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An Assessment on Land Suitability for Rice Cultivation Using Analytical Hierarchy Process in the Sivasagar District of Assam, India

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Abstract

The appropriateness of agricultural land necessitates regular accurate assessment and evaluation of fertility. Land Suitability Analysis (LSA) is one of the accurate evaluations to maintain & monitoring quality of the agricultural land. It is a necessary procedure to investigate the site suitability for any agricultural purpose. This study evaluates the land quality and rice production capacity in the Sivasagar District of Assam, India. This study used a multi-criteria Analytical Hierarchy Process (AHP) in remote sensing & Geographic Information System (GIS) software ArcGIS to evaluate the major factors influencing rice cultivation, including soil type, water availability, and meteorological parameters. This study classifies the suitability classes into four categories as per the procedure set by the Food and Agricultural Organization (FAO); highly suitable, moderately suitable, marginally suitable, and not suitable. Due to the differences among the rice crop conditioning agro-ecological parameters, only 13 km^2 of lands accounting 0.81% of total lands are highly suitable for the cultivation of rice, which is primarily determined by water availability considerations, land use and land cover (LULC), and the Normalized Difference Vegetation Index (NDVI). With 21.66 km^2 of available waterbodies, good groundwater prospects, an annual average precipitation of 185 cm to 214 cm, and a land surface temperature of 27.32°C to 32.63°C, projected production and suitability are declining due to inefficient management practices. Farmers in the study area must use more advanced strategies to gain greater accessibility to water resources, particularly those agricultural lands that are classified as moderately or marginally suitable.

Keywords: Analytical Hierarchy Process, Land Suitability Assessment, Land Surface Temperature, Land-Use and Land-Cover, Normalized Difference Vegetation Index.

Introduction

The world's agricultural lands are under tremendous strain to feed the growing population and maintain food security (1, 2). The usage of available natural resources is the most important question in today's era when we call the time for sustainable development. Approximately 42% of the world's population is actively engaged in agriculture, with a major loss of agricultural lands (3). Approximately 2.4 billion people live in poverty due to a lack of sufficient nutrition, and another 900 million are in danger due to increasing changes in natural phenomena and catastrophes. The world expects that more food grains will be produced using existing land resources without causing degradation (4). The most efficient use of existing natural resources is critical to attaining sustainable agriculture. Land degradation affects natural resources and is caused by inadequate land use and management. Site selection is an important aspect of sustainable land utilization management methods (3). Land degradation requires the implementation of sustainable agriculture approaches. One of the most effective approaches for preventing soil degradation is to evaluate the land's suitability. Agriculture's functions include producing food and fiber, regulating climate, water, and soil, improving water and air quality, improving nutrient recycling for soil fertility, and protecting essential species for ecological function (5). Remote sensing and GIS are the most commonly utilized tools for modeling and analyzing multiple aspects of the earth's surface. The multi-criteria decision-making approach offers a broad range of applications in land suitability evaluation due to the use of GIS (6). Land Suitability Analysis is an essential technique for managing agricultural land-use plans effectively and achieving the best appropriate use

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of available agricultural lands (1, 7, 8). LSA is a multi-criterion based interdisciplinary assessment including the participation of different departments including lithology, meteorology, social science, economics, etc. (1, 9). This assessment helps to optimize land-use by identifying how to utilize available resources based on their estimated potential and LSA are conducted to determine the best land-use type based on property and user demands (2). With a variety of environmental and agroecological components influencing land viability, a land suitability assessment using AHP allows for appropriate crop management and land utilization decisions, which could lead to a conflict for long-term agricultural sustainability (10). AHP induced MCDM techniques are capable of problem analysis, alternative solution generation, and alternative evaluation. These techniques are primarily intended to help decision-makers select the best application among the available options (11). An analysis of the relative relevance of various criteria can be done through the use of the Analytic Hierarchy Process (AHP), which has been used in land suitability assessment studies. Thus, combining AHP, and GIS approaches could be a powerful way to improve the accuracy of determining whether a particular area of land is suitable for a specific crop (12). According to this method, the AHP scale is supposed to determine the criterion's relative importance. The decision-maker uses this scale to guide them in creating the Pairwise Comparison. This indicates if each element is stronger than the others precisely, very strongly, slightly stronger, pretty strongly, or equally strong (13).

Sivasagar is a district in Assam, India, where more than half of the population is directly engaged in agriculture. With a recent negative deviation in the agricultural occupational structure, farmers may be facing agro-ecological and agro-economic challenges. Farmers sometimes fail to properly utilize resources owing to a lack of knowledge, technology, and information.

