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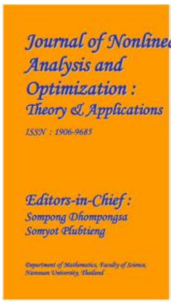

LAND CAPABILITY ASSESSMENT OF ALIPURDUAR DISTRICT FOR AGRICULTURAL SUITABILITY USING MULTI-CRITERIA BASED DECISION-MAKING APPROACH

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Abstract
Soil degradation is an urgent concern for its crucial role in sustaining life on Earth. The gradual process of soil formation is threatened by the growing demands of a burgeoning human population. Agriculture, the primary driver of this demand, often leads to soil deterioration due to unsustainable practices and poor land management. Failure to consider soil quality and suitability for crops can severely impact agricultural productivity.

The present study has assessed the land capability classification of Alipurduar District through Multi-Criteria Based Decision-Making Approach using AHP Method, utilizing 11 parameters. The findings reveals diverse Land Capability Classifications (LCC) in the region. Approximately 21% and 29% of the district's land are classified under Class II (Moderately Good Cultivable Land) and Class III (Fairly Good Cultivable Land) respectively, providing favorable conditions for farming activities. Conversely, 36% and 14% are designated as Class IV (Well Suited for Grazing) and Class V (Fairly Well Suited for Grazing & Forestry or Grazing), indicating lesser suitability for agriculture. Validation of the Land Capability Classification was conducted using receiver operating characteristic area under the curve (ROC-AUC) analysis, yielding a value of 0.871, with significance value of 0.00 and a standard error of 0.052. These results and subsequent analyses highlight the importance of sustainable land management practices to preserve soil health and ensure agricultural productivity in the region.

Key Words:
Land Capability Assessment, Land Capability Classification, Alipurduar District, Agricultural Suitability, Multi-criteria Based Decision-Making Approach, AHP, Soil health, Agricultural Productivity, Sustainable Land Management.

1. Introduction
Soil is a vital natural resource and the challenges associated with its degradation is becoming more acute day by day. Indeed, soil is essential for supporting life on Earth and soil formation can take thousands of years (Chandra & Singh, 2009). As the human population continues to grow rapidly, there is an increasing pressure on soil to meet the rising demand for food and fiber (Havlin et al, 2010). However, the degradation of soil can compromise its efficiency and ability to supply sufficient nutrients for crops. This degradation is often a result of unsustainable agricultural practices and land misuse. When agricultural lands are used without considering their soil quality or suitability for specific crops, it can lead to detrimental effects on soil health (Deshmukh, 2012). Soil quality, particularly its fertility, is crucial for enhancing crop production, because it is susceptible to human intervention and management. In most cases, farmers use the chemical fertilizers to boost productivity. While this measure may offer short-term benefits, it often proves unsustainable due to the associated long term socio-economic and environmental impacts (Atalay, 2016).To address these challenges, it is important to prioritize the conservation and management of soil quality in agricultural lands (Panhalkar et al, 2014). This involves understanding the specific needs and limitations of the soil in terms of land

capability and suitability for particular crops. By adopting sustainable agricultural practices, such as crop rotation, organic farming, and precision agriculture, it is possible to maintain soil quality and minimize damage (De La Rosa et al, 2004). Additionally, implementing soil conservation measures, such as erosion control, proper water management and reduced chemical inputs can contribute to the long-term preservation of soil fertility. These efforts aim to strike a balance between supply for increasing demands for food production and ensuring the sustainability of soil quality for future generations (Helms, 1992).

Land capability classification (LCC) is a system used to categorize soils based on their ability to sustain specific land uses without causing permanent damage or deterioration over an extended period. The concept of land capability emphasizes the long-term productivity and sustainability of land for agricultural purposes (Gad, 2015). Land Capability is the “quality” of land to produce common cultivated crops and pasture plants without deterioration over a long period of time. FAO (1983) defined land capability as “the ability of land to support a particular type of use without causing permanent damage”. Land capability classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time (U.S.D.A. Natural Resources Conservation Service National Soil Survey Handbook, part 622). The LCC was originally developed by the US Soil Conservation Service (USDA 1939) and an early version was first published in 1939 (USDA 1939; Helms 1992). While developed in the United States, the LCC system is actively used in land evaluation efforts in countries all over the world. It was born out of an attempt to farm land while maintaining the quality of the soil (Helms, 1992). The LCC system assigns land to one of eight classes based on the degree of specific limitations of the land such as erosion (e), excess wetness (w), problems in the rooting zone (s) and climatic limitations (c) (Helms, 1992). The specific limitations included in any given LCC system vary, as the degree of each limitation needed to receive a specific class score. The LCC system emphasizes soil erosion hazards (Mullins et al, 1990) due to the relative irreversibility of degradation caused by soil erosion for most land.

However, there are some limitations of the LCC system. First, the inclusion of climate in theseLCC determinations is a limitation of the original LCC system. According to the Food and Agriculture Organization of the United Nations (FAO 2019), it is difficult to adequately consider climate limitations due to the variations of climate requirements between crops and cultivators, and the kinds of climatic hazards. Second, the different factors used to categorize land into LCC classes and subclasses is not standard and does vary between states within the United States and among the other countries. Land capability classification is an interpretativegrouping of soil mapping units mainly based on inherent soil characteristics, external land features and environmental factors that limit the use of land for agriculture, pasture or other uses on a sustained basis (IARI, 1971). The soils are grouped according to their limitations forfield crops, the risk of damage if they are used for crops, and the way they respond to management. It does not include capability of soils for trees, tree fruits, small fruits, ornamentalplants, recreation or wildlife. The land capability classes are further divided into land capabilitysubclasses based on the predominant limitations for land use namely, erosion (e), drainage (w),soil properties(s) and climate(c). The extent of the area under each association is given below.

