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Land capability assessment for land use planning in West Tripura District, Northeast India with an integrated AHP-MCDA approach

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Abstract. *Panja K, Krishnaiah YV, Das D, Hati M, Mondal V, Chakma A. 2026. Land capability assessment for land use planning in West Tripura District, Northeast India with an integrated AHP-MCDA approach. Asian J Agric 10 (1): g100114. https://doi.org/10.13057/asianjagric/g100114.* Land capability assessment is essential for evaluating land resources, revealing the strengths and limitations of land utilization, and addressing problems of land encroachment, land degradation, deforestation, and food security. In West Tripura, Northeast India, rapid urbanization and changing agricultural practices have inadvertently altered the landscape, impacting the livelihoods of local people. Proper land use planning based on land capability is needed to address land-related issues. The primary objective of this study is to analyze the land capability of the district and identify specialized land capability zones to plan for future land use through conscious utilization of the district's natural resources. In this study, USDA land capability classification was derived from soil texture, lithology, soil depth, soil fragments, slope, elevation, drainage density, rainfall, soil moisture, soil pH, land use and land cover, groundwater potential, and temperature. These factors were considered as basic parameters for evaluating land capability in this hilly region. Analytic Hierarchy Process (AHP) techniques were used as part of multi-criteria decision analysis, and weighted overlay analysis was performed through Geographic Information System (GIS) to identify potential Land Capability Classes (LCC) in the district. The present study identified seven land capability classes. Land areas in the riverine plains and *lunga* (intermontane valley) areas were categorized as very good (Class I), good (Class II), moderately good (Class III), and fair (Class IV). The remaining classes are unsuitable for agricultural practices but suitable for pasture, plantation, forestry, wildlife habitat, and natural vegetation. This study reveals that land capability classes II and III occupy nearly half (49.94%) of the potential land area. Field observations and land use analysis indicate that good and moderately good LCC areas associated with fertile floodplains and intensive agricultural practices are being encroached upon by unplanned land utilization, especially rapidly expanding settlements and rubber plantations.

Keywords: Analytic Hierarchy Process, GIS, LULC, multi-criteria decision analysis, Tripura

INTRODUCTION

Land capability is the assessment of land's ability to produce various crops without degrading its quality over extended periods (Klingebiel and Montgomery 1961). It provides insight into suitable land for cultivable crops by considering all limitations of the physical environment. This classification is essential because it helps determine whether a parcel of land is suitable for agriculture or other activities, as every parcel of land has different potential (Sarkar et al. 2023). This assessment provides information about the strengths and weaknesses of land and offers opportunities for wise land utilization decisions. Appropriate land use planning ensures proper utilization and management of natural resources that benefit society (Ippolito et al. 2021). Thus, land assessment is essential in the current context of globalization, industrialization, and urbanization for achieving sustainable agricultural development and economic growth (Mallick et al. 2024, 2025).

Land capability classification was first introduced by the US Soil Conservation Service in 1930, and guidelines were developed by the United States Department of Agriculture (USDA), where classes range from I to VIII (Dar et al. 2024). In this classification, classes I, II, III, and IV are designated as suitable for agricultural land, while the remaining classes are unsuitable for agriculture but can be used for pasture, woodland, grazing, and wildlife habitat. The classification employs a limitation method in which individual land characteristics are compared with the critical limits of the classes (Adams and Engert 2023). Hence, land functionality is determined by the capability and potentiality of land (Mishra and Babu 2021). This classification is based on biophysical characteristics and physical limitations such as soil texture, lithology, soil depth, soil fragments, slope, elevation, drainage, rainfall, soil moisture, soil pH, Land Use and Land Cover (LULC), groundwater, and temperature. Pedological factors play a crucial role in grouping land into different classes. The classification has been developed for better implementation of land use planning and management, as human activities are mostly influenced by land and environment (Akpoti et al. 2019).

Historically, Tripura was predominantly characterized by hilly and undulating forest land. In early times, people of Tripura depended on forest products and practiced primitive shifting cultivation (Choudhuri 2019). After India's independence in 1947 and the liberation war of

Bangladesh in 1971, a large number of Bengalis migrated to Tripura and majorly settled in plain areas (Majumdar 2003; Nath 2019). This population explosion due to rehabilitation and migration played a leading role in forcing the development of an intensive agriculture-based socioeconomic society, which evolved over the narrow riverine valleys. The sudden increase in population, demand for food and shelter, intensive agriculture, and commercial land use (such as plantations) led to current developmental activities without proper land suitability assessment and planning (Panja et al. 2023; Kumar 2024). Under modern conditions, along with the ongoing wave of rapid urbanization, the rate of land encroachment has increased manifold, leading to land degradation, land infertility, and declining agricultural productivity. In such critical situations, developmental activities should be chosen rationally to match the quality of existing land; otherwise, they may hamper productivity, land carrying capacity, and soil fertility (Clawson and Stewart 1965).

Agartala, the second-highest urbanized area, is situated in West Tripura, which has experienced one of the highest rates of urbanization and commercial transformation, leading to shrinkage of natural and agricultural land. Thus, evaluation of land use and capability of the district is essential for better formulation of rational land use and agricultural diversification policies. In this regard, Geographic Information System (GIS) plays a significant role in identifying land capability for crops and developmental activities in the region (Krishnaiah 2011; Girmay et al. 2018; De Feudis et al. 2021). It combines physical and social factors and provides information about land potential. This helps planners sustainably use the land without hindering its productivity, enabling land to be used to its maximum potential. This study provides information about the land capability of West Tripura District, Northeast India, and suggests strategies for future land use planning.

MATERIALS AND METHODS

Study area

Physiographically, Tripura has a distinct valley-ridge topography in Northeast India (Das et al. 2024). Five ranges extend from north to south, where valleys are situated between two consecutive ridges. The study area is located in the western part, sharing a boundary with Bangladesh. The western part is covered with floodplains, and the eastern part has hilly topography. The Baramura hill range is situated in the eastern part and extends from north to south. The gradient of the district increases from west to east, where the valley-ridge topography is locally known as *tilla* (ridge) and *lunga* (valley) and spreads throughout the district. Floodplains are associated with major rivers. The Haora is the main river; after originating from the Baramura range, it flows westward and finally enters Bangladesh. The fertile land of floodplains and *lungas* provides opportunities for farmers for intensive cultivation. Rice is the main staple crop cultivated in three major seasons: pre-monsoon, post-monsoon, and winter. The second leading crop of the district is maize, cultivated in both kharif and rabi seasons. The district experiences a sub-tropical monsoon climate; therefore, monsoon variability plays an important role in crop production. The district extends from 23°40'N to 24°07'N and 91°12'E to 91°32'E. The location of the district makes it significant physiographically and geopolitically (Figure 1).