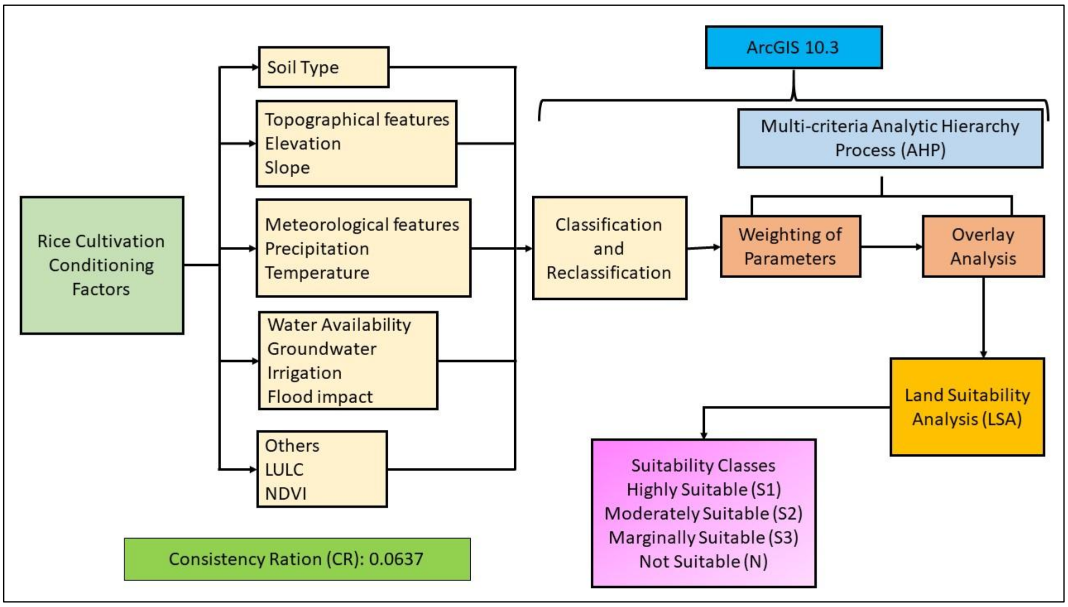

Figure 1: Overlay of the Study

Methodology

Study Area

Sivasagar is an agricultural district in which the majority of people are directly or indirectly involved in agricultural activities. It is located in the in the north-eastern part of the Indian state of Assam shown in Figure 2 (A and B), with the latitudes ranging from 26.45°N to 27.15°N and longitudes ranging from 94.25°E to 95.45°E, covering a total area of 1599 square kilometers shows in Figure 2 (C). The tropical climate provides the region with seasonal monsoonal rainfall during the summer. The district is bordered on the south-east by Nagaland and on the north-west by the Brahmaputra River.