- Class I, (Good Cultivable Land).
- Class II (Moderately Good Cultivable Land)
- Class III (Fairly Good Cultivable Land)
- Class IV (Well Suited For Grazing)
- Class V (Fairly Well suited For Grazing &Forestry)
- Class VI (Lands Well Suited For Grazing & Forestry)
- Class VII (Lands Suited For Wildlife & Recreation) &
- Class VIII (Water Bodies)

The present review has revealed that the concept of ‘capability’ has not been clearly distinguished from all other related terms. There is a lack of international standardization of terms which refer, or are related, to capability particularly concerning the distinction between ‘capability’ and ‘suitability’. ‘Capability’ is viewed by some as the inherent capacity of land tosupport a generally defined land use (Klingebiel & Montgomery, 1961; FAO, 1976), or refersto a range of uses, e.g. for agricultural, forestry, or recreational development (McRae & Burnham, 1981). ‘Suitability’, on the other hand, refers to the fitness of a given type of land for a particular use, for example, suitability for sugar cane or rice, etc. (Brinkman & Smyth, 1973; FAO, 1976; McRae & Burnham, 1974). However, some authors consider that the two terms are interchangeable, with no essential difference between them (Vink, 1975). For the purpose of this paper 'capability' is used to refer to "the potential of the land for use in specifiedways, or with specified management practices" as defined. (Dent & Young, 1981). This meanscapability is more simply an assessment of the relative suitability of the land for a particular use.

'***Classification***' means ordering or arranging objects into groups or classes on the basis of their similarities or relationships. The product of this process is a classification system, and subsequent placement of objects into the system is called identification (Sokal, 1974). Such identification of objects and their subsequent delineation over an area of land becomes mappingor regionalization. The science of classification is called taxonomy (Bailey et al, 1978). Classification has been applied somewhat loosely in most resource survey fields under all of these meanings. As the term is commonly used in a broad sense, the present author will includeall of these related aspects of the classification process, identification and regionalization under'classification'. It is important to emphasize that classifications are man-made rather than natural, and that a set of objects can be arranged in many different ways according to the classification procedure applied to the data. Although the classification procedure can be carried out in many ways, most writers agree on the fundamental purposes of classification: to provide a grouping which is valid for the scientific activity being undertaken and to allow generalizations to be made about the object classified (Grigg, 1965; Sokal, 1974; Sitorus, 2010).

GIS is the tool for input, storage and retrieval, manipulation and analysis and output of spatialdata (Abdel Rahman, 2019). GIS functionality can play a major role in spatial decision making.(Kazemi & Akinci, 2018). GIS have the ability to perform numerous tasks utilizing both spatialand attribute data stored in it. Considerable effort is involved in information collection for the suitability analysis for crop production. Remote sensing in combination with GIS will be a powerful tool to integrate and interpret real world situation in most realistic and transparent way. The suitable areas for agricultural use are determined by an evaluation of the climate, soil and topographical environmental components and the understanding of local biophysical restraints. In this kind of situation, many variables are involved and each one should be weighed according to their relative importance on the optimal growth conditions for crops through Multi-Criteria Evaluation (MCE) and GIS. One of the most useful features of GIS is the abilityto overlay different layers or maps. However, the overlay procedure does not enable one to take into account that the underlying variables are not equally important (Ghaffari et al, 2001).One approach that can help to overcome such limitations is MCE which has received renewedattention within the context of GIS-based decision-making (Carver, 1991; Pereira & Duckstein,1993). Overall, GIS provides a powerful platform for integrating and analyzing spatial data, facilitating suitability analysis for various purposes, including agricultural land use. The combination of GIS and MCE enables more comprehensive and informed decision-making processes in the field of crop production and resource management. The main aim of this studyis to identification of Land Capability Classes (LCC) of Alipurduar district and suggest some management practices.

2. Study Area

The Alipurduar District in West Bengal, which is characterized by its diverse topography, including rivers, streams, hills, tea gardens, paddy fields and forests. The study area encompasses the entire Alipurduar district, extending from approximately 26° 16' 00'' N to 26°52' 00'' N and from 89° 00' 00'' E to 89° 54' 00'' E, covering an area of 3136 square kilometres(District Survey Report of Alipurduar District July, 2021). The district is located in the north-easterncorner of West Bengal and is bordered by Bhutan to the north, Cooch Behar district to the south,Assam to the east and Jalpaiguri district to the west (Fig. 1.1). This district have 6 blocks namely Alipurduar I, Alipurduar II, Kumargram, Kalchini. Madarihat and Falakata (Fig. 1.2).

The GIS-based model aims to assess the land capability of the district, taking into account its diverse topography and various factors that influence land use suitability. By using GIS technology, the model can integrate and analyze spatial data to classify different areas based on their capability for specific land uses. This classification can provide valuable information for land management, planning, and decision-making processes in the district.