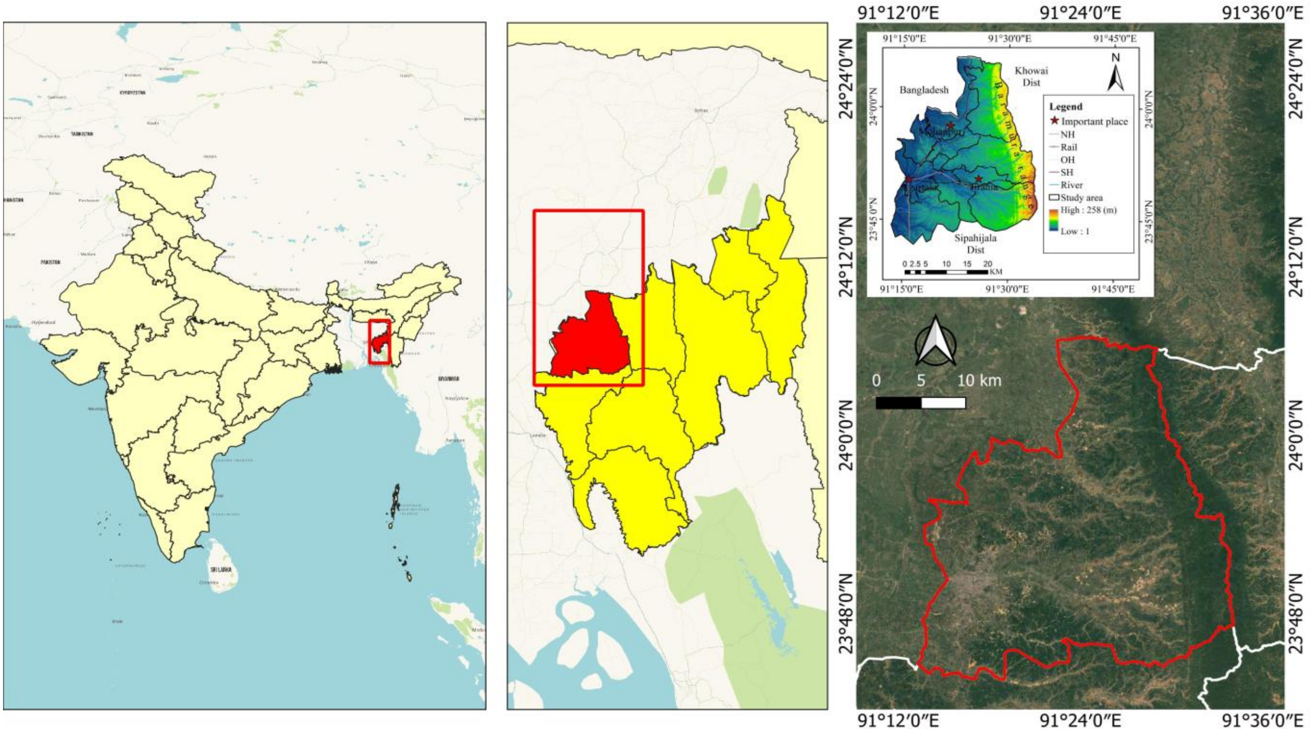


Figure 1. Location map of the study area

Data

The land capability of West Tripura District was calculated based on thirteen major factors: soil texture, lithology, soil depth, soil fragments, slope, elevation, drainage density, rainfall, soil moisture, soil pH, land use and land cover, groundwater, and temperature. All factors were selected through literature review, thorough discussions with agricultural experts and local farmers, and field study. The soil texture map at 1:50,000 scale was derived from the NBSS data portal (https://esdac.jrc.ec.europa.eu/content/tripura-soils-sheet-1). The soil texture map was further digitized and rasterized in GIS software. Mean annual rainfall data for the region were extracted from IMD 0.25°×0.25° gridded maps, and both thematic layers were reanalyzed and resampled to 30-meter resolution. Drainage density, slope, and elevation maps were prepared from the Digital Elevation Model (DEM) and extracted using spatial analysis tools in ArcGIS 10.7. Field investigation and GPS surveys helped collect training samples for pixel-based Maximum Likelihood Classification for land use maps. The stratified random sampling method was employed to collect 480 ground points for training and validation of land use and land cover mapping. Soil moisture and soil pH were determined from collected samples tested using a 4-in-1 multi-parameter handheld soil tester. Test zones were marked with a handheld Garmin eTrex 20. Thirty-six zones were selected from 6 soil groups under various terrain conditions. Rainfall and temperature data were collected from the IMD gridded data portal (https://www.imdpune.gov.in). Thematic layers were prepared for all indicators, and all layers were resampled to a common scale and cell value (30×30), reclassified, and reprojected to WGS 1984 UTM (Zone 46) coordinate system for overlaying and preparing the land capability map.

Methods

An Analytic Hierarchy Process (AHP) was used to analyze the land capability of West Tripura District. This process normalizes all critical relationships between factors and assigns weights according to their involvement in the process. This is a widely accepted technique in the Multi-Criteria Decision-Making Approach through which different criteria are analyzed by bringing them to a common scale (Saaty 1980; Kihoro et al. 2013). According to the relative importance scale, a pairwise comparison matrix was prepared to determine weight values. AHP was calculated following these steps:

Step 1. Pairwise comparison matrix

The comparison matrix was calculated by determining the relative significance based on Saaty's scale of importance (Table 1).

Step 2: Normalization

Based on expert rating of each considered factor, column sums of the matrix were estimated by adding specific column-wise values vertically. Normalization of the comparison matrix was computed to eliminate outliers. Each individual value was normalized column-wise.

Step 3: Weight calculation

The normalized pairwise comparison matrix was used to estimate the weightage of selected factors. Weights were calculated by dividing the sum of row values by the number of criteria.

Step 4: Consistency Ratio (CR)

The overall accuracy of the pairwise comparison matrix and estimated weightage of selected factors were assessed by computing the Consistency Ratio (CR). It shows the relevance of importance values for each factor. If the value is less than 0.10 (10%), then the matrix is considered consistent (Saaty 1980; Aburas et al. 2015). The CR of the Pairwise Comparison Matrix (PCM) was derived from the average eigenvalue of the matrix, Lambda max (Kanga et al. 2017).

Step 4a: Lambda max calculation

For calculating the consistency index, Lambda max was estimated to determine the difference between Lambda max and the number of considered factors (n). In ideal situations, Lambda max equals the number of factors, which indicates higher consistency in the estimated PCM.

Step 4b: Consistency Index (CI)

The consistency index expresses the actual difference between Lambda max value (14.5424) and the number of considered factors (13). The lower CI (0.128) indicates higher consistency of the pairwise comparison matrix.

Step 4c: Consistency Ratio (CR)

The final consistency ratio was calculated by comparing the consistency index with the Random Index (Table 2):

$CR = CI / RI$

For this study: $\lambda = 14.5424$, $CI = 0.1285$, $RI = 1.56$, $CR = 0.0823$

Table 1. Intensity scale of AHP Analysis

Intensity of importance	Explanation
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong importance
9	Extremely more importance of one variable than another
2,4,6 and 8	Intermediate values between adjacent scales

Source: Saaty (1980)

Table 2. Random Index values for AHP analysis

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.54	1.56	1.57	1.58

Since CR value was less than 0.10, the AHP was considered acceptable. Finally, all weighted factors were overlaid to execute the land capability model (Cengiz and Akbulak 2009; Pramanik 2016). The formula for estimating land capability is:

$$LC = \Sigma (W_i \times W_{sub})$$

Where, W_i: Normalized weight of the i^{th} criterion/element

W_{sub}: Weight of the corresponding subclass within that criterion

RESULTS AND DISCUSSIONS

Soil texture

Soil texture is important for land capability assessment as it influences fertility, drainage, soil erosion, and water-holding capacity (AbdelRahman et al. 2016). The soil texture of West Tripura District varies from clay to coarse loam. Coarseness is less in the western part than in the eastern part. In the district, soil texture is interrelated with topographic expression. Fine loam soil texture in undulating topography has deep to moderate water drainage capacity and is moderately erosion-prone. In contrast, floodplains have clay to silty loam soil texture and experience slight soil erosion. Clay to silty loam soil texture is found along the major Haora River and in various *nalas* (streams) and *charas* (tributaries) like Lohar Nala, Sonai Gang, Bengeswar Gang, and Kala Chara. Deep to poorly drained soil is suitable for intensive cultivation. Flat-top pediment areas face high erosion due to steep slopes, resulting in a high proportion of coarse fragments in the soil. Interhill valleys, representing *lunga* areas, have fine loam soil texture, which is favorable for cultivation. *Lunga* land is enriched with soil nutrients as all erosive materials from hillslopes accumulate in these areas. Coarse texture is high among sandstone and siltstone observed in the hilly area of Baramura, which restricts agricultural activities (Figure 2.A).

Lithology

Land characteristics depend on lithological and geological conditions (Gray et al. 2016; Vasilyev et al. 2019). The geological formation of West Tripura ranges from Bokabil under the Surma group to Present-Day Deposits under the Newer Alluvium. Bokabil formation has a lithological structure of shale, siltstone, and mudstone with yellow sandstone, covering a hilly area of 163.60 km². Hard sedimentary rocks of Miocene age form the components of the eastern mountainous ridge, whereas unconsolidated sand, silt, and clay lithological structures are observed in present-day deposit geological formations that depict fluvial morphology. An area of 32.08 km² is suitable for cropping. The maximum area is covered with Tipam sandstone, which has a lithological structure of ferruginous sandstone, siltstone, and clay, covering an area of 594.54 km² and is susceptible to severe erosion. The Dupitila formation formed the synformal valley in the Northwestern part, covering an area of 206.44 km², and has lithological conditions of sandy and silty clay. Water retention capacity is relatively low, making it moderately suitable for cropping. The most suitable land for agriculture is observed in recent alluvium found in river valleys (Figure 2.B).

Soil depth

Soil depth is a crucial factor for plant growth as it influences root penetration (Mary and Nowshaja 2016; Saha and Mondal 2022). Disruption in soil profile hinders plant production and water regulation. Irrigation is also affected by variations in soil depth. In the district, soil depth is high in floodplains and *lunga* areas, whereas it is less in tilla and hilly areas. Topsoil erosion is important for soil depth formation. Soil depth in *lunga* and floodplains is high because soil nutrients, organic matter, and carbon are transported from hills and tillas and accumulate in these areas. Thus, *lungas* and floodplains become fertile for crop production (Figure 2.C).

Coarse fragments

Coarse fragments influence water-holding capacity, water retention capacity, and pore size distribution of soil (Ceacero et al. 2020; Wu et al. 2021). They determine water percolation in soil. If fragments are more abundant in soil, water can easily percolate, and soil water-holding capacity is reduced with increased coarse fragments. The only benefit of coarse fragments is related to soil temperature and soil loss reduction. Stoniness in soil creates hindrance to root growth and reduces productivity. In the study area, soil fragments are more abundant in hills and tillas than in plain land (Figure 2.D).

Slope

Slope is an important topographic factor for determining land capability. It impacts erosional processes, runoff, land fragmentation, and the hydrological system, which can restrict agricultural productivity (Gashaw et al. 2018; Yohannes and Soromessa 2019). The slope of the study area was extracted from 30-meter SRTM DEM (https://earthexplorer.usgs.gov). It was classified into five categories, where the maximum area is covered under gentle slope (688.79 km²). Moderate slopes of 5° to 10° are observed over 259.29 km², and 66.4 km² area is under moderately steep to very steep slopes. The first two classes are suitable for agriculture, but steep slopes limit cultivation. However, jhum cultivation (shifting cultivation) has been observed in the sloppy topography of the district. Lunga land and floodplains of major rivers have slopes of less than 5°. These landforms are most suitable for cropping. Thus, slope plays a crucial role in the land evaluation process (Figure 3.A).

