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Suitability Analysis for Agricultural Land based on GIS Technique

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Abstract— *Land use suitability analysis in a GIS context is a GIS-based process used to determine the appropriateness of a given land for a particular use. In this paper we analyzed the optimal utilization of agricultural land in Cachar district, India. The district is located in the Eastern Himalayan Region and has a total area of 3,786 square kilometers. A GIS based study was performed to evaluate the agricultural suitability land within the district. The agricultural land suitability map generated was divided into 5 categories as good, fair, moderate, poor and not suitable. The parameters taken into consideration were land use/land cover, soil texture, rainfall, slope and organic carbon/organic matter content of soil. During the execution of the work Geo-Referencing, Digitization and Attributing of different layers were carried out. Finally, integration of all the layers was performed in the GIS platform in order to generate the final output map. The study can be helpful in identifying the areas where land use for agriculture should increase, decrease or remain unchanged on the basis of the above mentioned factors. Such kind of analysis allows identifying the main limiting factors for the agricultural production and enables decision makers to develop crop managements which in turn will increase the land productivity.*

1. INTRODUCTION

The term “Land Suitability” refers to the appropriateness of a certain part of land for a specific type of land use. There are many factors that directly or indirectly control the ability of this part of land. We all know that an irreproducible natural resource such as land is one of the most important indicators of economic growth of a country. Crop land suitability analysis is a prerequisite to achieve optimum utilization of available land resource for agricultural production in a sustainable manner (Halder 2013). The FAO (Food and Agricultural Organization) recommended an approach for land suitability for crops in terms of suitability ratings ranging from highly suitable to not suitable. The lack of sound land use policy has resulted in widespread land degradation and chaotic development causing the loss of the best quality farmland to non-agriculture land. Moreover the increasing population numbers, particularly in developing country like India, building the pressure both on natural and agricultural resources. In order to meet the food demand of rapidly growing population farming community need to produce more and more. The main objective of this study is to predict the inherent capability of land in order to support the specific land use for long periods of time without deterioration. This research work provides information at the local level which could be utilized by farmers for selecting the proper land for agriculture.

With advances of information and communication technology, computer based decision support models have been developed towards land evaluation. GIS have the ability to perform numerous tasks utilizing both spatial and attribute data stored in it. In multi-criteria evaluation many data layers are to be handled in order to arrive at the suitability, which can be achieved conveniently using GIS.

2. STUDY AREA

The study area was the Cachar district, which is located in the Eastern Himalayan Region of India. The district has an area of 3,776 km^2 and situated in north-east part of India. Two sub-divisions and five revenue circle comprises an overall population of approximately 17, 36,617 (Census 2011). The district lies between 92° 24' E and 93° 15' E longitude and 24° 22' N and 25° 8' N latitude. The district is mostly made up of plains, but there are a number of hills spread across the district. Cachar receives an average annual rainfall of more than 3,000 mm. The climate is tropical wet with hot and wet summers and cool winters. The vegetation is mostly tropical evergreen and there are large tracts of rainforests in the northern and southern parts of the district.

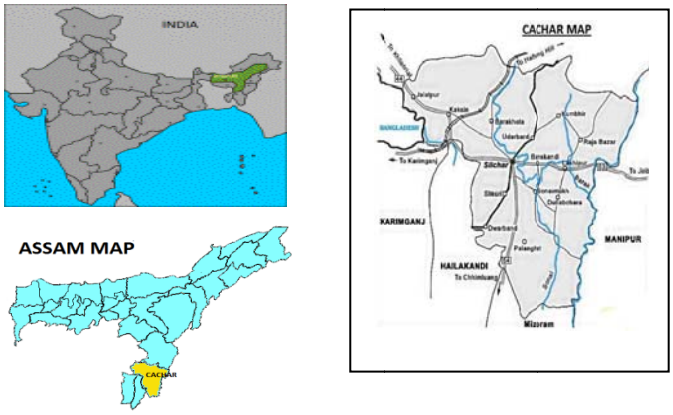


Fig. 1: Study area map

During the winter season, it is as cold as other parts of north India and the rainy season of this district starts from May and ends after October. Among the 15 agro-climatic regions of the country, categorized/identified on the basis of homogeneity in agro- characteristics, Cachar falls in the Barak Valley zone. The soil of the district is clayey loam, alluvial and red alluvial. The soil is highly porous and therefore, lacks moisture retention capacity and is susceptible to erosion. The district has a total forest cover of 2225 sq.km area which is 58.77 percent of its total geographical area as per the estimates of Forest Survey of India. The pH value and organic matter content is suitable for agricultural activity in maximum part of the district.