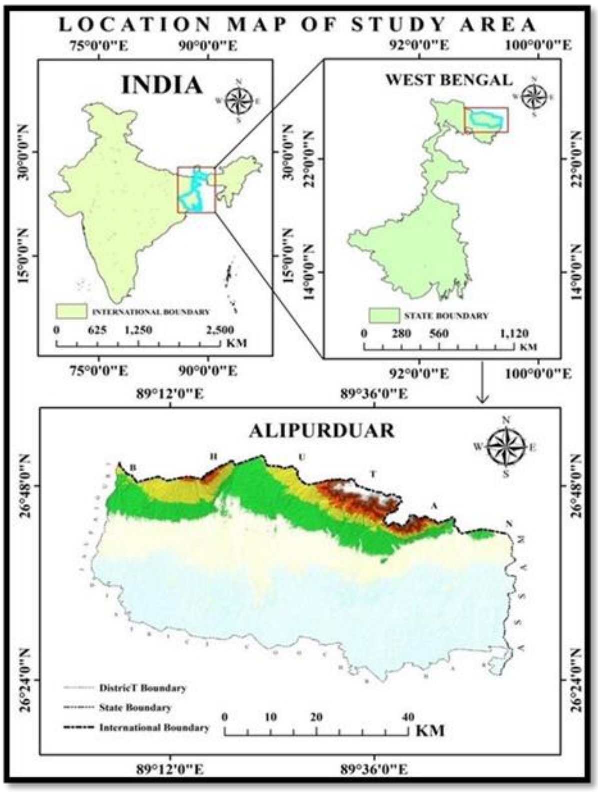

Figure 1.1: Location Map of the Study area

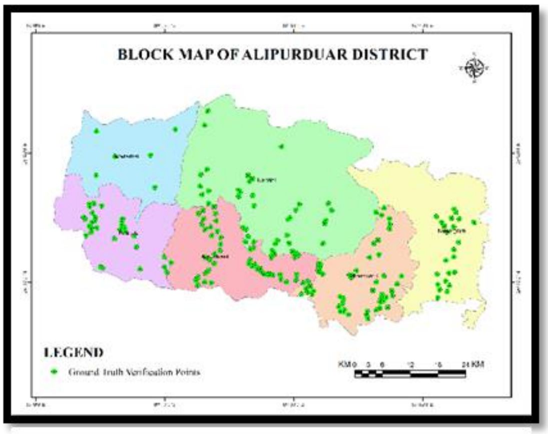

Figure 1.2: Administrative Set-up

3. Materials & Methods

3.1 Selection of factors and development of Thematic layers for preparation of Land Capability Map

Land Capability Classification (LCC) is a scheme used to classify soils based on their ability to sustain specific land uses without causing permanent damage or worsening over a prolonged period. The concept of land capability highlights the long-term productivity and sustainability of land for agricultural purposes (Gad, 2015). Land Capability is the "quality" of land to produce common cultivated crops, pasture and plants without deterioration over a long period.Land capability has been defined as "the capacity of land to sustenance a specific type of use without affecting permanent damage" (FAO, 1983). Total 11 factors were considered from numerous fields for the preparation of the land capability classification based on literature survey. The researchers have chosen the factors which are used by different researcher as a minimum once and very carefully followed the USDA Land Capability Classification (LCC) developed in 1939. Total 11 thematic layers for the selected parameters for this study. All the thematic layers for every parameters were prepared based on the accessibility of data and followed by the scheme of LCC USDA (1939) of parameters or natural break method or krigingmethod in the Arc GIS 10.3.6 platform. All the factors were broadly classified into Topographical Factors (Slope), Soil Physical Factors (Soil Depth, Soil Texture, Soil Drainage,Soil Permeability and Corse Fragments), Soil Chemical factors (Cation Exchange Capacity, Organic Carbon and Base Saturation) and Ancillary Factors mainly climatic data used (Flooding Data and Soil Erosion).

3.2 Materials

Total 11 factors (Table 3.1) including slope, meteorological, soil physical and chemical parameters have been selected for Land Capability Classification (LCC).The slope map was prepared from Shuttle Radar topographic mission digital elevation model (SRTM DEM). Theland use land cover (LULC) map has been downloaded from Bhuvan and the flooding map hasbeen taken from one published paper. Soil Texture (ST), soil permeability (SP), soil drainage (SD), soil depth (SD1) and base saturation (BS) data has been collected from soil series of WestBengal (ICAR-NBSS & LUP) and organic carbon (OC), coarse fragments (CF) and cation exchange capacity (CEC) data are collected from soilGrid (SoilGrids250m 2.0).

No. of Parameters	Theme	Source
1	Slope	SRTM DEM USGS EarthExplorer
2	LULC	Bhuvan | Thematic Data dissemination | Free GIS Data | OGC Services | Clip and Ship(nrsc.gov.in)
3	Flooding	Roy, D., Das, S., Paul, S., & Paul, S. (2022). Application of Analytical Hierarchy Process (AHP) Method to Flood Risk Assessment at Sub-Himalayan Region Using Geospatial Data: A Case Study of Alipurduar District, West Bengal, India. In Monitoring and Managing Multi-hazards: A Multidisciplinary Approach (pp. 167-196). Cham: Springer International Publishing
4	Soil Texture	Soil Series West Bengal,NBSS&LUP ICAR-NBSS&LUP
5	Base Saturation	
6	Soil Permeability	
7	Soil Drainage	
8	Soil Depth	
9	Organic Carbon (OC)	SoilGrids250m 2.0
10	Coarse Fragments (CF)	
11	Cation exchange capacity(CEC)	

Table No. 3.1 : Data type and Sources

3.3.1 Methodology

Methodology involves the systematic and theoretical analysis of the methods utilized within aspecific discipline or area of study (Louis, 2007). It encompasses the principles, practices andprocedures employed to conduct research, address problems or accomplish defined objectives.Methodology is pivotal in ensuring that investigations are conducted with rigor, adherence to ethical standards, and effectiveness (Kitchin & Tate 2013).

In academic research, methodology outlines the framework within which a study is conducted.This framework encompasses the techniques used for data collection and analysis, the theoretical underpinnings guiding the research, and the criteria used to assess the results. Methodology aids researchers in organizing their inquiries, maintaining coherence, and drawing valid conclusions (Arksey & O'malley 2005).

Ultimately, methodology offers a structured approach for conducting research, serving as a cornerstone for generating credible and dependable findings within a particular field or domain.The methodology flow chart for Land capability Classification is shown in Fig.3.1.