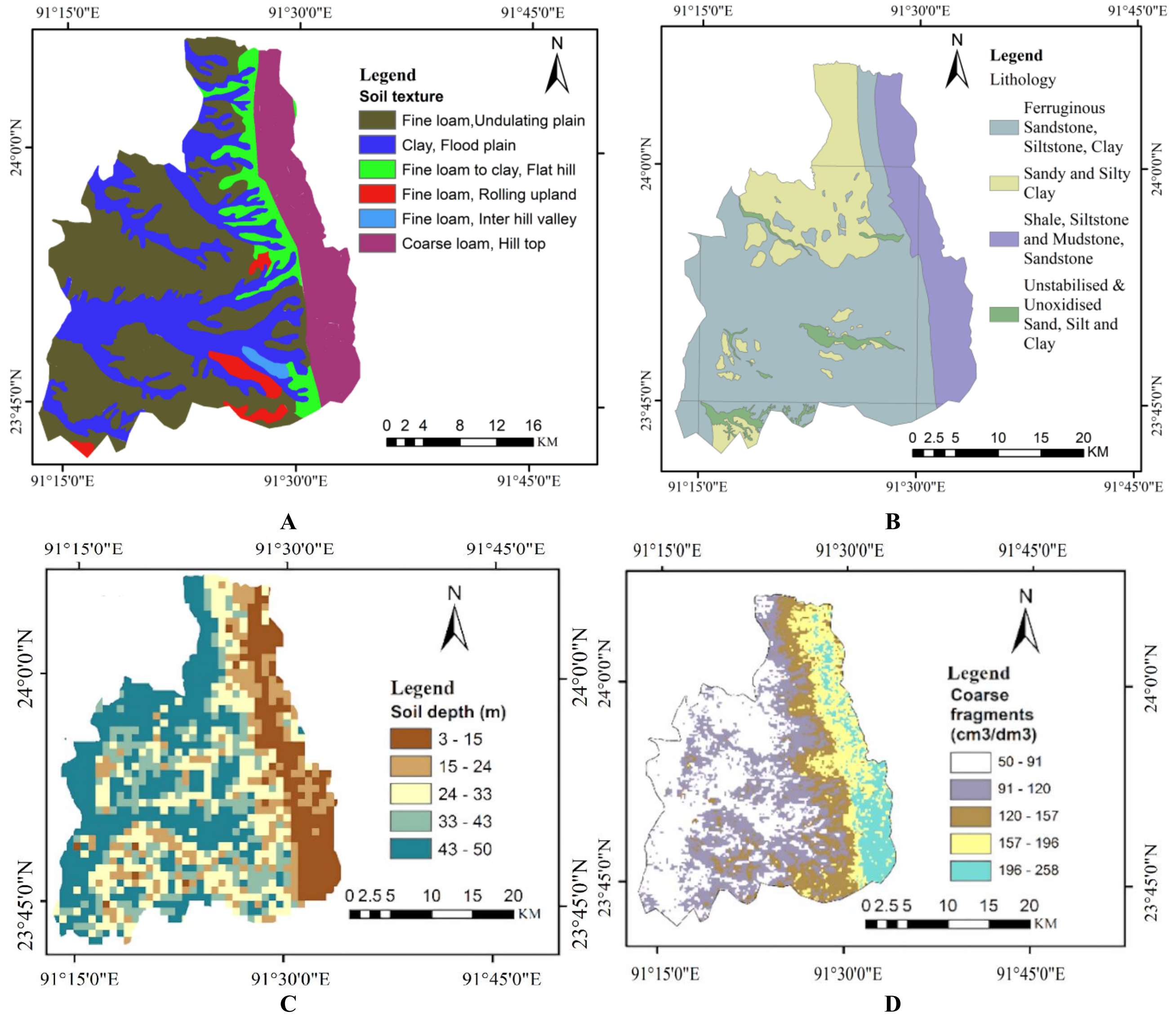


Figure 2. Spatial distribution of: A. Soil texture, B. Lithology, C. Soil depth and D. Coarse fragments in the study area

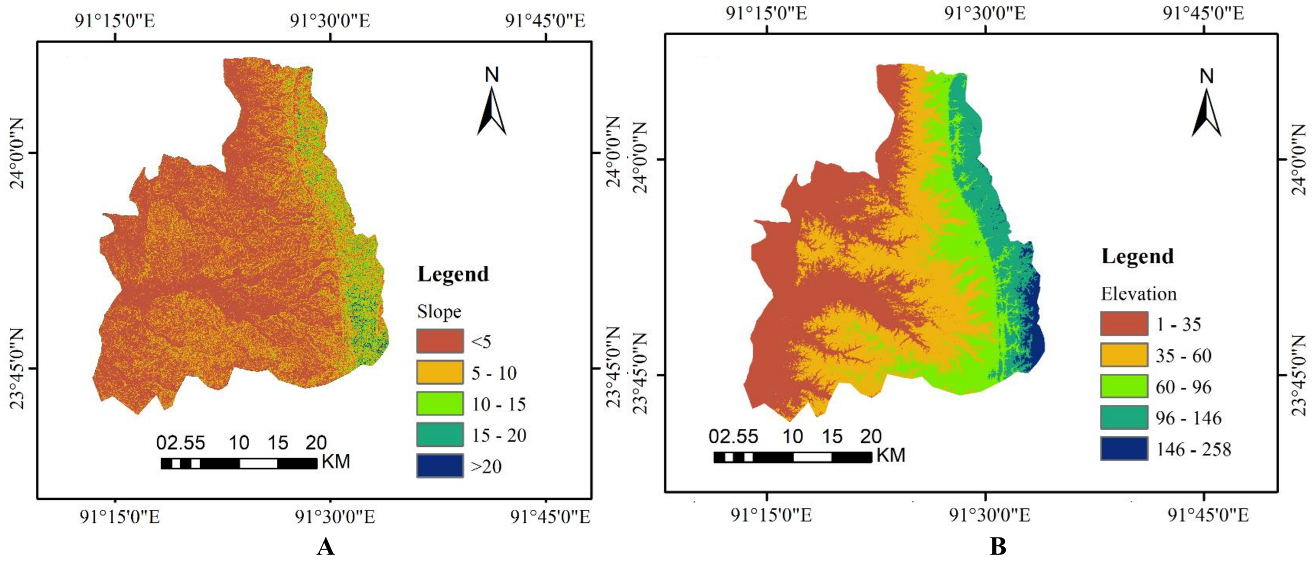


Figure 3. Spatial distribution of: A. Slope, B. Elevation in the study area

Elevation

Elevation reflects terrain characteristics of the study area. Variation in elevation impacts soil quality and land suitability for agriculture. The elevation of the district was categorized into five important classes. Each class represents distinguished landform characteristics. Plainland occupies 365.94 km² where elevation is within 35 meters from mean sea level. This land is the most fertile and has qualities suitable for all types of cropping. Uplands and tillas have elevations between 35 to 60 meters, occupying an area of 345.75 km². Within this landform, only *lunga* land is used for cultivation. Settlements are dispersed in tilla and upland areas. Flat-top topography at the foothill of Baramura experiences a high rate of erosion and covers an area of 171.83 km² within an elevation between 60 to 96 meters. Hilly areas are inaccessible and have elevations between 96 to 146 meters, and their topography presents challenges for livelihoods of native people. High ridges are observed in the southeastern part, with maximum elevation of 256 meters (Figure 3.B).

Drainage

Drainage is part of the global hydrologic cycle. It provides water to the land surface in the form of streams, rivers, *nalas*, *charas*, springs, and subsurface flow. Excessive drainage of the district is found in coarse soil texture of hilly areas. Water retention capacity of soil is low in this texture. Moderate soil drainage is observed in floodplains where aeration in soil provides ample oxygen for plant growth. Gleyed soil prohibits root formation as poor drainage obstructs oxygen supply. Drainage helps with irrigation during the lean monsoon season. Moderate to high drainage density is observed in the middle part of the district; thus, water is available for irrigation throughout the year. The availability of water supply at the land surface and soil texture combinedly support sustainable plant growth (El Behairy et al. 2022) (Figure 4.A).

Rainfall

Distribution of mean annual rainfall influences crop production and land capability. The study region belongs to a monsoon climate; monsoon variability is a common phenomenon. However, variation in spatial distribution of rainfall is relatively small. The eastern part receives an average of 2540 mm of rainfall, whereas an average of 2206 mm of rainfall was observed in the southwestern part. Each block receives approximately equal amounts of rainfall. Intensive cultivation is observed in floodplains, and jhum cultivation is practiced in hilly areas during the rainy season (Figure 4.B).

Soil moisture

Deficit of soil moisture creates water scarcity for plants, which prohibits plant growth and results in production loss. On the other hand, highly saturated soil is unable to aerate properly, which hinders root formation. Balance of soil moisture is needed for proper plant growth. Soil moisture depends on precipitation, evaporation, and runoff. Agriculture in the district mostly depends on rainfall; consequently, water scarcity is a common phenomenon. Therefore, intensive cultivation is observed adjacent to floodplains and rivers where runoff is high and water is available for plant growth. In tilla and hilly areas, moisture content is lower; hence, drought-tolerant crops are grown in these areas (Figure 5.A).