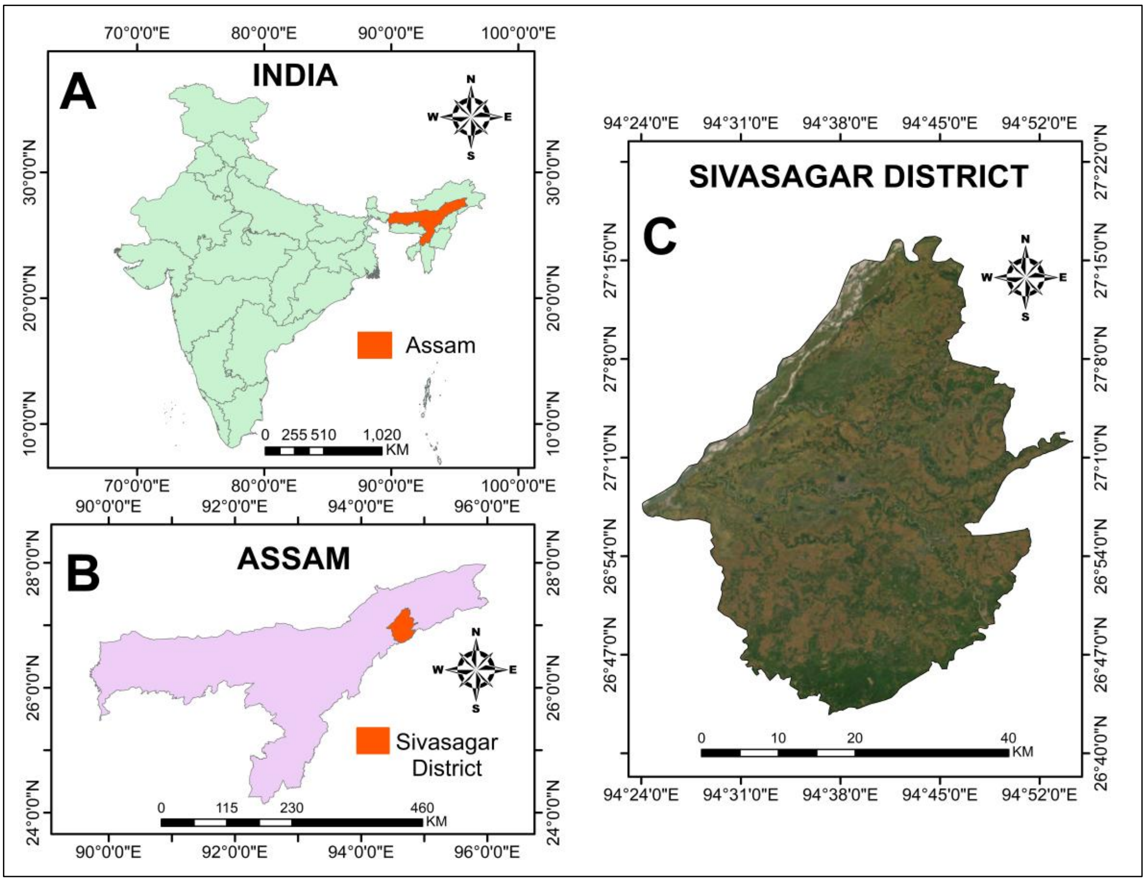

Figure 2: Study Area (A) India, (B) Assam, (C) Sivasagar District

Data Source

This study focuses on determining the suitability of land for rice growing in Assam's Sivasagar District area. The parameters for rice cultivation have been identified, and the factors have been ranked based on their suitability and importance for rice growing. The process comprises data input, decision-maker preferences, and information transformation using specified methods. The spatial multi-criteria Analytical Hierarchy Process (AHP) decision-making approach uses geographical data as input. Topography, soil features, climate, accessibility to water, and all other factors that influence the suitability of land for rice production (14, 15). The Analytical Hierarchy Procedure (AHP) depicts the effect of numerous criteria on a particular event (16). For this study, the data for various criteria obtained from various sources for the year 2023 are provided in Table 1. Land features, meteorological aspects, water availability, and land-use and land-cover (LULC) have been chosen as key parameters for rice cultivation (17). The parameters' sub-classes are graded independently based on their importance for rice cultivation. The Figure 1 and 3 shows the whole processes which have been used throughout the study. AHP demonstrates the interrelationships between various factors that contribute to a specific phenomenon. In the research area, the effects of all selected elements may have a different degree of impact on rice cultivation than in other rice farming locations. The study area is surveyed broadly, agricultural areas are observed, and farmers are interviewed in order to choose the factors. The weighting of parameters is also an important part of the AHP approach, and it is done based on the relationship between each parameter. The weight percentage is critical in the creation of the final land suitability map using overlay analysis. All of the maps in the spatial raster dataset had to be entered into the GIS program with their weighted percentage of influence on rice cultivation. The final land suitability map will be constructed using the overlay analysis method and sorted into various suitability classes and the classes of appropriateness will be classified using the land suitability technique (7).

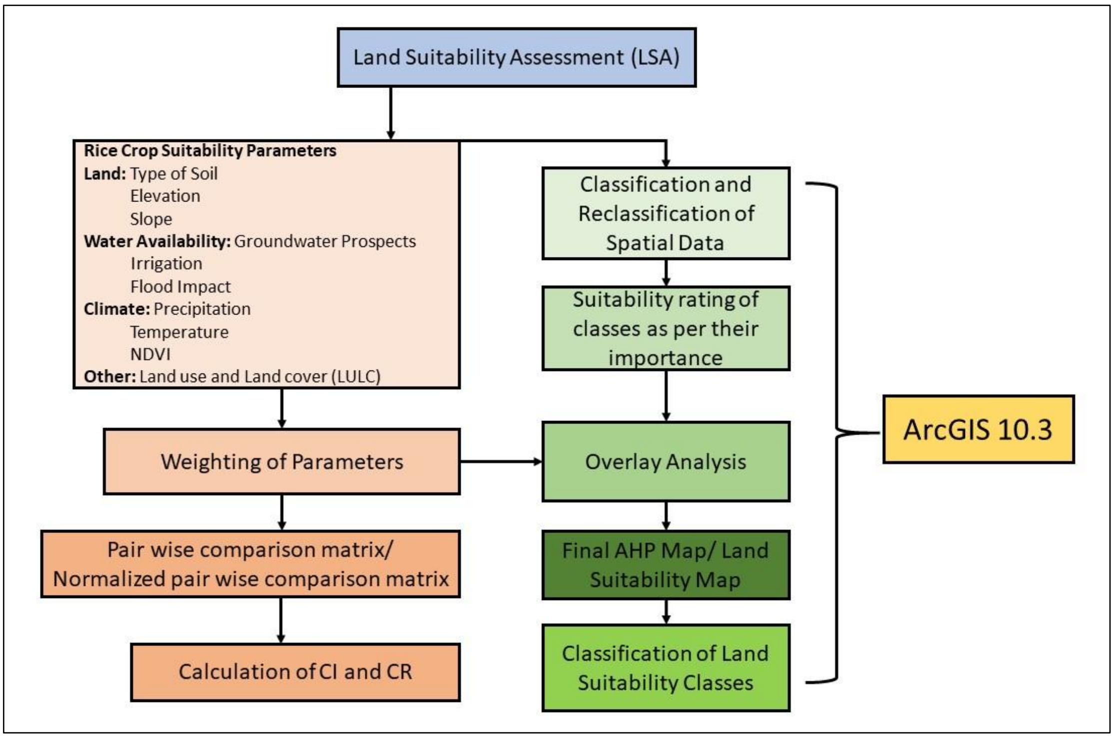

Figure 3: Methodology Flowchart of the Study

Table 1: Data Collection Sources and Details

Sl No.	Factors of LSA	Source/ Details	Year	Data type/ Resolution
1	Type of Soil	North Eastern District Resources Plan (NEDRP), NESAC (https://nedrp.gov.in/)	2023	Raster, 30m
2	Elevation	SRTM, USGS Earth Explorer (https://earthexplorer.usgs.gov/)	2023	Raster, 30m
3	Slope	SRTM, USGS Earth Explorer (https://earthexplorer.usgs.gov/)	2023	Raster, 30m
4	Precipitation	NASA POWER 10 m gridded precipitation data (https://power.larc.nasa.gov/), CRU Dataset on annual rainfall (https://crudata.uea.ac.uk/cru/data/hrg/)	2023	Raster, 10m
5	Groundwater	North Eastern District Resources Plan (NEDRP), NESAC (https://nedrp.gov.in/)	2023	Raster, 43.5m
6	Temperature	Landsat 8 OLI, May 2023 (https://earthexplorer.usgs.gov/)	July 2023	Raster, 30m
7	Irrigation	North Eastern District Resources Plan (NEDRP), NESAC (https://nedrp.gov.in/)	2023	Raster, 43.5m
8	LULC	Landsat 8 OLI, May 2023 (https://earthexplorer.usgs.gov/)	2023	Raster, 30m
9	NDVI	Landsat 8 OLI, May 2023 (https://earthexplorer.usgs.gov/)	2023	Raster, 30m
10	Flood Impact	Landsat 8 OLI, July 2023 (https://earthexplorer.usgs.gov/)	2023	Raster, 30m

