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Geo informatics-based land suitability analysis of green gram (*Vigna radiata* L.) for Kosi region of Bihar

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ABSTRACT

Land suitability analysis is an important aspect of the agricultural land use planning, and the several approaches viz. remote sensing, geographical information system and multi-criteria decision making were used to analyze the suitable lands for cereals, millets, pulses, oilseeds, and other crops using over layed digital thematic maps of the climatic condition, topography and soil physic-chemical properties and land use pattern for particular area of interest.

Hence, with these facts, the present study was carried out to analyze the suitable lands for green gram cultivation in Thakurganj block of Kishanganj district, Bihar, and to fulfill the objective, parameters viz. elevation, slope, temperature, rainfall, soil texture, soil pH, EC, OC, and land use pattern were analyzed and mapped under RS-GIS domain. However, satellite data of Land sat 8 and the shuttle radar topographic mission (SRTM) were used to map the land use pattern, elevation, and slope. Apart from these data sets, thematic data of annual rainfall and temperature were also analysed and integrated with derived data of analyzed soil pH, EC, organic carbon, and soil texture for their conversion into inverse distance weight (IDW) based mapping process in open source QGIS software. Finally, all these thematic layers were overlaid considering the statistical evaluation of multi-criteria discision making approach to prepare the potential land suitability map for green gram. The results revealed that the pH range of the soils in the study area ranged from 4.42 to 6.67, indicating that they were acidic in nature. However, EC of the soil was found to be non-saline, organic carbon was found to be low to medium and the majority of the area was found to have a loamy soil texture. In terms of elevation and slope, the study area lies between 45–92 m above the mean sea level, and the slope range was observed as 0-3% (gentle or flat). The results revealed that out of the total geographical area only 3537 ha (9.12 %) was found to be highly suitable, followed by 15621 ha (40.28%) moderately suitable, 17584 ha (45.34%) marginally suitable and the remaining 2040 ha(5.26%) was not suitable (NS) for green gram cultivation.

Keywords: *Geographical Information System, Green gram, Land suitability, Multi-Criteria Decision Making (MCDM) and Remote Sensing.*

Introduction

The land, known as a natural resource, provides mechanical and nutrient support to the plants [1]. Under the current situation, where the land is a limited resource, it is impossible to bring more area under cultivation [2]. Hence, crops must be cultivated in those areas where they are best suited to meet the ever-increasing world's population demand for food [3]. Rapid advancements in novel technologies like RS (Remote Sensing), GPS (Global Positioning System), and GIS (Geographic Information System) offered novel techniques to satisfy the demand for sustainable resource planning and were effectively utilized in studying the different facets of soils, compiling a comprehensive inventory of soil resources and planning land use for a specific site [4]. Integration of remote sensing data into a GIS database not only decreased the time and cost but also enhanced the detailed information for any geospatial features [5].

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In order to achieve it, systematic soil resource characterization is crucial, and survey data needs to be analyzed and integrated using GIS techniques to determine the appropriateness of crops [6]. Land suitability analysis is determined by crop requirements and land attributes, which are measurements of how well unit of land's characteristics fit those of a particular crop [7-8]. However, cropland suitability analysis is a crucial step in determining the full potential of the available land resources to implement sustainable agricultural practices [9-10]. Hence, the incorporation of RS-GIS and Multi-Criteria Evaluation could provide a superior database and guide map for decision-makers considering crop land substitution in order to achieve better agricultural production [11].

Green gram (mung bean) is a short-duration crop (around 70 days), a low-input crop, and drought-tolerant [12]. It serves as a rich source of minerals (7.6–9mg/100 g iron), vitamins and protein, containing 14.6–33.0 g/100 g protein [13]. Green gram is a popular food for low-income people, especially those who cannot afford animal protein, as its production cost is low.

But the cultivation of green gram in the lower Gangetic plains is limited. Unplanned agricultural land, agricultural fallow, floods, and sand spread in lowlands were observed in the Kosi region. However, analysis of agricultural land use pattern and suitable sites for the enhancement of pulses are currently lacking, and to mitigate the problem and bridge the gap, the present study was carried out with the objective of finding out suitable lands for green gram cultivation in Thakurganj block of Kishanganj district.