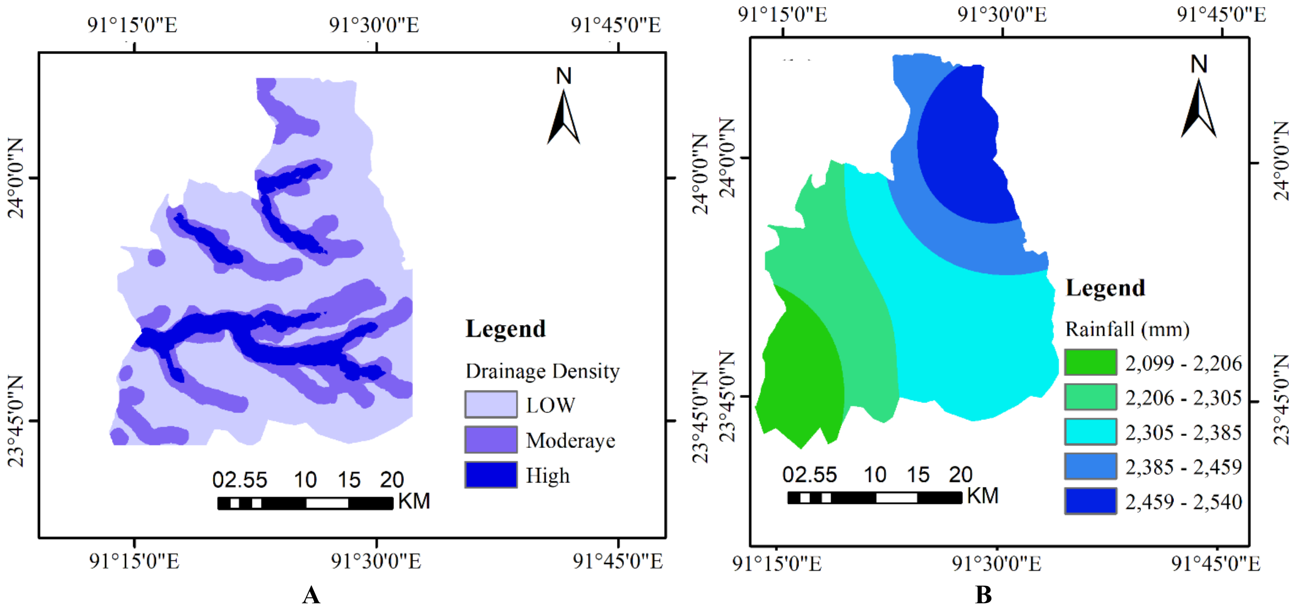


Figure 4. Spatial distribution of: A. Drainage density, B. Mean annual rainfall in the study area

Groundwater

Groundwater potential zones were delineated based on spatial distribution parameters such as slope, lineament, drainage, curvature, topographic wetness, topographic position, geomorphology, lithology, soil texture, rainfall, and LULC. The study area was divided into four groundwater zones. Excellent to good groundwater potentiality was observed in floodplains of Haora River and the northwestern part of the study area. Groundwater within a depth of less than 5 meters below ground level (mbgl) can be a great source for agriculture. Groundwater availability increases land capability by supplying available water to soil. Moderate and poor groundwater potentiality was observed in tilla and hilly areas. The western part of the district and floodplain areas have concave slopes, which accumulate water in these areas. Groundwater is the main source for irrigation in agricultural fields during monsoon gap periods and winter season. Thus, groundwater potential areas are the most suitable for crop production during kharif and rabi seasons (Figure 5.B).

Soil pH

The nature of soil in the district is characterized by acidic conditions. It mainly varies due to variation in vegetation cover (Huang et al. 2017). Especially areas with dense forest cover occupying *tilla* and hilly areas where humus formation is high enhance acidic conditions in West Tripura. *Lunga* and plainland agricultural fields contain relatively moderate acidic soil, which creates more suitable conditions for crops (Figure 6.A).

Temperature

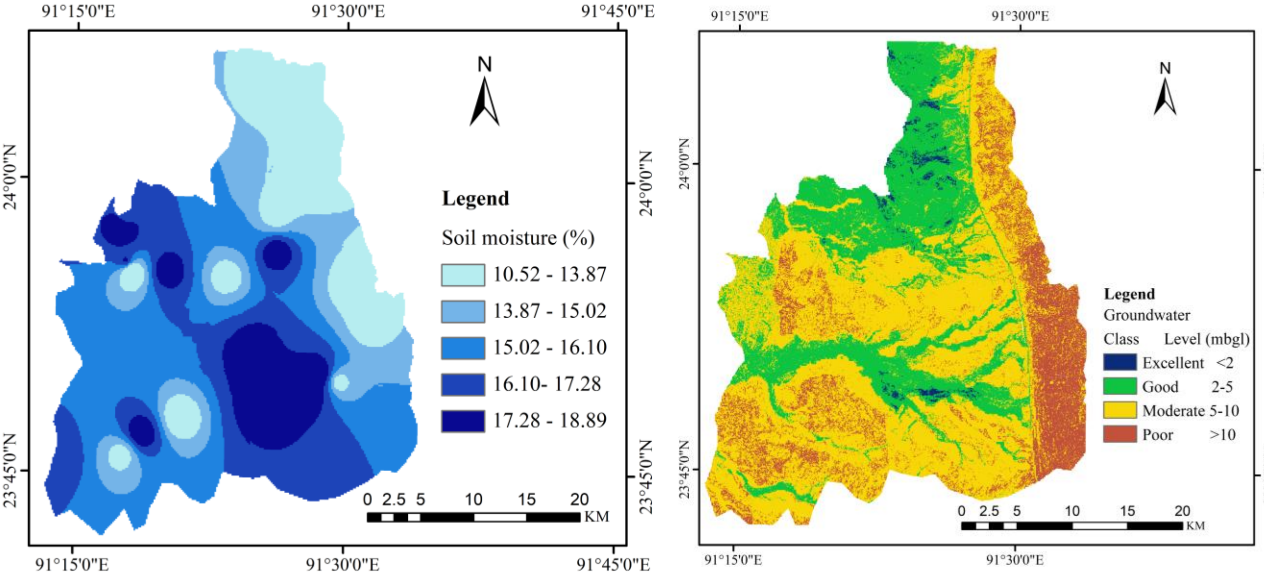
West Tripura belongs to a warm and humid subtropical climate. Mean annual temperature ranges from 24 to 25°C, which is suitable for healthy growth of crops, specifically paddy. This temperature supports intensive cultivation in the district (Figure 6.B).

LULC of West Tripura, 2020

West Tripura is one of the fastest-growing districts in northeast India. Consequently, land use in the district has changed drastically in recent decades. To identify the recent land use pattern, maximum likelihood classification was performed. Natural vegetation was identified as the highest land use class, occupying an area of 255.65 km². It is concentrated mainly in hilly areas. Scattered vegetation is found on tillas and plainlands. Sparseness increases due to encroachment through settlement construction and rubber plantation. Reduction of natural vegetation increases the likelihood of high soil erosivity. Rubber plantations are the second-highest land use class, occupying an area of 243.93 km² (Panja et al. 2023). Profit from rubber plantations encourages farmers to convert fertile agricultural land to rubber fields, although rubber accelerates topsoil loss. Settlements occupy an area of 227.6 km². They are concentrated in major valleys and low-lying areas of the district. The capital city of Agartala is located along the valley of the Haora River basin. Another significant land category is agricultural land, located in floodplains of major rivers and *lungas*, occupying only 153.77 km². Tea plantations, water bodies, shrublands, and bare land occupy areas of 57.84 km², 31.93 km², 30.91 km², and 13.27 km², respectively (Figure 7 and Table 3).

Table 3. Different land use categories of West Tripura, Northeast India (2020)

LULC categories	Area (km^2)	Area (%)
Agricultural land	153.77	15.15
Bare land	13.27	1.31
Natural vegetation	255.65	25.19
Rubber plantation	243.93	24.03
Settlement	227.60	22.43
Shrub land	30.91	3.05
Tea plantation	57.84	5.70
Waterbody	31.93	3.15



A B

Figure 5. Spatial distribution of: A. Soil moisture (%) and B. Groundwater depth in the study area

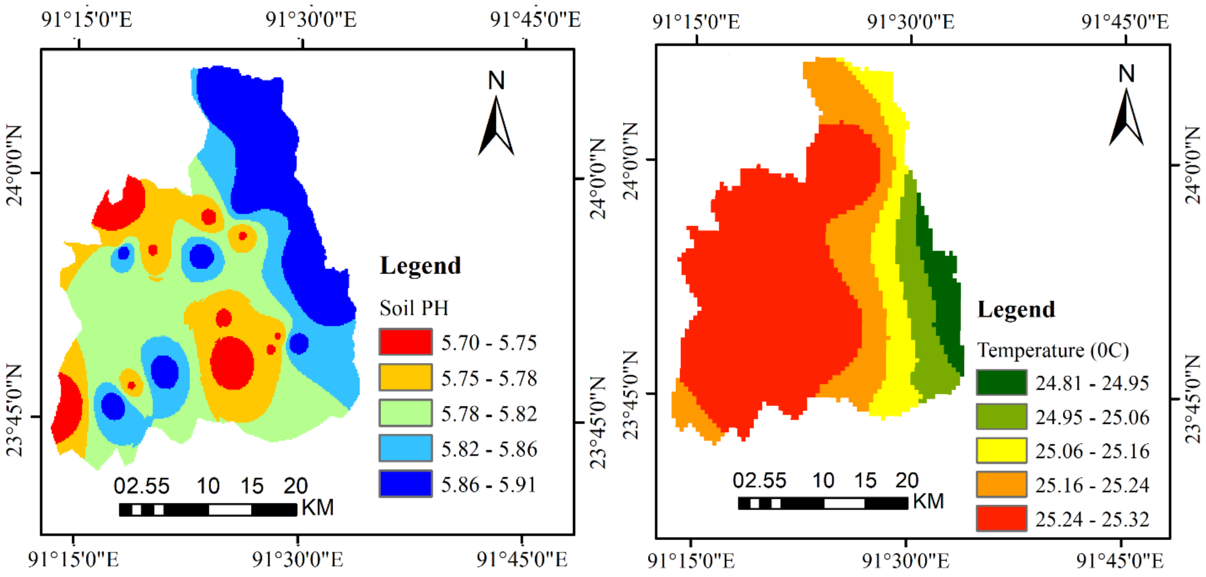
The LULC map shows overall accuracy and kappa accuracy of 88.81% and 86.88%, respectively (Table 4). Land use in West Tripura is mostly influenced by built-up area and rubber plantation expansion. The majority of built-up areas are settled over floodplains. Rubber plantation is one of the most economically viable cash crops, supporting food security in the region. Built-up areas are concentrated in the western part, and rubber plantations occupy tilla and foothill areas. Over time, both land uses have encroached upon natural land cover (open forest, shrubland) and converted them into non-cropping areas. Furthermore, this land use pattern has led to ecosystem degradation and reduced natural land capability of West Tripura, especially surrounding the northeast's second-largest urban center.