3. AIM AND OBJECTIVES

This work is aimed to identify the area suitable for agriculture in Cachar district and to propose a suitable agricultural land use plan for sustainable agriculture using GIS technique.

The main objectives are-

- To generate various thematic maps for different factors.
- Optimize land for agricultural purpose based on topographical and climatic factors.
- To identify the areas suitable for agriculture and to prepare integrated map of land suitability for sustainable agriculture.

4. DATA SOURCE

Data collection and the base map preparation are the primary and fundamental steps for this study. In our methodology, land suitability is evaluated by overlaying different types of theme based map in a GIS environment. In this present study the following data were used –

- District planning map of Cachar prepared by National Atlas and Thematic Mapping Organization (NATMO) of scale 1:250,000 to extract boundary.
- Thematic maps of soil, rainfall and slope of scale 1:1000, 000 prepared by NATMO.
- Present land use/land cover map from the site of Bhuvan.
- Map of organic carbon (OC) content from Indian Institute of Soil Science.

All these spatial datasets were prepared including all necessary geometric and thematic editing of the original datasets.

5. METHODOLOGY

ARCGIS software package was used for creation of digital database, data integration and analysis. All thematic maps were digitized in a continuous mode, in vector format, and then the digitized values were edited. The different polygons in thematic maps were labeled separately. Unique attributes were given for all the features of different thematic maps. Initially, each one of the polygons in the final thematic layer was visualized into one of the categories: (i) good, (ii) fair, (iii) moderate, (iv) poor and (v) not suitable- in terms of their importance with respect to land suitable for agriculture purposes. Then, suitable weights were assigned to each thematic layer after considering their characteristics. Knowledge based weight was assigned to each feature and they were integrated. The total weights of the final integrated polygons were derived as sums or products of the weights assigned to different layers, according to their suitability. The equation used in a GIS for the assessment of land suitability potential index (LSPI) for agricultural purpose-

$$LSPI = 0.25\,(LU)_{i=1\text{-}7} + 0.25\,(ST)_{i=1\text{-}4} + 0.2\,(RF)_{k=1\text{-}3} + 0.15(SL)_{l=1\text{-}7} + 0.15(OC)_{m=1\text{-}2} \quad (1)$$

Where, LSPI is the numerical index of the land suitability, LU is the present land use (with classes 1-7), ST is the soil type (with classes 1-4), RF indicates the rainfall (with classes 1-3), SL indicates the slope (with classes 1-7) and OC is the organic matter content of soil (with classes 1-2). The superscripts i, j, k, l and m indicate subclasses based on importance in determining land suitability (Bandyopadhyay et al. 2009).

The next step is the integration of all thematic spatial layers using the above equation in GIS, based on assigned weight and score. The input parameters on land suitability are in descriptive form. To achieve effective conclusions through computation and other mathematical operations, the descriptive information has been converted into agricultural land suitability indexes. The influence of parameters on agricultural land suitability was sorted in the following order: land use, soil type, rainfall, slope and organic matter. After understanding their behavior with respect to agricultural land suitability, the different classes were given suitable scores on the scale of 0-10 according to their merit among other classes in the same thematic layer (see Table 1.). Classes with the score of 10 means it has the good influence on land suitability for agriculture, score with 0 means it has no influence.

Finally the land suitable for agriculture in terms of productivity potential was generated. The methodology adopted in the present study is shown in Fig.2 with a flow a chart diagram.