Material and Methods

2.1 Study area

The study area Thakurganj block of Kishanganj district, Bihar comes under Agro-Climatic Zone II (North-east part of Bihar) (Fig.1). The block's geographical area is 387.82 km^2 with extensions of 26.229312° N to 26.530040° N and 87.951256° E to 88.117202° E. The elevation varies from 45 to 92 m above mean sea level with utmost uplands to medium uplands falling in a part of the northern Indian plains just before the hills of Darjeeling in West Bengal. The Mahananda and Mechi rivers flow in from north east to west and join the Ganges tributaries, which fill various ponds, lakes, and oxbows among other water bodies, underlain by mostly younger alluvial deposits in a broadly flat plain.

2.2 Computer Hardware, Software, and Satellite Data used:

The multi-spectral satellite image of Landsat 8 of 2022/2023 was downloaded from USGS Earth Explorer (earthexplorer.usgs.gov) and used to analyze land use pattern. Google maps and the Bhuvan portal were also preferred for the visual interpretation of land use patterns. In addition of these data, elevation and slopes were extracted through Carto- DEM and Shuttle Radar Topography Mission (SRTM). Hence, QGIS software (Version 2.8 & 3.28) was used for the visual interpretation of satellite images, digitization, digital image processing, image classification, and mapping.

2.3 Soil sampling and analysis

There are 63 surface soil samples (0-20 cm) were collected for the analysis of soil pH, EC, OC, and soil texture by following the standard procedures, and mapped using the interpolation technique.

2.4 Development of thematic maps

The thematic maps of soil parameters (soil pH, EC, OC, and soil texture), topographical features (slope and elevation), climatic factors (mean temperature and mean rainfall)and land use land cover pattern were prepared and reclassified corresponding to suitability class as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (NS) using standard practice defined by [7 & 14; 8; 15; 16](Table 1).

2.5 Methodologyapplying of MCDM using spatial AHP procedure

An integrated GIS and Analytical Hierarchy Process (AHP) was employed to evaluate the study area's land suitability for green gram. Similar work viz. for some *rabi* crops viz. wheat, barley, mustard and sugarcane was carried out by [15], and some the major *kharif* crops such as rice, maize, sorghum, pearl millet, and cotton through the MCE technique by using the soil physic-chemical parameters and climatic characteristics [17;18 &19].

In the RS-GIS domain, the Analytical Hierarchy Process (AHP) procedure was utilized to assign the relative importance of criteria, sub-criteria, and suitability classes. There is reported that a hierarchy in the relationship between the objectives and their attributes. The objectives can be distinguished at the highest level, while the attributes can be broken down at a lower level [20].

However, in terms of the creation of a comparison matrix at each and every level of the hierarchy, the pair-wise comparison matrix (PWCM) which rates the relative significance of the two factors was applied for the evaluation of the cropland's suitability [20], (Table 1). Where Hence, a scale was introduced by [21] with values ranging from 1 to 9, and it was used to determine the relative importance/weight of criteria, sub criteria, and suitability classes, where the row factor is rated at 9 which indicate more significant than the column factor. However, a rating of 1/9 means that the row factor is less significant in comparison to the column factor (Table 2).

To avoid bias in the weighting of the criteria, the Consistency Ratio was employed. A CR value of 10% (0.1) or less is regarded as appropriate [22], as a general rule of thumb.

Consistency Index (CI) = $(\lambda - n) / (n - 1)$ … (1)

Consistency Ratio (CR) = CI / RI …. (2)

Where: λ represents the average of the consistency vector, RI represents RandomIndex and is the number of criteria or sub-criteria in each pairwise comparison matrix.

The analysis can proceed if the CR is 0.10 or less. If the consistency value is more than 0.10, the judgment needs to be revised in order to identify the sources of the inconsistency and make the necessary corrections [21]. If the pairwise comparison exhibits perfect consistency, as indicated by a CR value of 0. The judgments matrix is deemed reasonably consistent as long as the threshold value stays below 0.1. The weighted overlay analysis method was integrated with all nine theme layers in the GIS platform to create a land suitability map for the green gram in the Thakurganj block. The final suitability map was produced using the weighted sum overlay technique of the derived data in the open-source geospatial Q-GIS software after the standardized thematic layers and their weights for the green gram crop were determined using the following methodological steps (Fig.2).