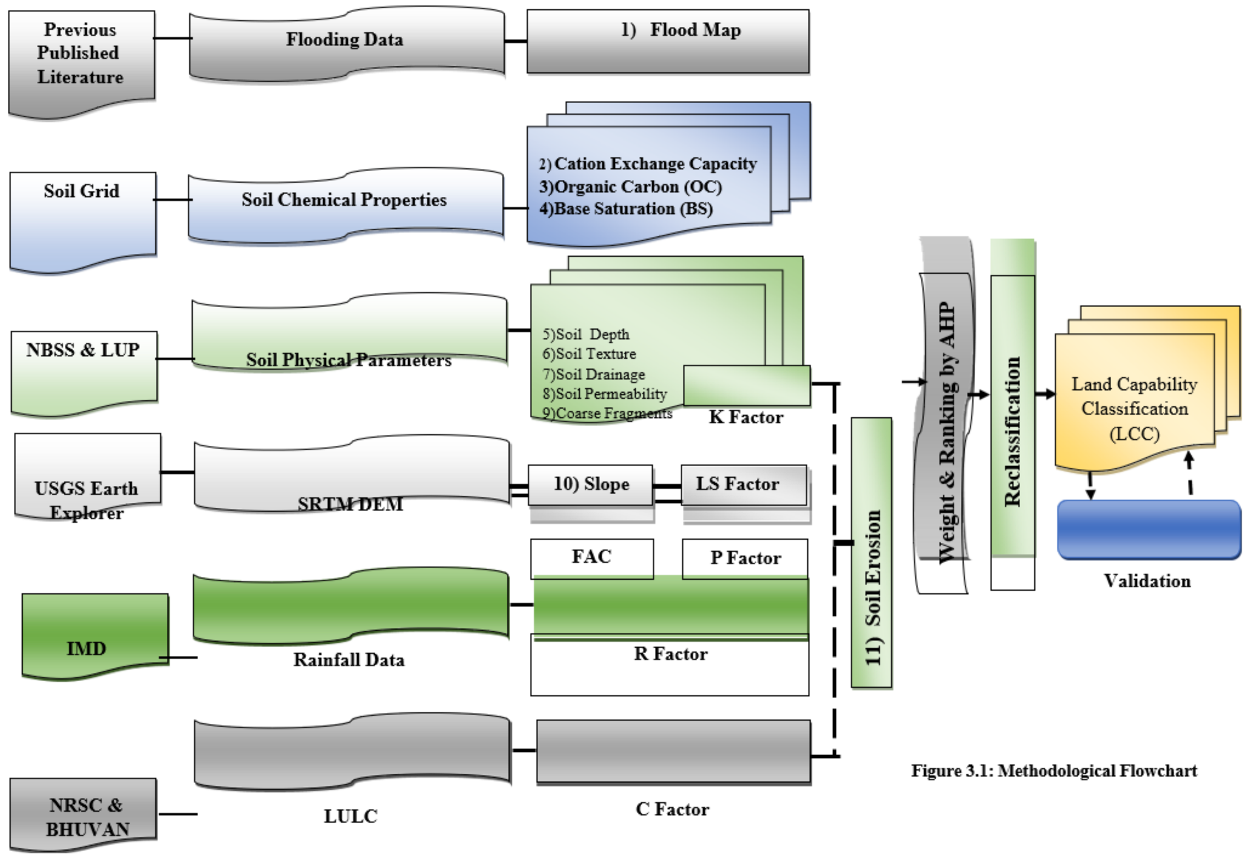

Figure 3.1: Methodological Flowchart

3.3.2. Multi attribute decision methods

The Analytic Hierarchy Process (AHP) is a type of multi-attribute decision method (MADM) utilized for making decisions amidst various conflicting criteria (Yamagishi et. al, 2023). Thesemethods enable decision-makers to systematically compare options and prioritize them according to the significance of each criterion (Wang et al, 2009). In AHP, the initial step entailsconstructing a decision hierarchy consisting of an objective, alternatives, and criteria (Darko etal, 2019). This hierarchy simplifies the decision problem into smaller parts for more manageable evaluation. Criteria represent the specific factors employed to evaluate andcontrast alternatives. By organizing the decision problem in this manner, decision-makers cangain a clearer understanding and make well-informed decisions (Gregory et al, 2012).

In this study, eleven distinct criteria and alternatives were used to aid decision-making. Thesecriteria were chosen carefully based on their relevance to the decision problem. Pairwise comparisons were then used to determine the relative importance of each criterion, with experts providing judgments (Satty, 1990, Pérez, 1995). The consistency of these comparisons was assessed and if it fell below a certain threshold, it was considered acceptable. This process aimed to develop a comprehensive understanding of the decision problem (Satty, 2008).

To support these comparisons, a 1–9 point scale (Satty, 1990) (Table 4.1) was used for assigning numerical values to criteria based on their significance. The random index (RI) (Table 4.2) was used to ensure consistency in comparisons. Normalized preference scores were calculated to reflect the relative importance of each criterion and alternative. These scores were then weighted to enable informed decision-making (Dolan, 2010)

The consistency ratio (CR) was calculated (Table 4.1 &) to validate the AHP model used in the study, ensuring reliability. By employing these techniques and metrics, the study established a reliable decision-making process grounded in rational judgments and informed evaluations (Thokala, 2016).

$$nij = \frac{aij}{\sum_{i=1}^{n} aij}$$

$$wi = \frac{\sum_{i=1}^{n} aij}{n}$$

nij is normalised pair-wise comparison matrix, Wj is the criteria weight using AHP, and aij is a matrix element in rows i and j.

$$Consistency\ Ratio\ (CR) = \frac{\mathrm{CI}}{RI}$$

$$Consistency\ Index\ (CI) = \frac{\lambda\mathrm{max}}{\mathrm{n}-1}$$

$$\lambda\,\mathrm{max} = \frac{\sum \lambda}{n}$$

$$\lambda = \frac{\mathrm{WSV}}{W}$$

$$WSV = A \times W$$

Where, W represents the weight assigned to the criterion vector, A denotes the pairwise comparison matrix, RI stands for the random index, n represents the number of criteria, λmaxsignifies the largest eigenvalue of the matrix, λ denotes the consistency vector, and WSV indicates the weighted sum vector. The distribution of weights to subcategories under each factor was determined utilizing the Analytic Hierarchy Process (AHP) technique, and the consistency ratio (CR) was calculated based on the pairwise comparison matrix. Saaty suggeststhat a Consistency Ratio (CR) of 0.10 or lower indicates acceptability for further analysis. Should the CR exceed 0.10, it implies a necessity to review judgments, identify sources of inconsistency, and rectify them accordingly. CR of 0.056 indicates perfect consistency in pairwise comparisons. As long as the threshold of 0.10 is not surpassed, the judgment matrix maintains a reasonably consistent state (Satty, 1990, Arulbalaji, 2019).