Land capability classes

Multi-Criteria Decision Analysis (MCDA) was applied to analyze land capability of West Tripura District. It was used to compute the comparative relationships between selected parameters, labelled as topographic factors (including elevation and slope), soil characteristics including physical properties (such as soil depth, soil texture, soil fragments, lithology) and chemical properties (soil pH), and other factors including rainfall distribution, temperature, and groundwater potential in West Tripura District. The significant impact of selected parameters on land capability and relative importance was determined using Saaty's intensity of importance scale (Table 1). AHP simplified complex relationships among variables by constructing a pairwise comparison matrix and assigning weights according to their significance (Table 5). Finally, weighted overlay of thematic layers produced the Land Capability Classification map of West Tripura.

Table 4. Accuracy assessment of land use land cover categories

LULC Categories	**Agricultural land**	**Natural vegetation**	**Rubber plantation**	**Tea plantation**	**Settlement**	**Shrubland**	**Waterbody**	**Other's land**	**Total**	**UA**	**PA**
Agricultural land	101	2	0	0	10	0	2	3	118	90.18	85.59
Natural vegetation	1	97	2	4	0	2	0	1	107	89.81	90.65
Rubber plantation	0	3	81	2	0	1	0	2	89	93.10	91.01
Tea plantation	0	2	3	29	0	0	0	1	35	80.56	82.86
Settlement	4	2	0	0	85	1	1	1	94	86.73	90.43
Shrub land	0	2	0	1	0	51	0	0	54	89.47	94.44
Water body	4	0	0	0	0	0	45	0	49	93.75	91.84
Bare land	2	0	1	0	3	2	0	27	35	77.14	77.14
Total	112	108	87	36	98	57	48	35	581		
Overall accuracy=88.81%											
Kappa accuracy=86.88%											



A **B**

Figure 6. Spatial distribution of: A. Soil pH and B. Mean annual temperature in the study area

Table 5. Pair-wise comparison matrix for land capability factors

	St	**Li**	**Sdp**	**Sfg**	**Slp**	**El**	**Dd**	**Rf**	**Sm**	**Tem**	**SpH**	**Gwd**	**LULC**	**Weight**
St	1	1	2	3	2	2	3	3	3	5	5	7	9	15.9
Li	1	1	1	2	2	3	3	3	3	7	5	5	9	15.4
Sdp	1/2	1	1	1	1/3	1/2	2	2	5	5	5	7	5	10.6
Sfg	1/3	½	1	1	1/3	1/2	½	1/3	2	5	7	7	7	7.6
Slp	1/2	½	3	3	1	2	3	2	3	5	5	5	7	13.2
El	1/2	1/3	2	2	1/2	1	½	1/3	1/2	3	5	5	7	7.6
Dd	1/3	1/3	1/2	2	1/3	2	1	1/2	2	3	5	5	7	7.6
Rf	1/3	1/3	1/2	3	1/2	3	2	1	2	3	3	5	5	8.8
Sm	1/3	1/3	1/5	1/2	1/3	2	½	1/2	1	3	2	3	5	5.2
Tem	1/5	1/7	1/5	1/5	1/5	1/3	1/3	1/3	1/3	1	3	3	3	2.9
SpH	1/5	1/5	1/5	1/7	1/5	1/5	1/5	1/3	1/2	1/3	1	2	3	2.3
Gwd	1/7	1/5	1/7	1/7	1/5	1/5	1/5	1/5	1/3	1/3	1/2	1	3	1.8
LULC	1/9	1/9	1/5	1/7	1/7	1/7	1/7	1/5	1/5	1/3	1/3	1/3	1	1.2

Note: λ = 14.5424, CI= 0.1285, RI=1.56, CR= 0.0823. St: Soil texture, Li: Lithology, Sdp: Soil depth, Sfg: Soil fragments, Slp: Slope, El: Elevation, Dd: Drainage density, Rf: Rainfall, Sm: Soil moisture, Tem: Temperature, SpH: Soil pH, Gwd: Groundwater and LULC: Land Use Land Cover

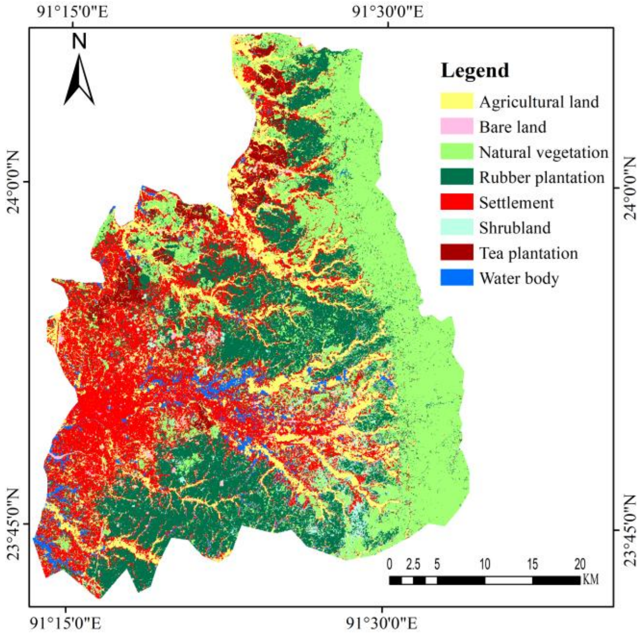


Figure 7. Spatial distribution of land use land cover of West Tripura, Northeast India 2020

The analysis assigned greater weightage to physical, hydrological, and chemical properties of land. According to the USDA-prescribed method, land capability of West Tripura primarily depends on soil texture and depth, lithology and terrain conditions, rainfall distribution, drainage, and groundwater potentiality. LULC is a secondary factor, as it results from the combination and distribution of prevailing primary factors. According to prevailing conditions, LCC were delineated. However, the most intensive cultivation-capable zones (LCC I-III) are also suitable for settlement and built-up development. On the other hand, current trends indicate conversion of agricultural fields to monoculture rubber plantations, which have minimal impact on the overall distribution of land capability zones in West Tripura District.

The AHP table emphasizes importance of each factor and identifies soil texture with maximum weightage, followed by lithology, soil depth, and slope distribution from the perspective of West Tripura's land capability estimation. Due to the presence of loamy soil texture suitable for crop root development, physical setups including soil layer depth, slope, elevation, and rainfall also play important roles in cultivation and harvesting of crops, groundwater potentiality, and water availability for plants and irrigation purposes. In West Tripura, flatter areas (below five-degree inclination) with higher soil depth ranging from 43 to 50 meters cover most of the cultivable plains and sustain a large portion of food and land demands in the district and state.

Land capability classification based on characteristics of factors

According to USDA, there are eight land capability classes, varying from very high capability (Class I) to non-capable land (Class VIII) for traditional settled agriculture (Akıncı et al. 2013). The first four classes (I, II, III, IV) can be used for various types of agriculture and horticulture, whereas the remaining three classes (V, VI, VII) are classified as non-cultivable land. In the case of West Tripura, Land Capability Class I covers an area of 35.82 km² and is suitable for all types of cropping and has been practiced under double or multi-crop patterns. In this LCC zone, due to concave morphometric characteristics with flat to gentle slopes and low elevation (below 35 meters), younger alluvium plains of Haora, Lohar Nala, Sonai Gang, and Bengeswar Gang are formed. These areas are composed of fertile clay and loam soil and have high groundwater potential. Intensive cultivation of rice is suitable for this class (Figure 8).

Land Capability Class II differs from Class I as it is situated slightly above active floodplain land, featuring floodplains with low-magnitude undulating topography. It covers 217.97 km² of total land (Table 6). These zones are favourable for agricultural practices due to lower chances of prolonged water stagnation and higher irrigability resulting from gentle slopes and proximity to perennial water sources (Figure 9.A). Paddy, maize, pulses, and vegetables can be grown in this region.

Land Capability Class III land is moderately good for agriculture. The region covers an area of 288.99 km². This zone is characterized by distinct changes in slope position and elevation. Slope ranges from 5° to 10°. It is located at moderate distances from main channels. *Lungas* and *charas* are narrow valley-like topographies between tillas and undulating areas. The valley floor is composed of clay, sandy loam, and small soil fragments eroded from upland areas. *Lungas* and *charas* are tributary valleys emerging from tillas and foothills and joining main rivers. Areas occupied by *lungas* such as Laxmilunga, Purba Barjala, and Jirania have the most fertile land commonly used for cultivation (Figure 9.B). In each *lunga*, small ponds and canals are dug adjacent to agricultural land to conserve water so that soil moisture can be retained during dry seasons. Paddy, maize, pulses, and oilseeds are planted in kharif and rabi seasons.

Land Capability Class IV is associated with small tillas and uplands (Figure 9.C). Slope ranges between 5° to 10°, and elevation varies from 35 to 65 meters. The land covers an area of 292.36 km² (Table 6). Fine to sandy loam and coarser fragments have been observed in the soil. Soil depth is minimal due to sheet and gully erosion, which has made the land less fertile by removing soil nutrients and organic matter. Moisture content is low in soil; thus, cultivation depends on rainfall. Soil and water conservation is essential in this region. Agricultural production and efficiency are lower in this zone. The land can be used effectively by planting tea and rubber. This is the lowest agriculture-suitable land capability class, experiencing intermediate conditions suitable for Water-Stress-Resilient (WSR) crop species and plantations (rubber and tea) (Ganchaudhuri et al. 2022; Panja and Krishnaiah 2023). Since rubber and other WSR crop species, including maize, corn, and jhum rice, are naturally seasonal drought-resistant, their sowing and growing time ranges from pre-monsoon to monsoon (April to September). They need well-drained sloping land; therefore, they are compatible with LCC IV category agriculture. These crops require less soil moisture and mildly acidic loamy to sandy soil to grow and are practiced in monoculture systems with minimal tillage and irrigation.