Factors Affecting Rice Cultivation

Type of Soil

The soil is essential for productivity and production in all agricultural endeavors. Rice is one of the important crops whose success entirely depends on the kind of soil that is present in the cultivation area. Preserving soil fertility is crucial to maintaining the capacity and quality of the soil (18). The key components of a good agriculturally acceptable soil are its relationship to water, the mineralization of nutrients, and its composition of organic matter.

Elevation

Not all crops grow well in every climate and topography because elevation affects the soil's nutrient quality, slope, and rainfall (19). Although humans have made some accommodations in nature, they still face difficulties when it comes to farming in extremely mountainous terrain (20). The cultivated crop needs root systems that are appropriate to support the topography, which presents a number of issues such as the type of soil, availability of water resources, crop variety selection, etc.

Slope

Slope steepness affects rainfall-induced water flow and results in the topsoil layer being lost. The area's steepness of slope has a direct effect on the erosivity of rainfall (21). The complicated phenomenon of soil degradation during rainfall is caused by the impact of rainfall and surface flow, which separate the soil, as well as the movement of particles caused by splashing rain and surface flow (22).

Precipitation

Climate change, including rising temperatures and unpredictable precipitation, is projected to negatively impact agricultural production. Precipitation is a direct factor in paddy cultivation, and the correlation showed that rice production is strongly correlated with climatic variability as the crop is rainfed (23). It was discovered that the predicted precipitation throughout the rice-growing season exceeded the 1000–1100 mm of water needed for rice in the years with greater yields. In any case, they might be the reasons for the increases in rice output when taken together. Large seasonal variations in precipitation, along with comfortable temperatures and high humidity, are indicators of the climate (24).

Groundwater

India's achievement of food grain self-sufficiency can be attributed to groundwater; nonetheless, groundwater has been overused in several regions of the nation, with uncertain consequences for crop productivity (25). Lower groundwater levels lead to decreased yield, cultivated area, and overall output in wheat, rice, and maize during the winter season. Winter crop mean yields decreased by 1% to 3% for every meter that preseason groundwater depth decreased (5, 25).

Temperature

Extreme temperatures in the spring and summer can have a detrimental effect on crop growth and yields (26). Agricultural droughts cause decreased crop productivity due to unpredictable rainfall and soil moisture, affecting the national economy. India's agriculture heavily relies on the Monsoon, therefore even little changes can significantly impact productivity and crop yield (27, 28).

Firstly, TOA Radiance

$L\lambda = M_L * QCAL + AL$ [1]

Where, $L\lambda$= TOA Spectral Radiance

M_L= Radiance Multiband (X)

AL= Radiance Add band

Proportion of Vegetation (Pv)

$$Pv = \left\{\frac{(NDVI - NDVI\ min)}{(NDVI\ max - NDVI\ min)}\right\}^2 \quad [2]$$

Surface Emissivity (e)

$$e = 0.004*Pv + 0.986 \quad [3]$$

Finally, $T = \frac{K2}{\ln(\frac{K1}{LT}+1)}$ [4]

Where, T= Temperature

K1 = Constant Band

K2 = Constant band

Temperature = (DN*0.02)−273.15°C [5]

Irrigation

Irrigation access and availability are important considerations in all types of agricultural activities. To feed the world's growing population, farmers must use artificial irrigation systems to sustain agriculture in rain-deficit or rain-shadow locations (29). The presence of dams, canals, lakes, ponds, and reservoirs can help to support agriculture in drought-prone regions (30).

Land-use/ Land-cover (LULC)

LULC changes are transforming the world in unforeseen ways, influencing environmental systems on different scales. Environmental degradation is the outcome of unsustainable land management methods combined with the growing demand for land resources such as fuel, fresh water, food, and so on. One question that comes up is whether this is for urbanization or agriculture (31). In exchange for higher agricultural outputs, the conversion of these areas into agricultural land has a negative effect on a number of ecosystem services (32). Because of its negative impact on agricultural practices, soil fertility, ecosystems, water flow patterns, and humanity overall, LULC change remains an important topic of discussion around the globe (33).

Normalized Difference Vegetation Index (NDVI)

NDVI is a prominent remote sensing and GIS technique used for crop monitoring and management and it also allows to predict crop output and yield (26). This tool evaluates the amount of greenery of an area on a scale of -1 to +1, indicating major changes to appropriate land use (34-36).

$$NDVI = \frac{(NIR-R)}{(NIR+R)} \quad [6]$$

$$NDVI = \frac{(NIR-VIS)}{(NIR+VIS)} \quad [7]$$

For Landsat 8 OLI,

$$NDVI = \frac{(Band\ 5-Band\ 4)}{(Band\ 5+Band\ 4)} \quad [8]$$

Flood Impacts

Floods do severe harm to people, animals, and property, but they can also improve soil fertility by bringing in necessary nutrients and sediments brought by the floodwaters (37). Since rice is a primary rainfed crop, a modest flood right before crop season has a favorable rather than a negative effect on crop production (38, 39). It is evident that rice farming is more advantageous during floods than during periods of drought (40). Normalized Difference Water Index (NDWI) is a major index to calculate flood impacts in any region, and it is calculated by using the below formula.