Table 4.1: Satty's scale of relative importance (Source: Saaty 1990)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Slightly more importance of one overanother	Experience and judgment slightly favour one activityover another

5	Essential or strong importance	Experience and judgment strongly favour one activityover another
7	Demonstrated importance	An activity is strongly favoured and its dominancedemonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is ofthe highest possible order of affirmation
2,4,6,8	ermediate values between two adjacent judgment	When compromise is needed

Table 4.2 Saaty's ratio index for different values of N

Order of matrix											
N	1	2	3	4	5	6	7	8	9	10	11
RCI value	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	149	1.51

Table 4.3 Pairwise comparison matrix for all factors

Factor	Base Saturation	CEC	OC	Flood	Coarse Fragment	Soil Erosion	Slope	Soil Permeability	Soil Depth	Soil Texture	Soil Drainage
Base Saturation	1	2	3	4	5	6	7	8	8	9	9
CEC	1/2	1	2	3	4	5	6	7	8	8	9
OC	1/3	1/2	1	2	3	4	5	6	7	8	8
Flood	1/4	1/3	1/2	1	2	3	4	5	6	7	8
Coarse Fragment	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7
Soil Erosion	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6
Slope	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5
Soil Permeability	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4
Soil Depth	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3
Soil Texture	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2
Soil Drainage	1/9	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1

Table 4.4 Pairwise comparison matrix, weight and consistency ratio of the data layer used

Factor	Base Saturation	CEC	OC	Flood	Coarse Fragment	Soil Erosion	Slope	Soil Permeability	Soil Depth	Soil Texture	Soil Drainage	Sum	Weight
Base Saturation	0.326	0.404	0.383	0.341	0.296	0.267	0.239	0.216	0.178	0.169	0.145	2.964	0.269
CEC	0.163	0.202	0.255	0.256	0.237	0.223	0.205	0.189	0.178	0.150	0.145	2.203	0.200
OC	0.109	0.101	0.128	0.171	0.178	0.178	0.171	0.162	0.156	0.150	0.129	1.631	0.148
Flood	0.081	0.067	0.064	0.085	0.118	0.134	0.137	0.135	0.134	0.131	0.129	1.215	0.110
Coarse Fragment	0.065	0.05	0.04	0.04	0.059	0.089	0.10	0.108	0.11	0.113	0.113	0.89	0.081

		1	3	3			2		2			6	
Soil Erosion	0.054	0.040	0.032	0.028	0.030	0.045	0.068	0.081	0.089	0.094	0.097	0.658	0.060
Slope	0.047	0.034	0.026	0.021	0.020	0.022	0.034	0.054	0.067	0.075	0.081	0.480	0.044
Soil Permeability	0.041	0.029	0.021	0.017	0.015	0.015	0.017	0.027	0.045	0.056	0.065	0.347	0.032
Soil Depth	0.041	0.025	0.018	0.014	0.012	0.011	0.011	0.013	0.022	0.038	0.048	0.254	0.023
Soil Texture	0.036	0.025	0.016	0.012	0.010	0.009	0.009	0.009	0.011	0.019	0.032	0.188	0.017
Soil Drainage	0.036	0.022	0.016	0.011	0.008	0.007	0.007	0.007	0.007	0.006	0.016	0.145	0.013
Principal Eigenvalues, 12.181 , Consistency Ratio (CR) = 0.056													

5. Result & Discussions

Slope, coarse fragment and organic carbon (Fig 5.7, 5.5 & 5.3) of the study area higher in the northern, north-eastern and north-western part contrary all these parameters are having lower value in the rest of the parts of the study area except organic carbon. The above mentioned parameters are having inversely proportional relationship with LCC. Notably soil depth (Fig 5.9) is higher in the Kumargram, Alipurduar- II and south-eastern part of Falakata and Alipurduar- I block. Soil depth is proportionally related with LCC. Regarding the soil texture (fig 5.10) northern, southern, south-western and eastern part of Kalchini, southern and south- western part of Alipurduar-II and Northern part of Alipurduar-I has fine loamy soil whereas rest of the part of the study area is covered with coarse loamy soil. In case of soil drainage andsoil permeability (Fig) they varies very slightly among the study area almost all the blocks covered by same class. Soil drainage (Fig 5.11) classes are poorly drained, imperfectly drainedand moderately well drained. The permeability classes are medium permeable and rapid permeable. In case of Cation Exchange Capacity (Fig) it’s higher in eastern and north-eastern part of Madarihat and Falakata whereas north-western and nort-eastern part of Kalchini and Alipurduar-I rest of the area having the intermediate value in terms of Cation Exchange Capacity (Fig 5.2). Base saturation (Fig 5.2) is higher in Alipurduar-II and Kumargram and thevalue of Base saturation is decreasing as its going to other areas. In case of Flooding (Fig) Alipurduar-I, Alipurduar-II, Kumargram and southern part of Madarihat are very susceptible to flood as these area having proximity to river whereas northern part of Kalchini, Madarihat and Kumargram blocks are less susceptible to flood. Flooding conditions (Fig 5.4) are not suitable for doing any activity on land thus it has proportionally inverse relation to LCC.