Land Capability Class V falls under the foothill area of Baramura range (Table 6). It occupies an area of 102.3 km². Slope angle varies from 10° to 15°. Fine loam to clay soil has been found on flat-topped hills. Jhum cultivation can be practiced on flat land areas. The land is covered with plantations, shrubland, and natural vegetation. Prevailing conditions are similar to LCC IV, but due to greater inaccessibility and mountainous terrain, cropping and rubber plantations are restricted.

Land Capability Class VI land is not suitable for cropping. It comprises hilly areas of the district with slopes varying from 15° to 20° and elevations ranging from 96 to 146 meters (Figure 9.D). Soil is composed of fragments of yellow sandstone and siltstone, and the surface area is covered with shale and clay. Regolith developed from weathered fluvio-maritime deposits is observed in the soil. Flat hilly areas are used for jhum cultivation during the monsoon period. Rubber plantation is restricted; in contrast, banana and areca nut plantations have started. With increasing height, plantation areas gradually convert to mixed forest and natural vegetation. Within this LCC zone, moderate to low (below 13%) soil moisture along with moderate to mildly acidic soil properties restrict LCC V and VI for traditional water-intensive cultivation of staple crops like high-yield variety rice, maize, and potato.

Land Capability Class VII land is highly unsuitable for crop cultivation. This is the topmost area of Baramura hill, occupying an area of 22.21 km². The land has elevations between 146 meters and 256 meters and steep slopes of more than 20°. The land is covered with sandy loam to stony soil. It is characterized by very thin layers of mountainous soil and is inaccessible due to dense cover of natural vegetation (Figure 8).

Table 6. Characteristics of land capability classes of West Tripura, Northeast India

Class	Characteristics	Area (km²)	Area (%)	Dominant capability of land
Class: I	Very good land, no limitations, all crops are cultivated	35.82	3.53	Very intensive cultivation
Class: II	Good land, limitation is slight, choice of crops slightly reduces.	217.97	21.48	Intensive cultivation
Class: III	Moderately good land, limitation is moderate, choice of crops reduced.	288.99	28.47	Moderate cultivation
Class: IV	Fairly good land, limitation is moderate to high, choice of crops is restricted.	292.36	28.81	Limited cultivation, Pasture
Class: V	Unsuitable for cultivation, limitation is high.	102.3	10.08	Plantation & Pasture
Class: VI	Not suitable for crops, limitation very high.	55.25	5.44	Forestry
Class: VII	Mostly Unsuitable, limitation is extremely high.	22.21	2.19	Natural reserves

The classification is based on USDA-prescribed land capability classes where capability depends on potential factors that control the physical condition of land. In West Tripura, Baramura hill ranges have been categorized into LCC V-VII due to the highest slope steepness and low soil depth, leading to higher runoff and topsoil loss, low water retention capacity during rain splash, and soil organic and plant nutrient loss (Miheretu and Yimer 2017). On the other hand, riverine plains of Haora, Mohanpur, Dukli, and Old Agartala are estimated under very high to moderate land capability due to higher soil depth supported by maximum depth and mild to neutral soil pH. Classes I and II are the most cultivable as higher drainage density indicates maximum accumulation of floodwater and dissolved sediments (eroded mudstone, sand, and clay forming sandy loamy soil), soil nutrients, and organic matter. Washout of topsoil reduces soil depth and increases soil fragmentation, which prohibits root growth. Variation in soil depth may affect soil wetness and water retention capacity. Climatic conditions may prohibit plant growth due to seasonal variability.

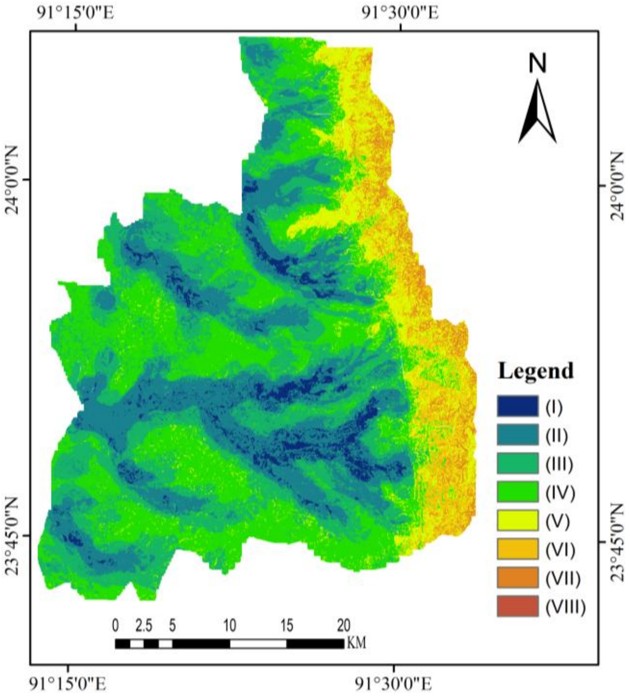


Figure 8. Spatial distribution of land capability classes of West Tripura, India

Figure 9. Field photographs of different land capability classes. A. Plain land under class I & II, B. *Lunga* land under class II & III, C. *Tilla* & uplands under class IV & V, D. Hills under class VI & VII

Distribution of land use with the land capability classes

The land capability map derived based on USDA formulation and the recent LULC pattern of West Tripura in 2020 depict contrasting scenarios. USDA and ICAR prescribed land capability classes suitable for agriculture due to the availability of high to moderate soil depth zones that support soil root system development and collection of desirable nutrients and water (Klingebiel and Montgomery 1961). In the case of Tripura, these characteristics are naturally observed in lower reaches of major rivers. Therefore, it can be stated that land capability majorly depends on water availability, proximity to perennial water sources, and level of short-term water stagnation (Elsheikh et al. 2013). Because of this, land can be cultivated easily without any hindrance. However, moving toward Baramura hill ranges, land potentiality and climate resilience decrease. In the current scenario, the amount of agricultural land in these classes is relatively low.

Rather, tea plantations, rubber plantations, and settlements occupy more area. Encroachment on fertile agricultural land by settlements, rubber plantations, and tea plantations accounts for 10.75%, 5.56%, and 3.24% of land from land capability Class I; 34.30%, 13.56%, and 7.06% of land from Class II; 24.64%, 30.35%, and 8.17% of land from Class III; and 25.17%, 36.95%, and 5.48% of land from Class IV (Table 7). Land capability class-wise size of water bodies is maximum in Class II (14.21 km²), Class III (9.8 km²), and Class IV (6.5 km²). The ratio between areal coverage of agricultural land and water bodies is used for spatial understanding of a region's water resource availability for agricultural purposes. The ratio between areal coverage of settlement area and agricultural land is considered a key indicator of the level of urbanization, economic development, and pressure on food security in a region.

In the case of West Tripura, the minimum ratio between agricultural and water area is computed in Class I, followed by Classes III, II, VI, VII, V, and IV. Class I indicates higher water availability per unit of cultivable land and less dependency on groundwater in parts of Mohanpur, Taranagar, and Ranibazar. However, for areas of Khunglung, Laxmilunga, and Barjala situated in Classes II and III, the ratio certainly increases, indicating less irrigability of fields. Class IV (areas of Mandwai, Bamutia, Radhapur) is identified as having less water-available agricultural zones, characterized by rain-fed cropping practices. Land capability class-wise relationships between agricultural land and settlement area show the lowest in Class I, indicating lowest encroachment, whereas Classes IV and VI indicate maximum occupancy of cultivable land by built-up areas (Figure 10). Agartala Municipal Corporation, Ranibazar, Jirania, Champaknagar, and surrounding areas of NH-8 situated in Haora have maximum built-up occupancy.

Results show that Classes II and III are the most vulnerable areas for cultivation because these two classes have been occupied to the greatest extent by tea estates, rubber plantations, and settlements. In these areas, reduction and alteration of fertile agricultural land to other non-cropping land use classes prohibit crop production, which leads to land degradation, land infertility, decreased yield, and food deficit in the district (Figure 10). To address problems of fertile agricultural land encroachment, proper land use planning is needed for the district.

Land capability is a systematic classification based on physical factors, land substance limitations, and land suitability of a region. It helps evaluate land classes for area-specific landscape dynamics. It includes physical, ecological, and anthropogenic interactions in a region (Saha et al. 2020). This comparative study of LCC and LULC in West Tripura District indicates three major findings:

(i) Availability of very good LCC is minimal, occupying only 35.82 km² alongside Haora River. Currently, 73.28% of land is in use for cultivation purposes. LCC II has the second-highest share in land area, occupying 217 km². It has higher occupancy of urban and rural settlement areas. In Classes III and IV, occupancy of plantations has increased significantly over potentially cultivable areas, and Classes V, VI, and VII are majorly occupied by natural vegetation.

(ii) The most capable land (LCC I and II) for intensive agricultural practices, based on field observations, currently experiences the highest transformation due to rapid expansion of built-ups. On the other hand, moderate and fairly good land faces overburdening to support anthropogenic activity in West Tripura District.

(iv) Rubber plantation has expanded toward Classes V and VI, which are supposed to be buffer zones for natural vegetation and undisturbed forest to support natural habitat for wild ecosystems in the district.