5.1 Land use/Land cover

The land use refers “how land has been put to different uses”. Land cover refers to “natural vegetation and water bodies”. Land use/land cover pattern of the region gives a total scenario about the present land use status of the area and it will also help in land suitability analysis (Gopala Krishna GVT et al. 2014). Land use of the study area is characterized by agricultural crop land, agricultural plantation land, wetlands, settlements, forest etc. From the land use point of view agricultural crop land areas are classified under the good category and agricultural plantation under the fair category.

Table 1: Weights and scores assigned to variables and classes for agricultural land suitability modeling

Sl. No.	Variables	Classes	Scores	Agricultural land suitability
1	Land use (weight=0.25)	Agricultural crop land	10	Good
		Agricultural plantation	8	Fair
		Grass and scrubland	6	Moderate
		Forest	2	Poor
		Wetlands	0	Not suitable
		Settlement	0	Not suitable
		River	0	Not suitable
2	Soil Type (weight=0.25)	Younger alluvial	10	Good
		Red loamy	8	Moderate
		Laterite	5	Poor
		Red sandy	2	Poor
3	Rainfall (annual) (weight=0.2)	3200 mm	10	Good
		3200-4000 mm	7	Fair
		4000 mm	5	Poor
4	Slope (meters per km) (weight=0.15)	Greater than 600	1	Not suitable
		300-600	2	Not suitable
		150-300	4	Poor
		80-150	6	Moderate
		20-80	8	Fair
		10-20	9	Good
		Less than 10	10	Good
5	Organic matter (%) (weight=0.15)	Greater than 1.29	10	Good
		0.86-1.29	9	Fair

Even though forest falls under the good agricultural potential land, it has been purposefully categorized under the poor class, because these areas are generally not used for agricultural purpose and treated as restricted areas (Bandyopadhyay et al. 2009). It is obvious that river, settlements and wetlands are not suitable at all for any type of agricultural activity.

5.2 Soil

The study area mostly consists of younger alluvial soils. Alluvial soils are suitable for most of the agricultural activity. These types of soils are made of variety of materials, including fine particles of silt and clay and larger particles of sand and gravel. So, younger alluvial soil is rated under the good category for agriculture. Red loam soil is composed mostly of sand and silt, and a smaller amount of clay. On the uplands, they are thin, poor and gravelly, sandy, or stony and porous, light-colored. But on the lower plains and valleys they are rich, deep, dark colored fertile loam on which, under irrigation, can produce excellent crops like cotton, wheat, potatoes etc, these have been assigned to be moderate. Laterites are soil types rich in iron and aluminum, formed in hot and wet tropical areas. The soils are deficient in available exchangeable bases, essential plant nutrients, potash, nitrogen and organic matter, so it is categorized as poor. Red sandy soils include nutrient deficiencies, acidity, low water storage and poor physical attributes, so it is not suited for agricultural purpose.

5.3 Rainfall

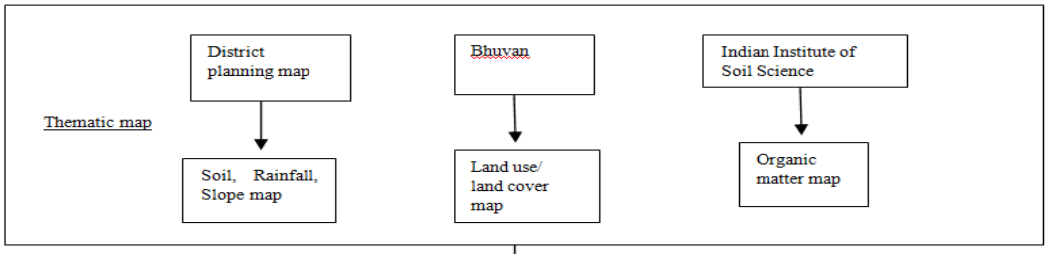
The agricultural activities of the study area are mainly depending on rainfall. According to the thematic map prepared by NATMO (National Atlas and Thematic Mapping Organisation), the district has been categorized in 3 major areas on the basis of annual rainfall. The study area experiences average annual rainfall of 3200 mm in the southern part, 3200-4000 mm in the middle part and 4000 mm in northern region of the district. Scores are assigned to each class according to their suitability for agriculture.

