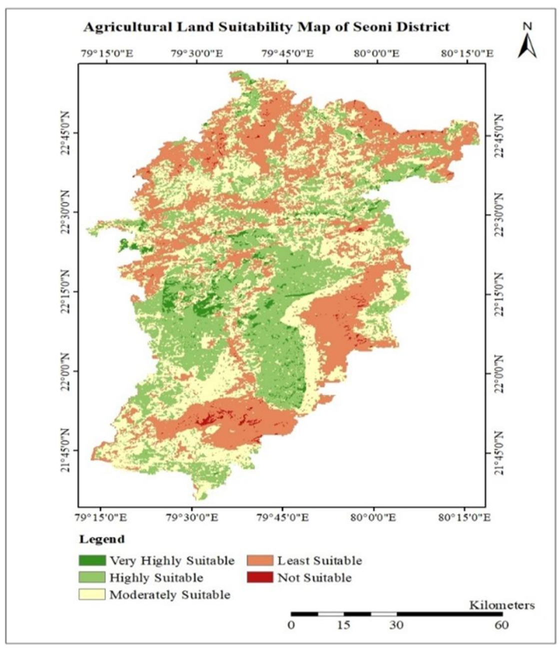

Figure 9: Land suitability map for agriculture

Table 7: Distribution of land on agricultural suitability

Classes	Location	Area (sq. km)	% Area
Very Highly Suitable	North-west to middle part of Seoni block	352.80	4.03
Highly Suitable	Western part of Barghat block, through-out Seoni block except some middle part, north-west and north-east parts of Keolari block, some patches in southern part of Ghansaur block	2421.85	27.66
Moderately Suitable	Southern middle part of Lakhnadaun block, North-west and south-east part of Kuri block, Major part of Dhanaura block, South-east part of Keolari block	2985.81	34.11
Least Suitable	Major part of Ghansaur, Lakhnadaun, chhapara, Kuri, and some part of Keolari and Barghat blocks	2910.12	33.24

Not Suitable	Middle part of Kuri block and south-west part of Keolari block	83.87	0.96

V. CONCLUSIONS

Land suitability is the ability of a given type of land to support a defined use. Land suitability analysis is a multidisciplinary approach by including the information from various domains such as social science, crop science, soil science, meteorology, economics and management (Pareta and Jain, 1992). Remote sensing is potentially a practical management tool for site-specific crop management in precision agriculture. Using GIS tool, it is easy to recognise, analyse, understand relationships between different parameter used in this study. Based on this study, it is concluded that;

A. The various land use classes are agricultural land, grass land, shrub land, forest, water bodies, Built-up land, and waste land. The Agricultural class has largest area of about 5180.3 sq. km of about 59.17% of the total study area. Waste land has the least area of about 15.8 sq. km covering 0.18% of the study area.

B. Agriculture is suitable in level to gentle sloping area. But as the slope of the land increases its suitability for the agriculture decreases. This is due to the high runoff at surface when slope is high. So, agriculture is not possible in steeper slopes.

C. The various soil types found in the study area are clayey, clayey skeletal, coarse loamy, fine, fine loamy, fine silty, loamy, loamy skeletal, and sandy. Out of these, Loamy soil is best soil and sandy soil is worst soil for the agricultural purpose.

D. From the lithological point of view, Vesicular basalt is best suited for agriculture. Since compact basalts are rocks so, it is not suitable for agriculture. From the geomorphological point of view, pediplain is best suited for agriculture.

E. Multi-criteria decision making is used to prepare final suitability map by integrating six layers namely LULC, slope, soil texture, lithology, geomorphology, and water level into the GIS environment.

F. The suitability map is classified into five classes namely very highly suitable, highly suitable, moderately suitable, least suitable, and not suitable. Very highly suitable land covers almost 352.8 sq. km of the study area mainly in the north-west to middle part of the seoni block. Highly suitable land covers about 2421.8 sq. km. This area covers western part of Barghat block, through-out Seoni block except some middle part, north-west and north-east parts of Keolari block, and some patches in southern part of Ghansaur block. These areas with very highly suitable and highly suitable land are best for the agricultural purpose. In these areas cultivation will give a good yield.

G. In the rest of the parts of the study area, about 2985.8 sq. km classified under moderately suitable could also favourable for some crop types. This area covers southern middle part of Lakhnadaun block, North-west and south-east part of Kuri block, major part of Dhanaura block, and South-east part of Keolari block.

VI. RECOMMENDATIONS

Present study is concentrated on the assessment of land suitability for agriculture purpose. The same methodology can be adopted for different crops to find its suitability for different land. In this way, we can increase the crop productivity. Also, for further study, we propose to select a greater number of factors like soil depth, climate, irrigation facilities and socio-economic factors which influence the sustainable use of the land. Field visit is recommended for further studies.