Base Saturation (BS)

Base saturation, expressed as a percentage (Fig 5.1), represents the ratio of exchangeable cations within the soil compared to its cation exchange capacity (CEC) (Hailegnaw, 2019). This factor is pivotal in soil fertility and influences a range of soil characteristics, consequentlyimpacting land suitability for various purposes (Juhos, 2019). Soils with highest percentage ofbase saturation have higher pH, therefore they are more buffered against acid cations from planet roots and soil process (Ulrich, 1986).

Cation Exchange Capacity (CEC)

The Cation Exchange Capacity (CEC) (Fig 5.2) has a direct impact on soil fertility, the availability of nutrients, pH regulation, soil structure, and the overall suitability of the land (Mulugeta, 2019). It is crucial to comprehend and regulate CEC levels for sustainable land management and planning practices (Groot, R. (1997).The soil with higher CEC has ability tohold more cation like Ca, mg, N, k however soils with low CEC are deficient in nutrients (Raman & Sathiyanarayanan,2009). It varies 0-

40 Cmol/kg in the study area.

Organic Carbon (OC)

Organic carbon (Fig 5.3) is the elements which determines soils quality and fertility of soil (Bationo, 2007). It improves physical, chemical and biological properties of soils. Alsoimproves soil structure, water holding capacity and nutrient capacity (Usharani, 2019). The soils having higher amount of cultivation having higher choice of crops for cultivation. It variesfrom 0-36 % in study area

Flood

Floods pose significant challenges to land capability, leading to soil erosion, sediment build up, water saturation, pollution, infrastructure and vegetation loss (Sharma & Malaviya, 2021).Implementing robust flood management approaches like strategic land-use planning, floodplain zoning, and erosion prevention measures is crucial for alleviating these consequences and preserving land functionality in flood-prone regions (Der Sarkissian, 2022).It develops waterlog conditions in any area which is not at all suitable for cultivation. Riverineareas are very porn to flooding which is normal (Fig 5.4) in the study area.

Coarse fragment

The presence of coarse fragments (Fig 5.5) in soil can negatively affect agricultural land capability in multiple ways, such as reducing water infiltration, altering soil structure, hinderingroot penetration, influencing soil temperature, promoting erosion, and complicating machinery operations (Ippolito, 2021). Implementing management techniques like soil amendment, contour farming, and terracing can alleviate these challenges and enhance the productivity of soils containing coarse fragments for agricultural purposes (Sarvade, 2019) . The soils includesrock fragments > 2mm. Coarse fragment has inversely proportional relation to cultivation. Higher amounts coarse fragments soils found to be difficult for agriculture practices. Coarse fragments varies from 0-25%.

Soil Erosion:

Soil erosion presents substantial risks to land capability, resulting in the loss of valuable topsoil, decreased water infiltration, reduced soil productivity, compromised soil structure, degraded water quality and enduring land degradation (Lal, 2015). It is imperative to implement erosion control strategies such as conservation tillage, maintaining vegetative cover, constructing terraces, and adopting contour farming practices (Telles, 2022). These measures are vital for safeguarding soil resources and ensuring the sustainable utilization of land (Andriyanto, 2015).RUSLE model have been used for the soil erosion Map using the formula (Fig 5.6)

A=RKLSCP (Parsa, 2003)

A=Annual Soil loss

R= Rainfall runoff erosivityK= Soil erodibility factor L= Slope length factor

S= Slope steepness factor

C= Cover Management factor

Sloppy land are more prone to erosion which is not suitable for cultivation. Mostly Low and Moderate erosional classes are found in the study area.

Slope

Slope plays a crucial role in determining the capability of land in multiple aspects, encompassing water drainage, soil erosion, accessibility, land stability, ecological function, and land use planning (Muchová, 2016). It is essential to comprehend and effectively manageslope characteristics for the sustainable management and development of land. The nearly levelsoils are generally deep, fertile and easily workable (Asmamaw & Mohammed 2019). These soils have no limitations. However sloppy lands have major limitations, restricts their uses forcultivation of crops. Sloppy lands effects the suitability of crops and nearly level soils have choice of crop cultivation. Slope (Fig 5.7) of the study area varies 0-70%.

Soil Permeability

Soil permeability (Fig 5.8) plays a crucial role in determining the agricultural potential of land (Seyedmohammadi et al, 2019). By effectively managing soil permeability through appropriate irrigation, drainage and soil management practices, farmers can improve water efficiency, enhance nutrient availability, and optimize crop production on their land (Hillel, 2011). Soil drainage sandy soils are more permeable than clay soils. The area having coarse texture havingRapid Permeability and fine texture having moderate permeability

Soil Depth

The depth of soil is pivotal in defining the suitability of land for agriculture and other purposes (Mulugeta, 2010). Having a clear understanding of soil profile depth is essential for making well-informed decisions concerning land management, crop choices and sustainable land use planning (Lobry de Bruyn, 2017). The deep soil can provide more water and shallow soils limitroot penetration. Deep soils can be managed and cropped without difficulty. Depth of the soil in the study area varies from 80 cm to 153 cm (Fig 5.9).

Soil Texture

Soil texture is essential in determining the appropriateness of land for agriculture and other uses (Bandyopadhyay, 2009). By understanding the characteristics of different soil textures andapplying appropriate management techniques, landowners can improve land utilization and productivity while reducing environmental impacts (Dale, 2000). The coarsed textured soils are not good for cultivation as these max organic carbon, plant nutrients and decrease water holding capacity. Coarse loamy and Fine loamy soils are found in the study area (Fig 5.11).

Soil Drainage

The texture of soil also influences its drainage properties. Coarse-textured soils facilitate rapidwater drainage, which is advantageous for preventing waterlogging (Kaur, 2000). Conversely,fine-textured soils exhibit slower drainage rates, potentially resulting in waterlogging and root asphyxiation in poorly drained regions (MacEwan, 1998). Clay soils with poor drainage are less capable than fertile loamy soils. It may determine which type of plants grow best in an area. Poorly Drained, Imperfectly drained and moderately well drained classes are found due to soil textural classes (Fig 5.11).