$$NDWI = \frac{Green-NIR}{Green+NIR} \quad [9]$$

Multi-Criteria Analytical Hierarchy Process (AHP)

Thomas L. Saaty developed the core multi-criterion theory of decision making and demonstrated how to calculate the weights for an assortment of activities based on their importance (41-43). AHP is a tool that allows you to study a certain event or result by analyzing all of the components that are directly or indirectly involved (44). AHP approaches are significant induction through RS, and GIS software is a significant advancement to the subject that is improving present studies (45). AHP includes a well-defined set of phases, including parameter weighting based on their importance for particular events, as shown in Table 2. AHP is the most suitable and adaptable application for obtaining precise results. The factors are organized in a hierarchical order (35).

Table 2: Suitability Ratings According to the Importance (39).

Intensity of Importance	Meaning
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, 8	Intermediate Values

The relative weight of all the factors is generated through pair-wise comparison (16, 41-43), and this can be helpful in obtaining the quantitative value for the percentage of impact caused by each particular factor. The pair-wise comparison of parameters needs to be recalculated to the normalized value (16, 35, 41-43), and finally, the Consistency Index and Consistency Ratio need to be calculated to examine whether the weighting of all parameters is consistent or not.

$$CI = \frac{\lambda\ max-n}{n-1} \quad [10]$$

$$CR = \frac{CI}{RI} \quad [11]$$

Where, n = total number of items

λ max = Largest Eigen Value

RI = Random Consistency Index

RI = 1.49 for this study as per the scale given in the Table 3.

Table 3: Random Consistency Index According to the Matrix Value (43).

Matrix Value (n)	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The Table 3 shows the matrix values of random consistency index were given by Thomas L. Saaty in the 1980s, where constant index values are very essential to calculate the consistency ratio of a multi-criteria process. The index values can be used as per the selected or adopted number of total parameters.

Results and Discussion

The agricultural land suitability factors include soil type, elevation, slope, precipitation, temperature, groundwater, irrigation, NDVI, LULC, and flood impacts. These are directly responsible for the cultivation of rice in the region and influence production and productivity. Land adaptability varies each year due to changes in the frequency of dynamic parameters, and factors such as soil type, groundwater, and irrigation can be overused and have a detrimental influence. To produce positive outcomes, these parameters must be positively correlated. Soil is the most significant consideration in agricultural activities. Agricultural productivity is limited by soil nutrient content, stoniness, inadequate water holding capacity, and drainage (2). The composition of silt, clay, chemical contents are also responsible (6). The Figure 4 shows the availability of Aeric Fluvaquents in 767.79 Km^2, Aquic Udifluvents in 78.61 km^2, Typic Dystrochrepts in 334.19 km^2, Aeric Haplaquents in 71.39 km^2, and Typic Paleudalf in 348.28 km^2. The suitability of the sub-classes of loamy soil have been clearly mentioned in Table 4 as per soil quality for rice cultivation.

Slope and elevation have an impact on land suitability due to water flow and stability. The highlands are unsuitable for agriculture because they lack soil nutrient capacity, which is lost owing to surface runoff. Because of active erosional activities, soil quality declines as the elevation slope increases. More than 70% of the study area's lands have a slope of less than 15%, making them ideal for rice farming. The elevation and slope of the study region clearly shown in Figure 5 and 6 respectively. For rice to thrive, soil is a crucial component. Because soil texture changes the amount of water available to plants, it has an impact on their growth and ability to absorb nutrients (46). The finer particles found in soil allow it to retain more water and nutrients, which is beneficial for rice plants that require a lot of moisture. Sands, on the other hand, let more water pass through their aggregate and store less water and nutrients. As a result, they might not be able to meet the needs of the plants when they are in the developing stage (47). One of the most significant geographical natural variables, terrain affects rice development indirectly by redistributing region water, temperature, and nutrients spatially. It also determines the spatial layout of cropland (48). In a region of interest, the nature of precipitation and yields of rice determine whether the effect of rainfall factors on rice output is positive or negative. While the duration of dry spells had an important adverse association with rice production, the yearly rainfall quantity and number of rainy days had a high significant positive correlation (49). Precipitation is important for climate change because it affects the ecosystem and society reactions (24). This study depicts the fluctuation of rainfall on a 10-meter grid. The Figure 7 shows that, the rainfall averages range from 185 cm to 214 cm, which is ideal condition for growth of rice crop; however, rainfall during rainy seasons surpasses 300 cm, which aids in the recharge of groundwater levels. Figure 8 depicts the level of groundwater suitable for rice cultivation. The groundwater level in Sivasagar district is 2 meters below ground level. Agricultural crops, particularly rice crops, have better access to water through their roots and so have higher crop performance potential.