5.4 Slope

Topographically, the district is characterized by undulating terrain constituting plains to steeply sloping hills. The slope varies from less than 10m to greater than 600 m per kilometer. On the basis of slope variation, the study area has been classified into seven slope classes. All the classes are given suitable scores and assigned a particular category in terms of land suitable for agriculture.

5.5 Organic matter

Soil organic carbon, the major component of soil organic matter, is extremely important in all soil processes. Organic carbon is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization. Organic material in the soil is essentially derived from residual plant and animal material, synthesized by microbes and decomposed under the influence of temperature, moisture and



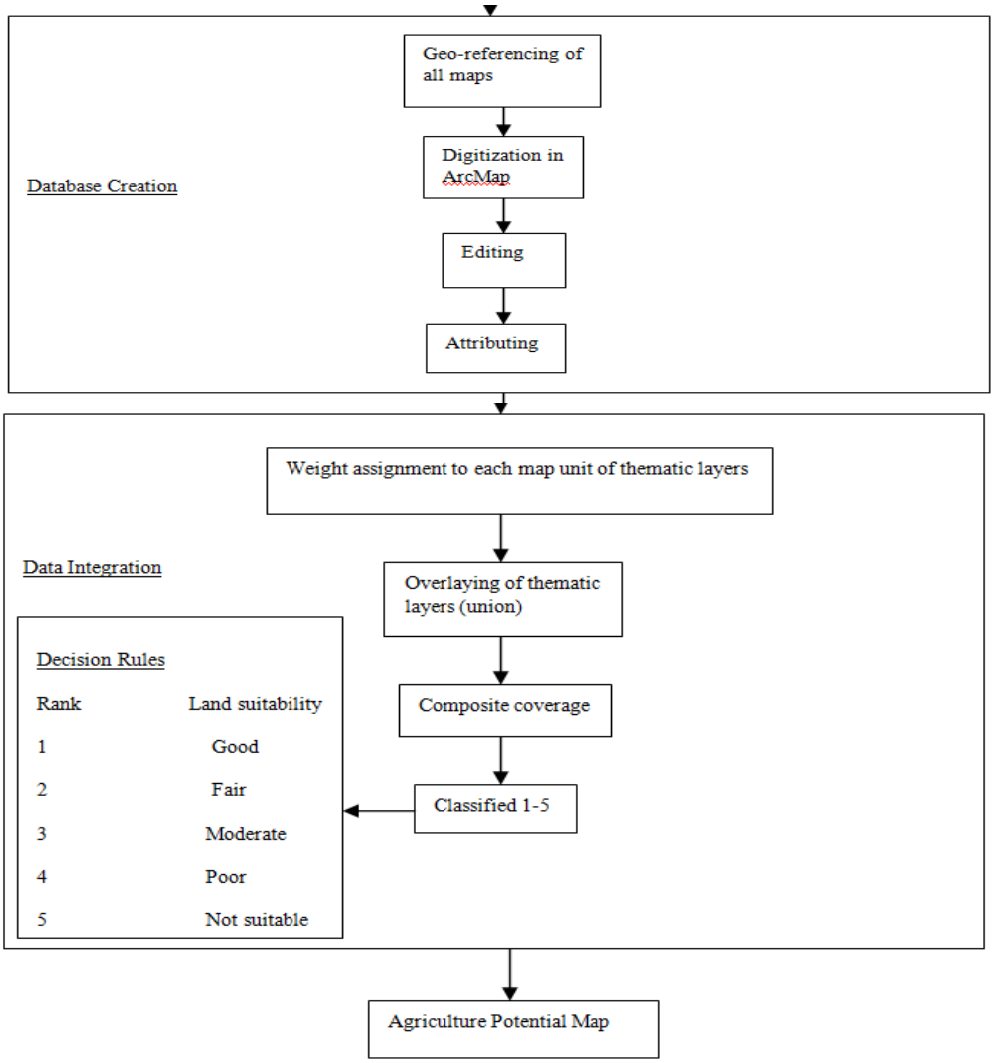


Fig. 2: Methodology for generating the land suitability potential map.

ambient soil conditions. According to the map prepared by Indian Institute of Soil Science the study area has been categorized in two major areas in terms of organic carbon, like (i) >0.75% (high) and (ii) 0.5 – 0.75% (medium). As the map gives amount of organic carbon only, to estimate the organic matter content we multiply this by a conversion factor of 1.72 (Bandyopadhyayet al., 2009). Amount of organic matter content indicates the soil health and its suitability for agriculture.