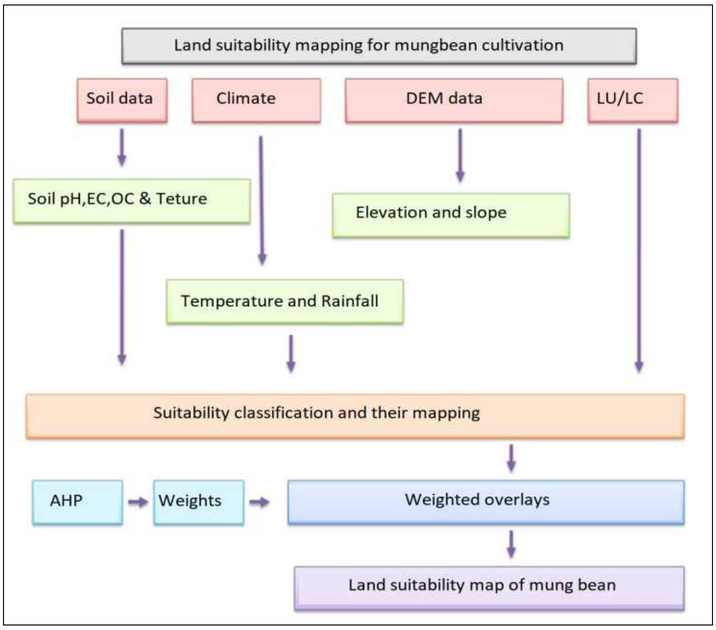

Fig. 2 Flow chart of Land suitability

Results and Discussion

3.1 Soil physio-chemical parameters

The pH (Fig. 9) range of the soils in the study area ranged from 4.42 to 6.67, indicating that soils were acidic in nature. However, EC (Fig. 10) was found to be low (non-saline), organic carbon (Fig. 11) low to medium, and loamy soil texture (Fig. 5) in the study area [27].

reported that in the soils of Mandya district, Karnataka were pH, EC and OC of the soils ranging from 7.4 to 9.4, 0.09 to 0.62 dSm^{-1} and 0.7 to 13.7 g kg^{-1} respectively.

3.2 Topographical features

In terms of elevation (Fig. 3), the study area lies between 45-92 m from the above of mean sea level, elevation continuously increases towards the north east from the south west. However, the slope (Fig. 4) range was observed as 0-3% (gentle or flat).

3.3 Climatic factors

The mean temperature of the Thakurganj block was found to be in the range of 21-22.5 °C (Fig. 6) and the temperature slightly decreases towards in the eastern part. In terms of rainfall, the mean rainfall was observed in the range of 1800–2100 mm (Fig. 7), the northern area receives comparatively high rainfall.

3.4 Land suitability analysis of green gram

Based on multi criteria decision making approach, the investigation revealed that 9.12% (3537 ha) of the area was found to be highly suitable (S1) for green gram cultivation, 40.28% (15621 ha) was moderately suitable (S2), 45.34% (1758 ha) of the land was marginally suitable (S3) and only 5.26% (2040 ha) of the total area was not suitable (NS) for the cultivation of green gram (Fig. 10). The middle part of the study area is moderately suitable, whereas western and eastern parts are marginally suitable due to constraint in soil texture (sandy), and very low OC. Bera et al. (2017) found similar results for agricultural crop suitability, whereas they found the land as highly suitable (34.12%), moderately suitable (43.84%), marginally suitable (15.03%), and not suitable (6.99%) out of the total geographical area.

Conclusion

The present study was conducted to analyse the suitable lands for green gram in Thakurganj Block in RS-GIS-based MCDM domain. Analysed soil characteristics, topographical features, and climatic factors indicated that 9.12% of the total area was found to be highly suitable (S1), followed by was moderately suitable (40.28%), marginally suitable (45.34%) and not suitable (5.26%) for the cultivation of green gram. In order to help the local farmers engaged in green gram cultivation, site-specific spatial suitability analysis may be helpful to enhance pulse production in Kosi region of Bihar. The findings of this study can be also used by policymakers to develop an appropriate plan for the promotion of green gram, providing special agricultural incentive policies.