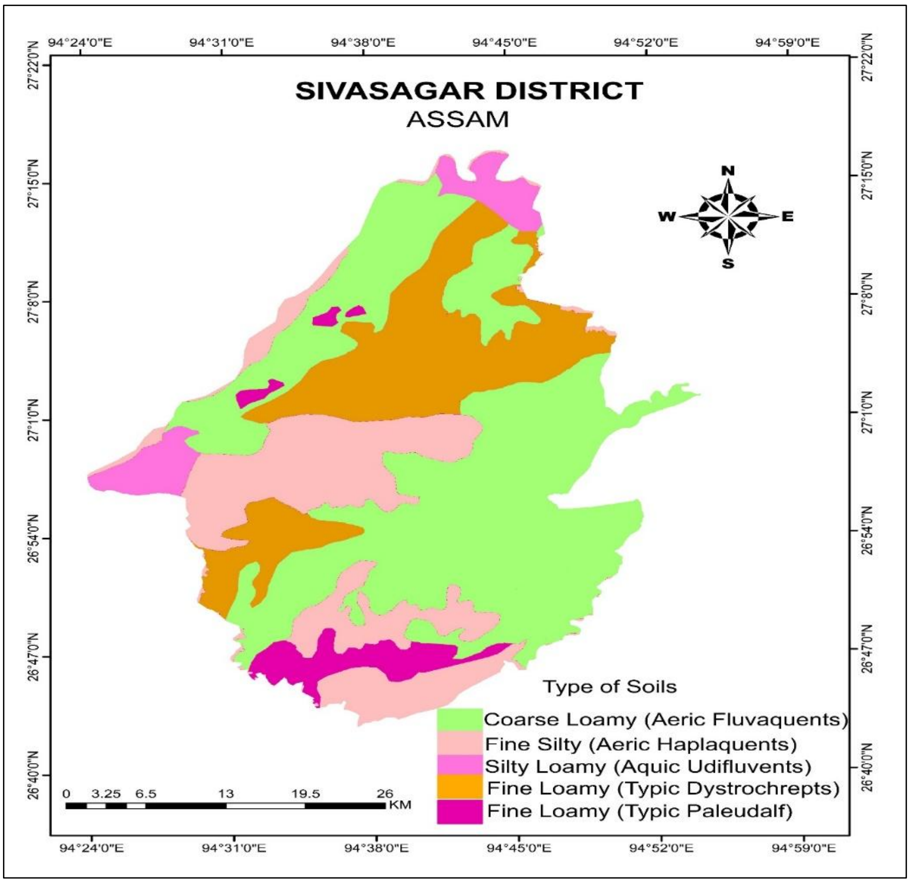

Figure 4: Type of Soils

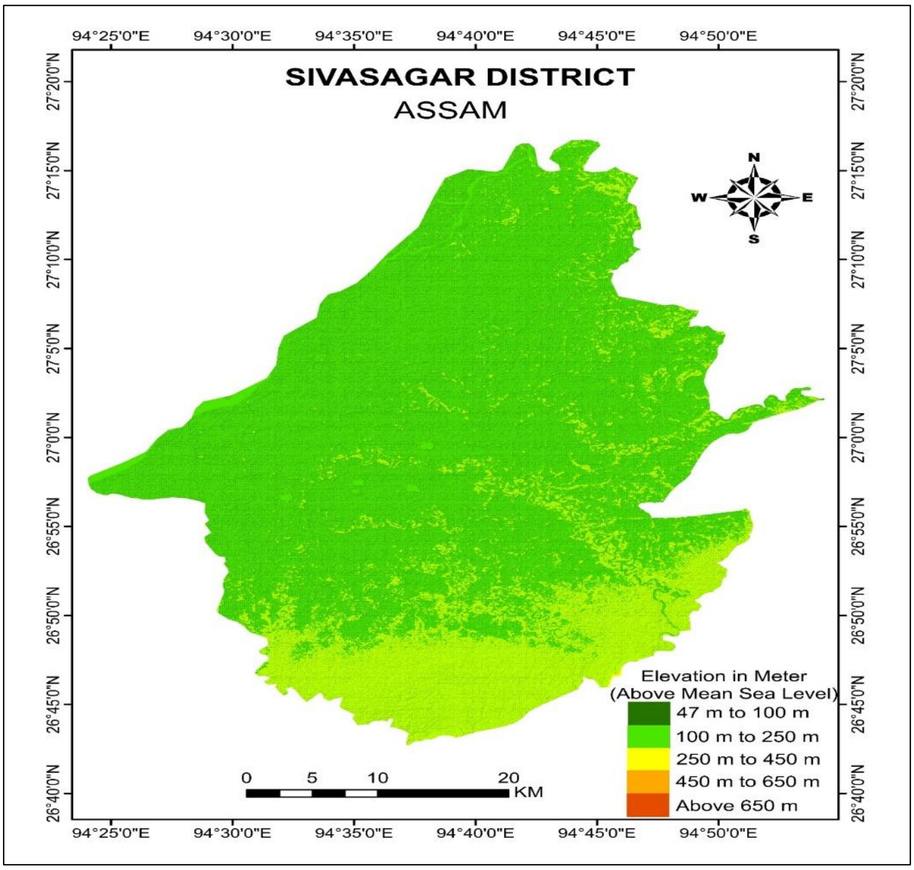

Figure 5: Elevation Map