Table 7. Distribution of current land use with land capability classes

Categories	Class I	%	Class II	%	Class III	%	Class IV	%	Class V	%	Class VI	%	Class VII	%
Rubber	1.99	5.56	29.56	13.56	87.72	30.35	108.02	36.95	13.71	13.40	2.56	4.63	0.37	1.67
Vegetation	0.39	1.09	16.25	7.46	32.00	11.07	54.64	18.69	79.61	77.82	51.09	92.47	21.67	97.57
Tea plantation	1.16	3.24	15.39	7.06	23.62	8.17	16.03	5.48	1.40	1.37	0.23	0.42	0.01	0.05
Agriculture	26.25	73.28	57.54	26.40	49.63	17.17	18.00	6.16	1.90	1.86	0.42	0.76	0.03	0.14
Settlement	3.85	10.75	74.77	34.30	71.22	24.64	73.60	25.17	3.56	3.48	0.54	0.98	0.06	0.27
Shrubland	1.09	3.04	6.60	3.03	10.95	3.79	10.63	3.64	1.31	1.28	0.28	0.51	0.05	0.23
Water body	0.68	1.90	14.21	6.52	9.80	3.39	6.50	2.22	0.62	0.61	0.11	0.20	0.01	0.05
Bare land	0.41	1.14	3.65	1.67	4.05	1.40	4.94	1.69	0.19	0.19	0.02	0.04	0.01	0.05

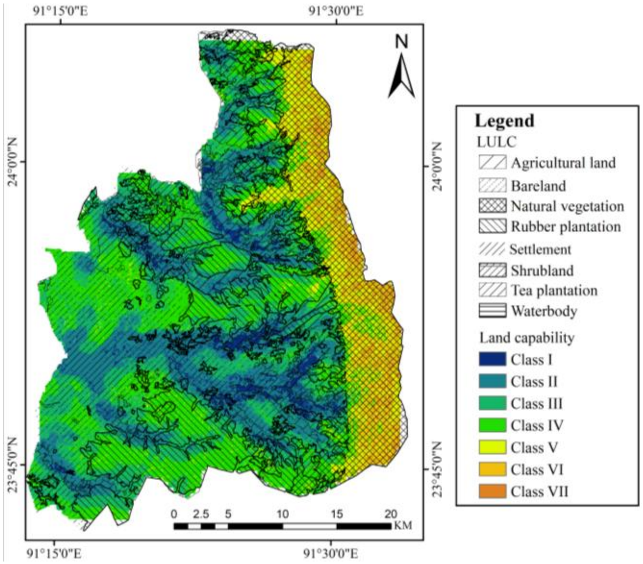


Figure 10. Spatial distribution of LULC with land capability classes

Land use planning recommendations

South Asian countries, especially India, have higher population density, growth, and population shifts due to various natural and geopolitical causes. Therefore, this region faces critical situations and has formulated various policies, including reallocation of food and amenities from food-surplus plain areas to food-deficit areas. Over time, increasing population pressure, rapid and unplanned expansion of built-up areas, commercial land use, and major food-supplying agricultural land have faced conversion and encroachment. The same scenario is evident in north-eastern states where undulating terrain and dense forest dominate land characteristics. Inhabitable land is confined to valleys of major rivers.

In Tripura, more specific observations from this study on assessment of land capability show that present land use in West Tripura District is unorganized and unstructured. As a result, the district faces environmental and economic challenges such as land degradation, deforestation, and food insecurity. These challenges can be overcome through conscious land use planning and management. The present scenario depicts that farmers use 73.28% of land for agriculture from the first land capability class, which is only 26.25 km². The percentage of agricultural land from the second land capability class has drastically declined to 26.39%, which is 57.54 km² area, meaning that maximum land in this class is used for other purposes. In the third land capability class, the proportion of agricultural land decreases to 17.17%, and the area for agriculture is only 49.63 km². Therefore, it can be stated that after land capability Class I, agricultural land area has drastically decreased and been converted to other classes. Although Classes II and III have equal potentiality as Class I, this is a significant reason for the decline in agricultural production in the district (Figure 10 and Table 7).

Research worldwide suggests minimal use of fertile land for non-agricultural activities in the first three land capability classes, which will improve land productivity and address food security problems. Maximum use of land for intensive cultivation in these classes is recommended due to availability of fertile soil, suitable biophysical conditions, and abundant irrigation. Mixed farming, horticulture, and technology-based agriculture should be included in Class III. It would be better to use land capability Class IV for settlements, agro-based industries, modern developmental activities, and plantations, as this zone is adjacent to agricultural land and has comparatively less fertile land. Productivity of this land could be increased through proper soil treatment.

Undulating areas of Class V should be used for plantations, but with increasing height, plantation areas may convert to mixed forest or agri-silvi and silvi-horticultural systems (Sarkar et al. 2022). In areas within open and degraded forests, agroforestry modules of the Tripura Forest Environmental Improvement and Poverty Alleviation Project (TFIPAP) should be implemented. This incorporates plantation of: (i) Multi-Purpose Tree species (MPTs), combining areca nut, agarwood with upland rice and ragi; (ii) silvi-horticulture systems combining timber and non-timber wood (such as *Tectona grandis* (teak), *Gmelina arborea* (gamhar) with orchards of lemon, oranges, black pepper, along with mixed vegetables and pineapple. Instead of monoculture plantations, these will help conserve biodiversity more effectively (Patari and Dasgupta 2022). Classes VI and VII should be reserved for natural vegetation and forestry, especially teak and *Shorea robusta*. This sustainable use of land classes will enhance regional prosperity. Nowadays, climate change presents challenges to land capability and land use planning, so real-time data-based analysis using remote sensing and artificial intelligence will aid in this decision-making process (Mallick and Krishnaiah 2023).

In conclusion, land capability classification of West Tripura is significant for sustainable land planning and securing land resources for agriculture. It shows interactions between natural resources and native people and ensures ecological balance by protecting the natural environment. Assessment was based on the USDA Land Capability Classification scheme. LCC were further overlaid with recent spatial thematic layers of land use, which helped draw a comparison of existing land use and optimum land use supported by biophysical characteristics in Tripura. The study promotes sustainable land use that will increase land efficiency in the context of overcoming environmental problems and securing food for the future.

Evaluation of land use and land capability identified a loss in the district's potential agricultural land due to unorganized and unplanned expansion of Agartala urban agglomeration, extending agricultural and jhum fields, and occupancy of charra beds and riverine areas in Mohanpur, Jirania, Hazamara, and Mandawi areas. Thus, LC classification of West Tripura prescribes land use and land cover based on natural resource management and planning. Land capability Classes V, VI, and VII are identified as less anthropogenically modified zones, having maximum natural vegetation cover. A contrary situation has been observed in LCC I and II classes, which are suitable for all types of cropping. Classes III and IV have limitations associated with high runoff, moderate to low soil depth, and water retention capacity.

Application of soil and water conservation techniques such as contour trenching, check dam building, and brushwood check dams for gully plugging are essential to maintain soil moisture and water table in this region. Crop rotation and intercropping are suggested to maintain land productivity. Technology-based agriculture is recommended for areas where land is best used for limited cultivation and pasture. In Classes V and VI, plantations, lumbering, and forestry may be concentrated, and Class VII should be reserved for forestry and natural vegetation.

Based on suggested land capability-wise land use planning, efficient intensive crop practices in riverine plains will become food-surplus and supply to food-deficit areas. Introduction of alternative farming of climate-resilient crops (millets, corn), pineapple, oranges, and other exotic fruits will help sustain both plainland and hilly area populations, bringing economic and food security directly. Indirectly, establishment of agroforestry including agarwood, sal, teak, other timber wood, and medicinal plants in shrub and bare land of foothill areas will reduce forest fragmentation and biodiversity loss. Measured land use and forestry monitoring should be implemented to restrict rapid expansion of homogenous rubber plantations and other exploitative land uses. This paper proposes and promotes UN Sustainable Development Goals 2030 to farmers as well as government to eradicate poverty, hunger, reduce inequality, and restore life on land.

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REFERENCES

AbdelRahman MAE, Natarajan A, Hegde R. 2016. Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar District, Karnataka, India. Egypt J Remote Sens Space Sci 19 (1): 125-141. https://doi.org/10.1016/j.ejrs.2016.02.001.

Aburas MM, Abullah SH, Ramli MF, Ash'aari ZH. 2015. A review of land suitability analysis for urban growth by using the GIS-based analytic hierarchy process. Asian J Appl Sci 3 (6): 869-876.

Adams VM, Engert JE. 2023. Australian agricultural resources: A national scale land capability map. Data Brief 46: 108852. https://doi.org/10.1016/j.dib.2022.108852.

Akıncı H, Özalp AY, Turgut B. 2013. Agricultural land use suitability analysis using GIS and AHP technique. Comput Electron Agric 97: 71-82. https://doi.org/10.1016/j.compag.2013.07.006.

Akpoti K, Kabo-bah AT, Zwart SJ. 2019. Agricultural land suitability analysis: State-of-the-art and outlooks for integration of climate change analysis. Agric Syst 173: 172-208. https://doi.org/10.1016/j.agsy.2019.02.013.

Ceacero CJ, Díaz-Hernández JL, del Campo AD, Navarro-Cerrillo RM. 2020. Soil rock fragment is stronger driver of spatio-temporal soil water dynamics and efficiency of water use than cultural management in holm oak plantations. Soil Tillage Res 197: 104495. https://doi.org/10.1016/j.still.2019.104495.

Cengiz T, Akbulak C. 2009. Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation: A case study of Dümrek village (Çanakkale, Turkey). Intl J Sustain Dev World Ecol 16 (4): 286-294. https://doi.org/10.1080/13504500903106634.