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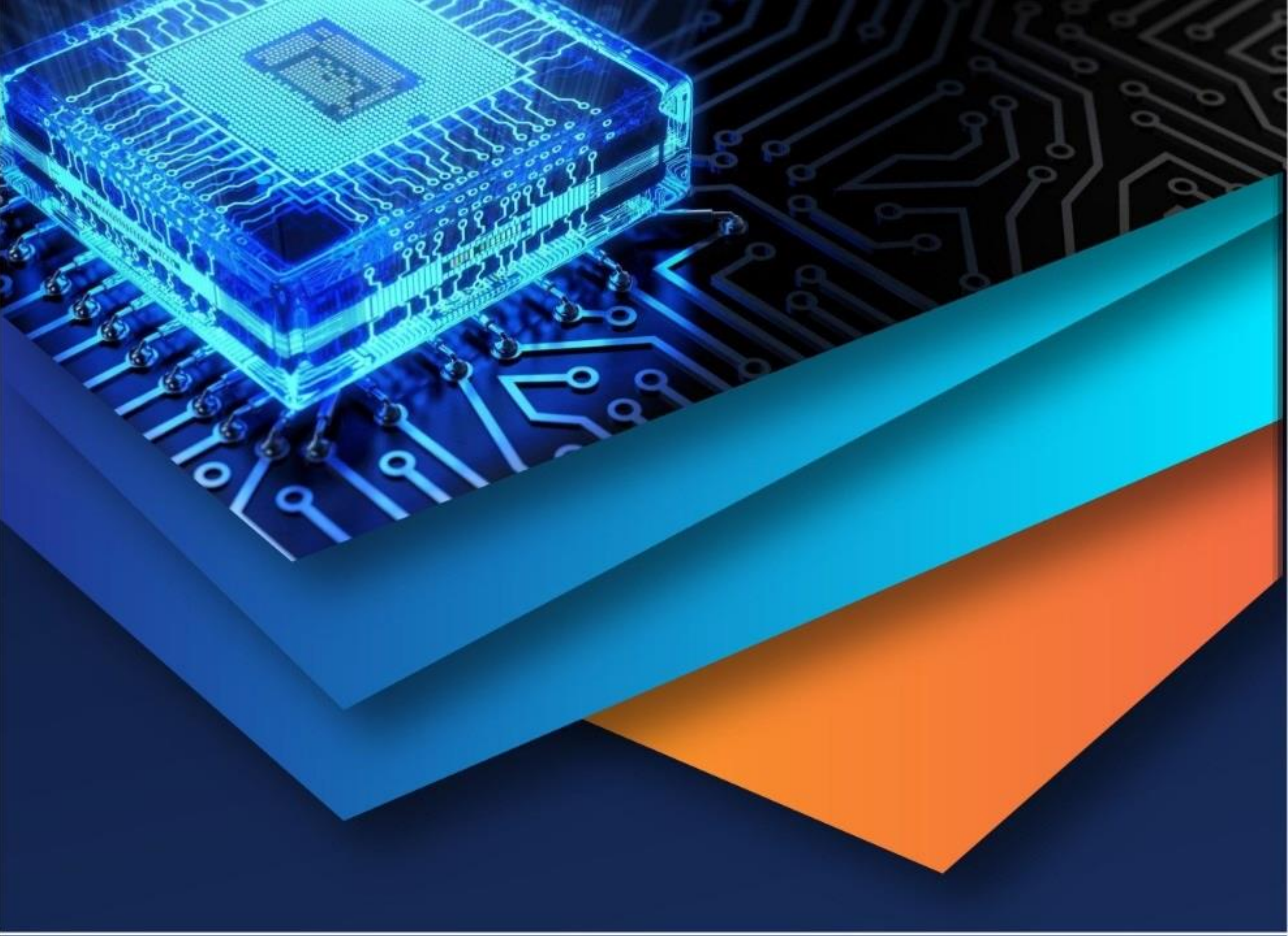
Table 8: Weightage overlay table

Feature	Class Name	Class Weightage	Theme Weightage
LULC	Agricultural Land	9	15
	Built-up Land, Water bodies	1	
	Forest	2	
	Grass Land, Shrub Land	6	
	Waste Land	4	
Slope	Nearly Level (0-1%)	9	15
	Very Gently Sloping (1-3%)	8	
	Gently Sloping (3-8%)	6	
	Moderately Sloping (8-15%)	3	
	Moderately Steeply Sloping (15-30%), Steeply Sloping (30-100%)	1	
Soil Texture	Clayey	4	20
	Clayey Skeletal	5	
	Coarse Loamy, Loamy Skeletal	7	
	Fine Loamy	8	
	Fine, Fine Silty	6	
	Loamy	9	
	Sandy	2	
	Waterbodies/Settlements	1	
Lithology	Alluvium, Compact Basalt	1	15
	Calc-Silicate Rocks, Limestone and Dolomite	2	
	Gneiss, Schist	5	
	Granite	6	
	Laterite, Limestone and Shale	7	
	Vesicular Basalt	9	
Geomorphology	Denudational Plateau	1	15

	Denudational Slope on Deccan Trap	3	
	Laterite	6	
	Pediplain	9	
	Region of Middle Level Plateau	7	
	Structural Plateau	2	
Depth to Water Level	< 4	9	20
	4 - 8	6	
	8 - 12	3	
	> 12	1	



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