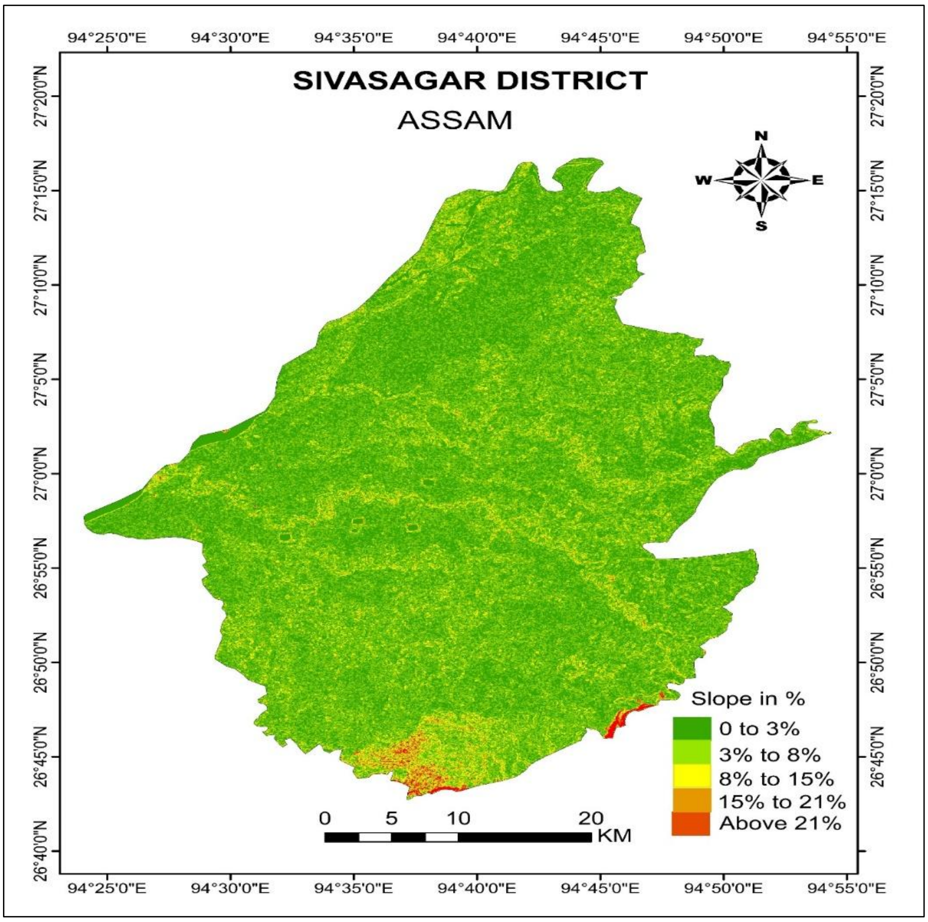

Figure 6: Slope Map

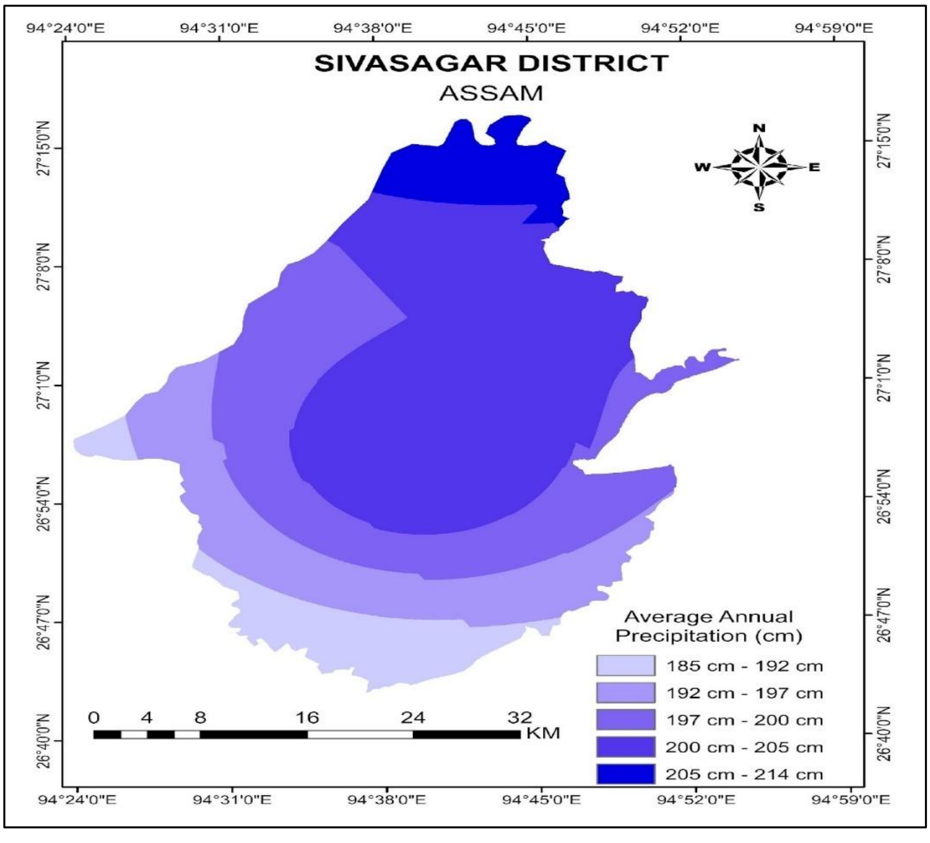

Figure 7: Average Annual Precipitation