Choudhuri G. 2019. Partition, migration and the ethnic movement in Tripura. IOSR J Humanit Soc Sci 24 (10): 1-8. https://doi.org/10.9790/0837-2410080108.

Clawson M, Stewart CL. 1965. Land Use Information. A Critical Survey of US Statistics including Possibilities for Greater Uniformity. Johns Hopkins Press for Resources for the Future Inc., Baltimore.

Dar AM, Dar M, Gul DT. 2024. Recent innovations in land capability classification for sustainable development: A brief overview. Environ Monit Assess 196 (12): 1172. https://doi.org/10.1007/s10661-024-13343-1.

Das D, Krishnaiah YV, Panja K, Mallick M, Hati M, Rai D, Chakma A. 2024. Assessment of landslide susceptibility in the Himalayan state of Tripura, India, using a multi-model approach. Curr World Environ 19 (2): 883-901. https://doi.org/10.12944/cwe.19.2.29.

De Feudis M, Falsone G, Gherardi M, Speranza M, Vianello G, Antisari LV. 2021. GIS-based soil maps as tools to evaluate land capability and suitability in a coastal reclaimed area (Ravenna, Northern Italy). Intl Soil Water Conserv Res 9 (2): 167-179. https://doi.org/10.1016/j.iswcr.2020.11.007.

El Behairy R, El Baroudy A, Ibrahim MM, Mohamed ES, Kucher DE, Shokr MS. 2022. Assessment of soil capability and crop suitability using Integrated Multivariate and GIS approaches toward agricultural sustainability. Land 12 (11): 1027. https://doi.org/10.3390/land11071027.

Elsheikh R, Shariff ARBM, Amiri F, Ahmad NB, Balasundram SK, Soom MAM. 2013. Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops. Comput Electron Agric 93: 98-110. https://doi.org/10.1016/j.compag.2013.02.003.

Ganchaudhuri S, Sarmah K, Roy L, Goswami J. 2022. Rainfall probability analysis for crop planning of Unakoti and West Tripura District of Tripura, India. Intl J Environ Clim Change 12 (11): 2520-2529. https://doi.org/10.9734/ijecc/2022/v12i1131245.

Gashaw T, Tulu T, Argaw M, Worqlul AW. 2018. Land capability classification for planning land uses in the Geleda watershed, Blue Nile Basin, Ethiopia. Model Earth Syst Environ 4: 489-499. https://doi.org/10.1007/s40808-018-0448-7.

Girmay G, Sebnie W, Reda Y. 2018. Land capability classification and suitability assessment for selected crops in Gateno watershed, Ethiopia. Cogent Food Agric 4 (1): 1532863. https://doi.org/10.1080/23311932.2018.1532863.

Gray JM, Bishop TFA, Wilford JR. 2016. Lithology and soil relationships for soil modelling and mapping. Catena 147: 429-440. https://doi.org/10.1016/j.catena.2016.07.045.

Huang L, Liu X, Wang Z, Liang Z, Wang M, Liu M, Suarez DL. 2017. Interactive effects of pH, EC and nitrogen on yields and nutrient absorption of rice (*Oryza sativa* L.). Agric Water Manag 194: 48-57. https://doi.org/10.1016/j.agwat.2017.08.012.

Ippolito TA, Herrick JE, Dossa EL, Garba M, Ouattara M, Singh U, Stewart ZP, Vara Prasad PV, Oumarou IA, Neff JC. 2021. A comparison of approaches to regional land-use capability analysis for agricultural land-planning. Land 10 (5): 458. https://doi.org/10.3390/land10050458.

Kanga S, Tripathi G, Singh SK. 2017. Forest fire hazards vulnerability and risk assessment in Bhajji forest range of Himachal Pradesh (India): A geospatial approach. J Remote Sens GIS 8 (1): 25-40. https://doi.org/10.37591/.v8i1.422.

Kihoro J, Bosco NJ, Murage H. 2013. Suitability analysis for rice growing sites using a multicriteria evaluation and GIS approach in great Mwea region, Kenya. Springer Plus 2 (1): 265. https://doi.org/10.1186/2193-1801-2-265.

Klingebiel AA, Montgomery PH. 1961. Land-Capability Classification (No. 210). Soil Conservation Service, US Department of Agriculture, Washington D.C.

Krishnaiah YV. 2011. Land capability of the Papagni river basin, Andhra Pradesh, using remote sensing technique. Trans Inst Indian Geogr 33 (1): 113-122.

Kumar S. 2024. Impact of partition on Tripura: Migration and socio-political changes. Intl J Sci Dev Res 9 (11): IJSDR2411077.

Majumdar R. 2003. The refugee crisis and political developments in Tripura. Indian Hist J 56 (3): 78-95.

Mallick M, Krishnaiah YV, Panja K, Das D, Rai D, Hati M, Chakma A. 2024. Land suitability assessment for tea cultivation in Jalpaiguri District of West Bengal, India, using AHP and DEMATEL techniques. Environ Dev Sustain 2024: 1-39. https://doi.org/10.1007/s10668-024-05711-1.

Mallick M, Krishnaiah YV, Panja K, Das D, Rai D, Hati M, Chakma A. 2025. Assessment of the soil erosion susceptibility zones in tea plantation areas of Jalpaiguri District, India: An integrated approach of RUSLE and WLC Model. J Indian Soc Remote Sens 53: 1855-1874. https://doi.org/10.1007/s12524-024-02078-8.

Mallick M, Krishnaiah YV. 2023. Spatio-temporal detection of land use land cover changes in Jalpaiguri District; Geospatial analysis. Intl J Sci Res 12 (12): 1945-1953. https://doi.org/10.21275/SR231227231047.

Mary STJ, Nowshaja PT. 2016. Land capability classification of Ollukara Block Panchayat using GIS. Procedia Technol 24: 303-308. https://doi.org/10.1016/j.protcy.2016.05.040.

Miheretu BA, Yimer AA. 2017. Land use/land cover changes and their environmental implications in the Gelana sub-watershed of Northern highlands of Ethiopia. Environ Syst Res 6: 7. https://doi.org/10.1186/s40068-017-0084-7.

Mishra P, Babu R. 2021. GIS based land capability classification of a watershed for land and water resource management. Intl J Curr Microbiol Appl Sci 10 (1): 1268-1272. https://doi.org/10.20546/ijcmas.2021.1001.150.

Nath H. 2019. The changing ethnic landscape of Tripura post-partition. J Indian Hist Cult 12 (1): 112-129.

Panja K, Krishnaiah YV, Chakma A, Mallick M, Rai D, Hati M, Das D. 2023. Impact of rubber plantation growth on LULC changes in Eastern-Himalayan region of West Tripura District using geospatial approach. Intl J Ecol Environ Sci 49 (5): 533-548. https://doi.org/10.55863/ijees.2023.2852.

Panja K, Krishnaiah YV. 2023. Evaluating land suitability for rice cultivation in West Tripura using multicriteria decision analysis and geospatial techniques. Intl J Sci Res 12 (12): 1802-1809. https://doi.org/10.21275/sr23122223247.

Patari P, Dasgupta, S. 2022. Impact of monoculture rubber plantation on non human primates and plant diversity in South Tripura. In: Das D (eds). Biodiversity of Our Mother Earth. Bharati Publication, New Delhi.

Pramanik MK. 2016. Site suitability analysis for agricultural land use of Darjeeling District using AHP and GIS techniques. Model Earth Syst Environ 2 (2): 56. https://doi.org/10.1007/s40808-016-0116-8.

Saaty TL. 1980. The Analytic Hierarchy Process. Mcgraw Hill, New York. https://doi.org/10.21236/ADA214804.

Saha S, Mondal P. 2022. Estimation of the effectiveness of multi-criteria decision analysis and machine learning approaches for agricultural land capability in Gangarampur Subdivision, Eastern India. Artif Intell Geosci 3: 179-191. https://doi.org/https://doi.org/10.1016/j.aiig.2022.12.003.

Saha S, Sarkar D, Mondal P, Goswami S. 2020. GIS and multi-criteria decision-making assessment of sites suitability for agriculture in an anabranching site of sooin river, India. Model Earth Syst Environ 7 (1): 571-588. https://doi.org/10.1007/s40808-020-00936-1.

Sarkar D, Saha S, Mondal P. 2023. Modelling agricultural land suitability for vegetable crops farming using RS and GIS in conjunction with bivariate techniques in the Uttar Dinajpur district of Eastern India. Green Technol Sustain 1 (2): 100022. https://doi.org/10.1016/j.grets.2023.100022.

Sarkar P, Das B, Das A, Chakrabarti A, Nath K, Singh V, Sahoo L, Lembisana H, Daschaudhuri D. 2022. Improvement in agroforestry systems of Tripura State of India: Sources for livelihood, health and nutritional security. Indian Farm Dig 1 (1): 28-35.

Vasilyev OA, Vasiliev AO, Andreev RV, Pushkarenko NN, Alatyrev SS. 2019. The influence of the lithological factor of soil formation on the properties and composition of soils in the broad-leaved forest of the forest-steppe zone of the Volga region. IOP Conf Ser Earth Environ Sci 226 (1): 012027. https://doi.org/10.1088/1755-1315/226/1/012027.

Wu X, Meng Z, Dang X, Wang J. 2021. Effects of rock fragments on the water infiltration and hydraulic conductivity in the soils of the desert steppes of Inner Mongolia, China. Soil Water Res 16 (3): 151-163. https://doi.org/10.17221/107/2020-swr.

Yohannes H, Soromessa T. 2019. Integration of remote sensing, GIS and MCDM for land capability classification in AnditTid watershed, Ethiopia. J Indian Soc Remote Sens 47: 763-775. https://doi.org/10.1007/s12524-019-00949-z.