Future Scope of the Study

Research findings may be helpful to assess the suitable crops and land use planning of the area of interest. Outcomes will be also helpful to support to providing the supplementary data source for the initiation of the same type of suitability analysis of other crops.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgment

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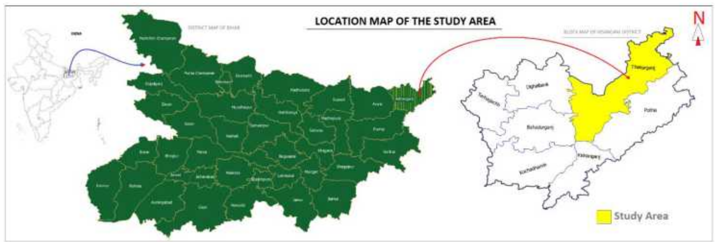


Fig.1 Location map of the study area

Table: 1 Climatic and soil-site suitability criteria for Green gram

Sl No.	Parameters	Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (NS)
01.	Slope (%)	0-3 %	3-9 %	9-22 %	>22 %
02.	Elevation (m)	<50	50-100	100-200	>200
03.	Mean Temperature (°C)	26-30	25-26	21-25	>30 &< 21
04.	Mean Rainfall (mm)	1069-1500	1500-1600	1600-1800	1800-2360
05.	Soil Texture (Class)	Loam/Silt/Silty Loam	Silty Clay/sandy loam/ Silty Clay Loam & Clay	Predominantly Clay	Muck/Peat/Sand
06.	Soil pH	5.5-7.3	7.3-8.4	7.3-8.4/4.5-5.5	<4.5 &>8.4
07.	EC (dsm^{-1})	<0.8	0.8-1.6	1.6-2.5	>2.5
08.	OC (%)	>0.75	0.5-0.75	0.5-0.35	<0.35
09.	Land Use Land Cover	Agricultural Cropland	Fallow/ Barren Land	Forest/Vegetation/Plantation/ Shrubs	Water bodies/Built-up

Source: [15; 19; 28 & 29]

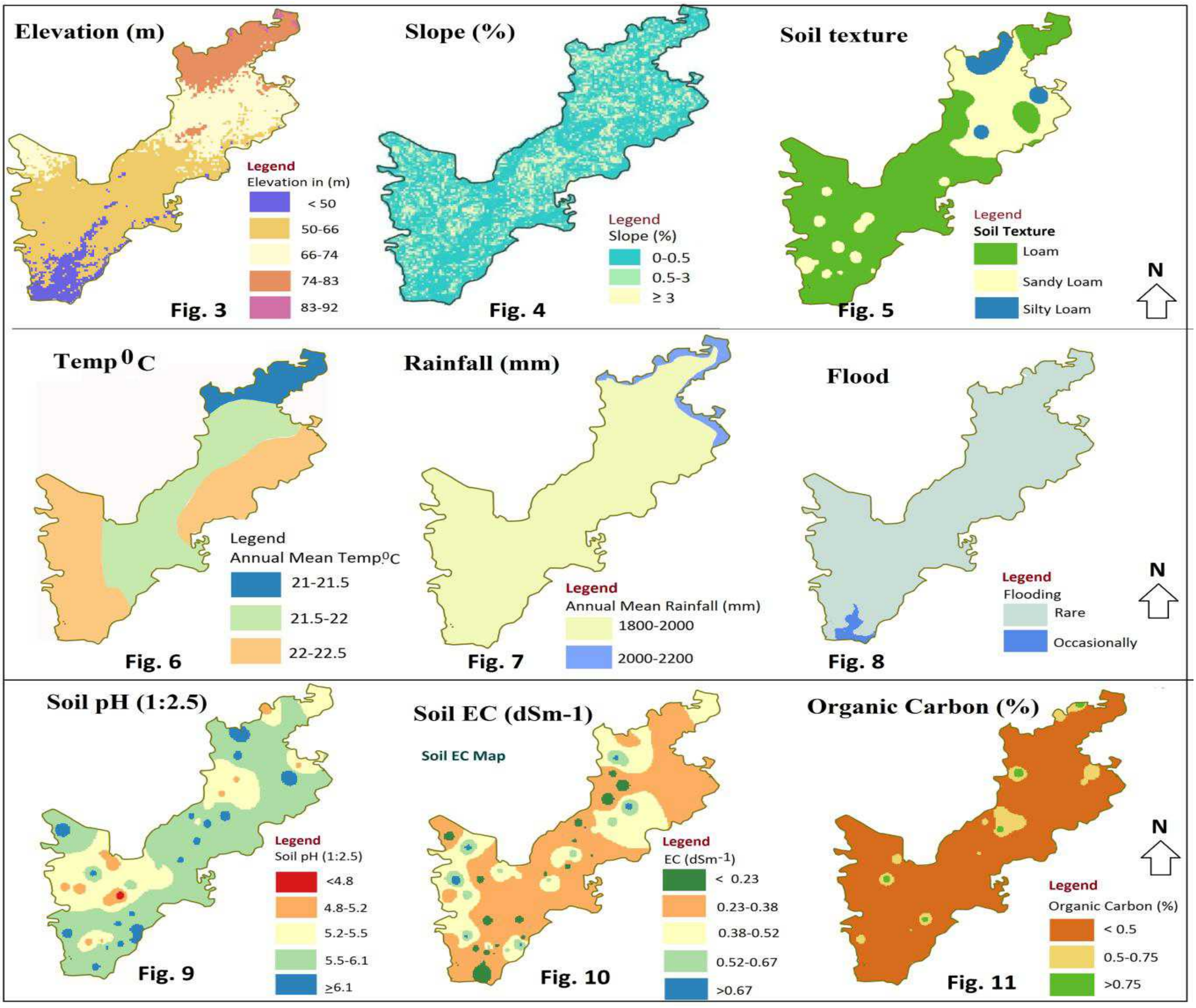
Table 2: Pair wise comparison matrix for assigning weights