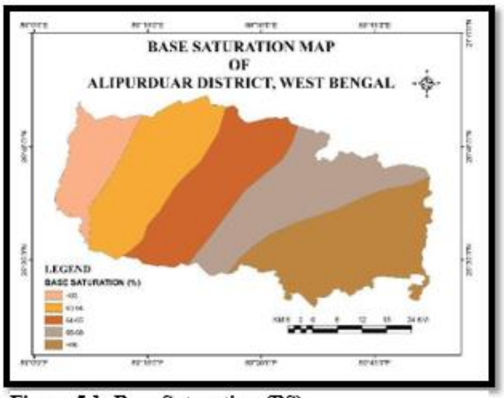

Figure 5.1: Base Saturation (BS)

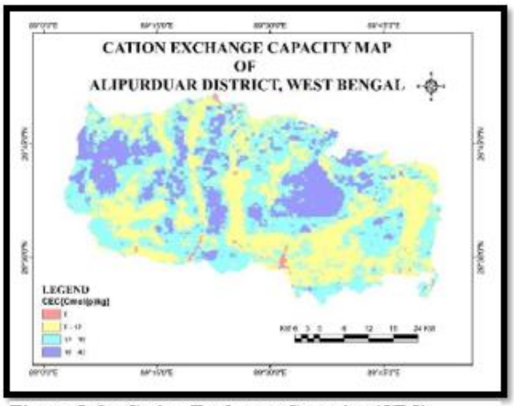

Figure 5. 2 : Cation Exchange Capacity (CEC)

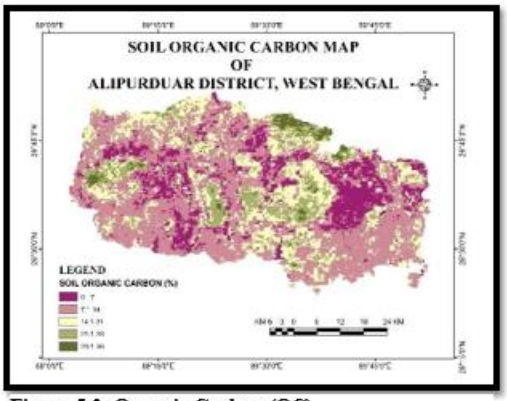

Figure 5.3: Organic Carbon (OC)