Organic matter (%) = organic carbon (%) x 1.72 (2)

6. RESULTS AND DISCUSSION

After categorization, all the thematic layers were integrated using GIS. The composite layer was then divided into five categories on the basis of total score derived from eqn. (1). The polygons that have a total score ranging from 8.2 to 10 were assigned under the good category for agricultural land use. Polygons having value from 7 to 8.19 were categorized under fair category. The moderate category land suitable for agriculture involves polygons that have total score between 5.30 and 6.99. The polygons that come under the poor category have a total score between 0.01 and 5.29 and polygons with 0 values, falls under the category of not suitable land for agriculture. By using the above method, the agriculture based land suitability map was prepared and is shown in Fig. 3. The category of the land suitability classes is shown in Table 2 and the pie chart below (see Fig. 4) shows the graphical representation of the same.

Table 2: Category and coverage of land suitability potential index in the district

Sl. No.	Agricultural Land Suitability Potential	Area in Km2	Percentage to Total Area
1	Good	849.62	22.44
2	Fair	728.79	19.25
3	Moderate	957.62	25.30

4	Poor	1005.88	26.57
5	Not suitable	244.09	6.44
Total		3,786	100

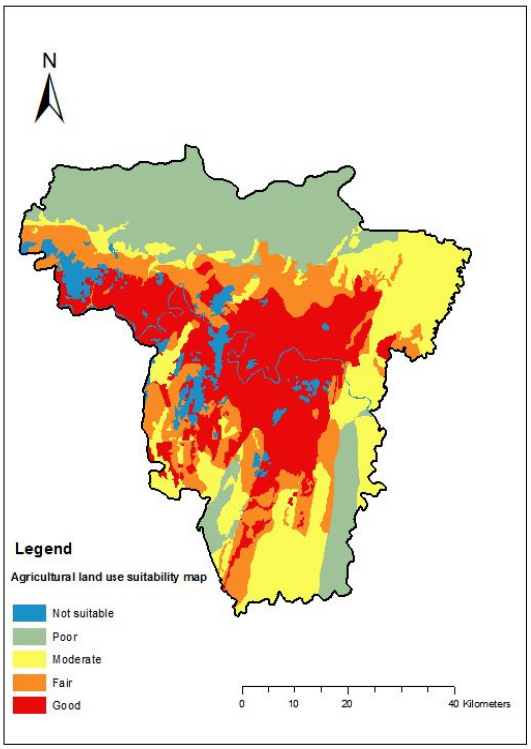


Fig. 3: Agricultural land suitability map

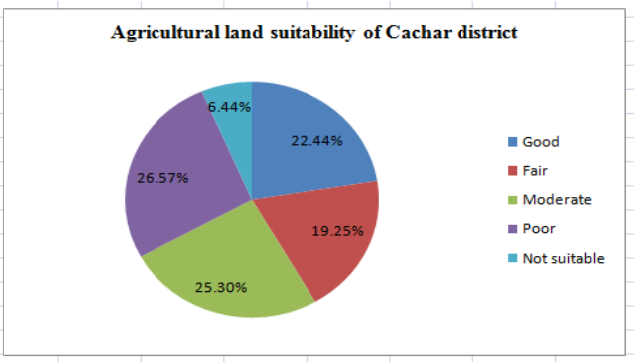


Fig. 4: Graphical representation of agricultural land suitability in the district.

7. CONCLUSIONS

In this study GIS technique was used to identify agricultural land suitability areas for Cachar district. The impact of soil types, rainfall, slope, land use and organic matter on spatial distributions of crop yield potential have been quantified and rated accordingly. The map provides spatial representation of capability of the land to support agriculture. From the study it is found that more than 60 % area of the district is lying under moderate to good suitable areas.

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