	OC	pH	Texture	EC	Temp.	rainfall	LULC	Elevation	Slope	Geometric Mean	Weight	Priority (%)
OC	1.00	3.00	4.00	3.00	5.00	5.00	4.00	5.00	4.00	3.47	0.36	35.84
pH	0.33	1.00	0.33	0.33	4.00	4.00	3.00	3.00	3.00	1.36	0.14	14.08
Texture	0.25	3.00	1.00	3.00	0.25	4.00	0.25	3.00	3.00	1.20	0.12	12.39
EC	0.33	3.00	0.33	1.00	4.00	0.14	4.00	3.00	3.00	1.24	0.13	12.81
Temp.	0.20	0.33	0.33	0.33	1.00	3.00	3.00	1.00	3.00	0.84	0.09	8.65
Rainfall	0.20	0.33	0.20	0.33	0.20	1.00	4.00	0.33	1.00	0.47	0.05	4.89
LULC	0.25	0.14	0.33	0.20	0.25	0.33	1.00	4.00	3.00	0.51	0.05	5.29
Elevation	0.20	0.33	0.14	0.17	0.14	0.25	0.25	1.00	3.00	0.33	0.03	3.38
Slope	0.25	0.14	0.14	0.25	0.25	0.14	0.33	0.33	1.00	0.26	0.03	2.67
Sum										9.67	100	100
Max=10.78			CI= 0.051			RI= 1.45			CR= 0.035			

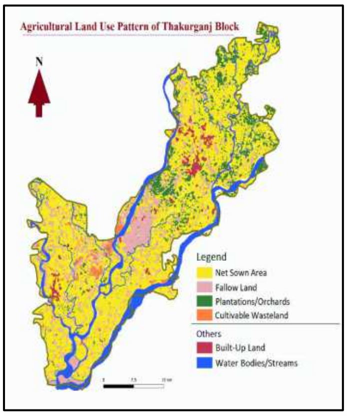
Table 3: Random Consistency Index (RCI) for analytical hierarchy process (AHP)

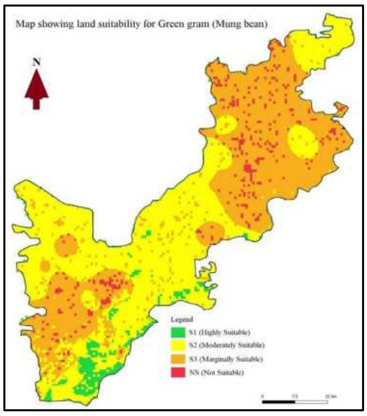
n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Reference: [23;17; 24; 25 & 26]



Spatial variability map of the study area Fig. 3 to 11.





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