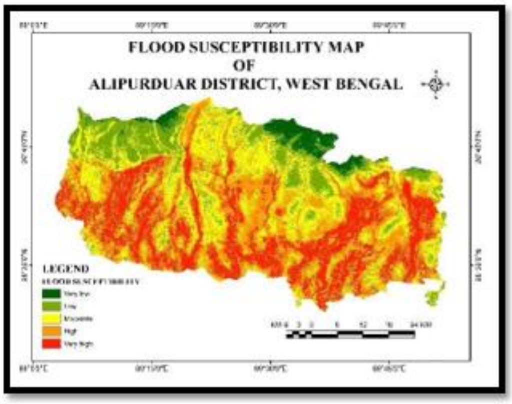

Figure 5.4: Flood

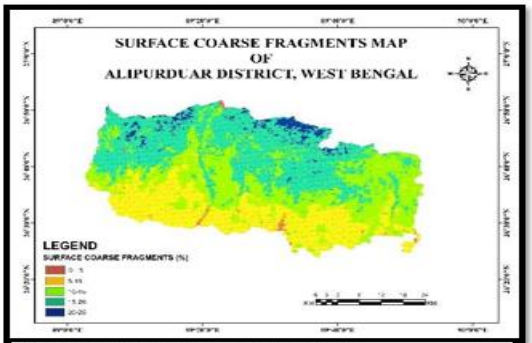

Figure 5. 5 : Surface Coarse fragments

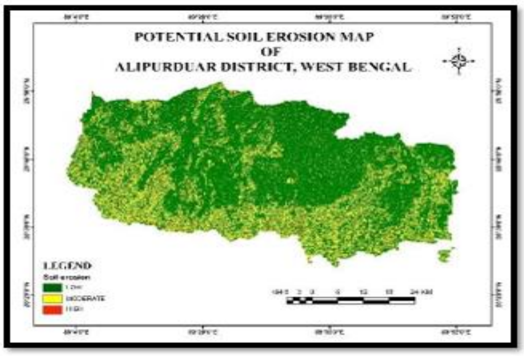

Figure 5.6 : Soil Erosion

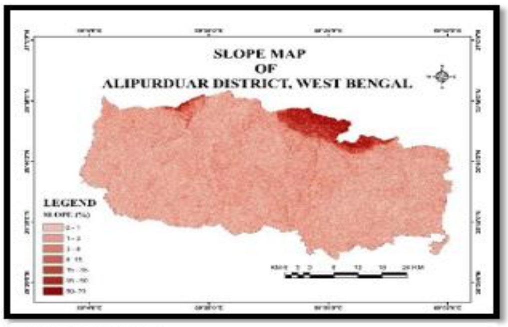

Figure 5.7: Slope

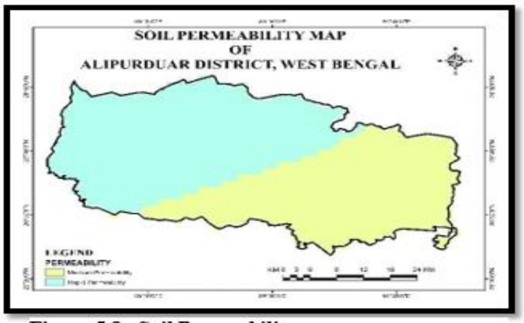

Figure 5.8 : Soil Permeability

Figure 5.11: Soil Drainage

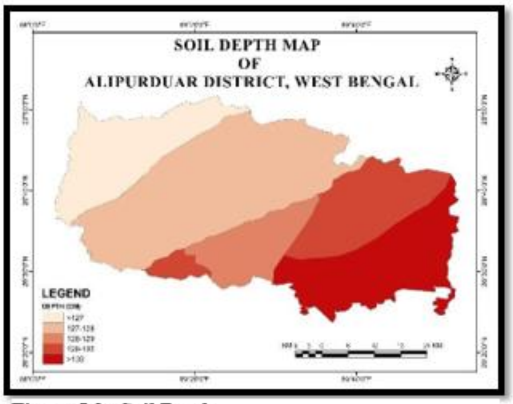

Figure 5.9 : Soil Depth

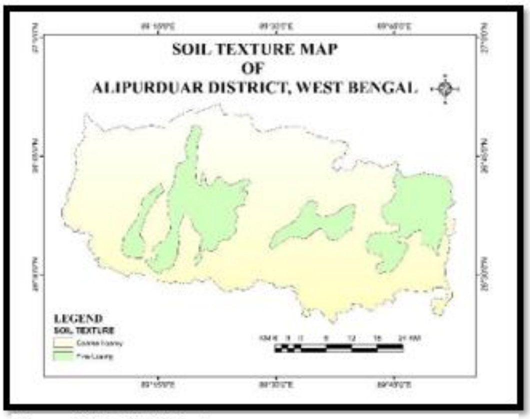

Figure 5.10 : Soil Texture

6. Land Capability Classification

The Alipurduar district displays considerable diversity in its Land Capability Classification (LCC). Within its total land area, 598 km^2 (21%) and 800 km^2 (29%) are categorized as ClassII (Moderately Good Cultivable Land) and Class III (Fairly Good Cultivable Land) respectively. These regions offer favourable conditions for agricultural activities, presenting farmers with various opportunities for crop cultivation. In contrast, 1002 km^2 (36%) and 388 km^2 (14%) are designated as Class IV (Well Suited For Grazing) and Class V (Fairly Well Suited For Grazing & Forestry) respectively (Fig 6.1) indicating lesser suitability for agricultural practices. This diverse distribution underscores the necessity for strategic planningand resource allocation to optimize agricultural development. Total 200 ground truth points (Fig 1.2) have been taken for the validation. The result derived from the receiver operating characteristic area under the curve (ROC-AUC) analysis in this study yielded an AUC value of 87.1%, represented as 0.871 shown in (Fig. 6.2). Furthermore, the asymptotic significance value for the model was recorded as 0.00, with a standard error of 0.052. The ROC-AUC analysis demonstrates a statistically significant alignment between the identified capabilityzones and the observed ground truth, indicating a strong predictive performance of the model

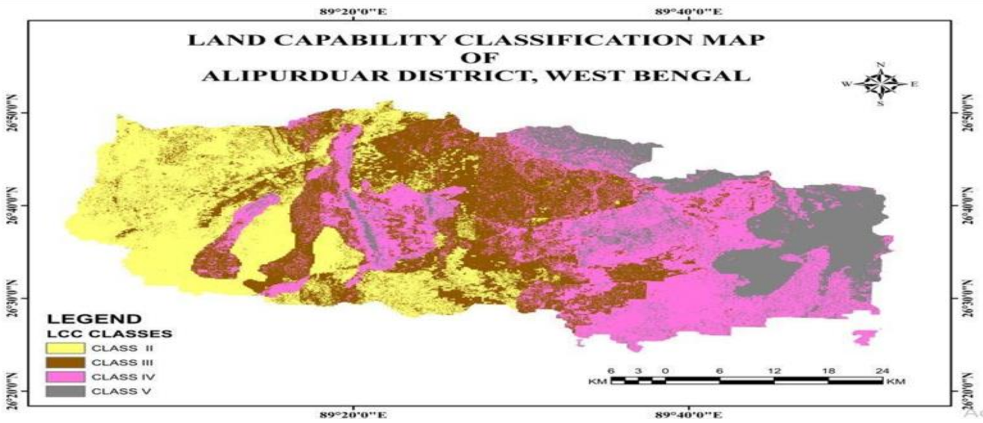

Figure 6.1: Land Capability Map

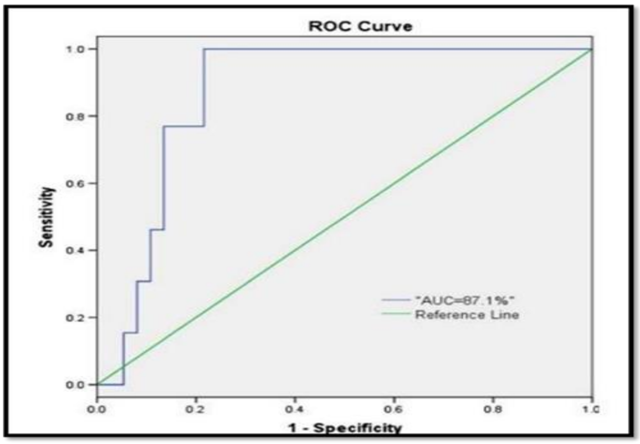

Figure 6.2 Receiver operating characteristic Curve

7. Conclusion

This study demonstrates the importance of remotely sensed data, GIS and multi criteria evaluation method integration to provide spatial information of capability of the land. Land capability is a very important piece of information for management and future planning. In thiscase LCC ranges from II to V. Class II is Moderately Good Cultivable Land and III is Fairly Good Cultivable Land. By adopting management practices like soil and water conservation class II can be converted into Class I and Class III into II.

On the other hand Class IV & Class V is suitable for Well Suited for Grazing and Fairly Wellsuited For Grazing &Forestry respectively. The issue of land degradation found in the class IVand V. Forestry may be recommended in these two classes. The created LCC map be used forbetter utilization of soil resources in Alipurduar district

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