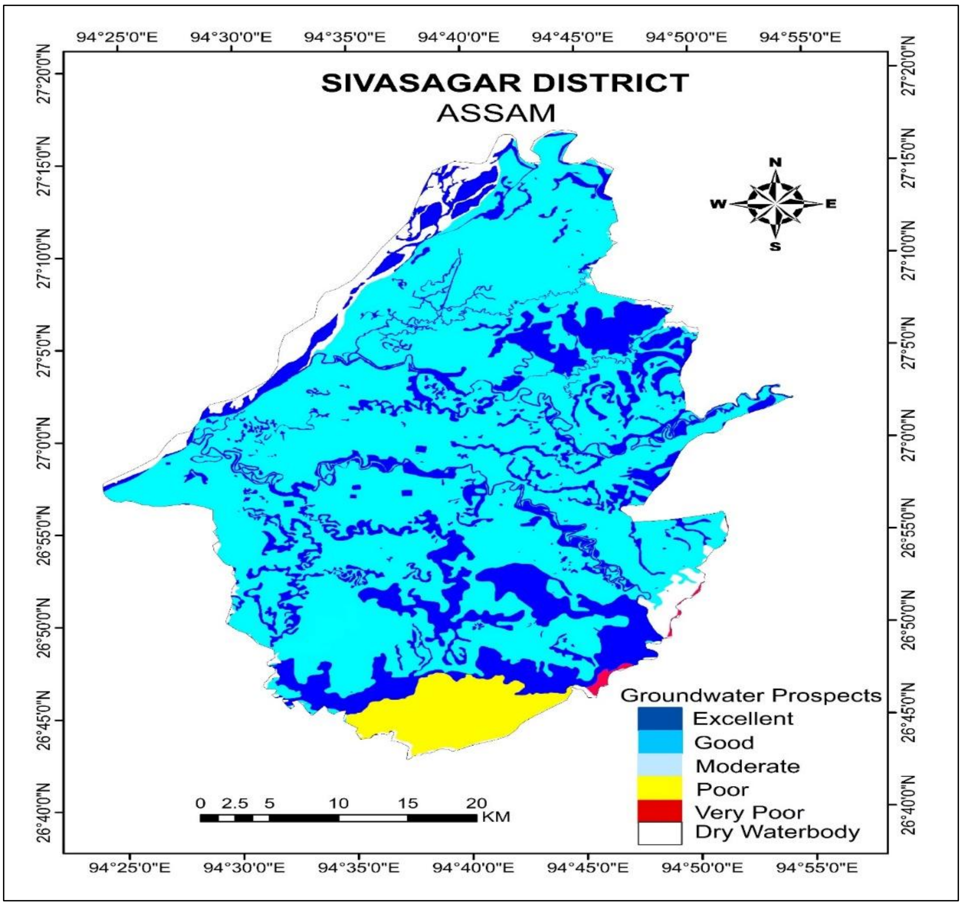

Figure 8: Groundwater Prospects

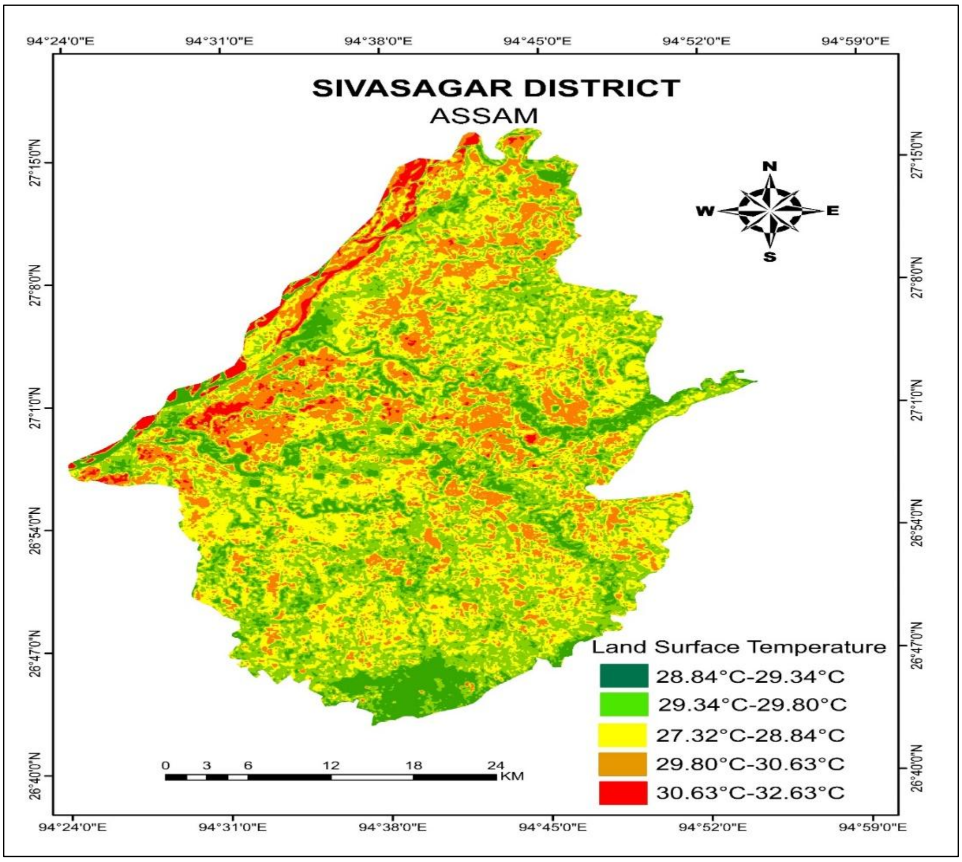

Figure 9: Land Surface Temperature

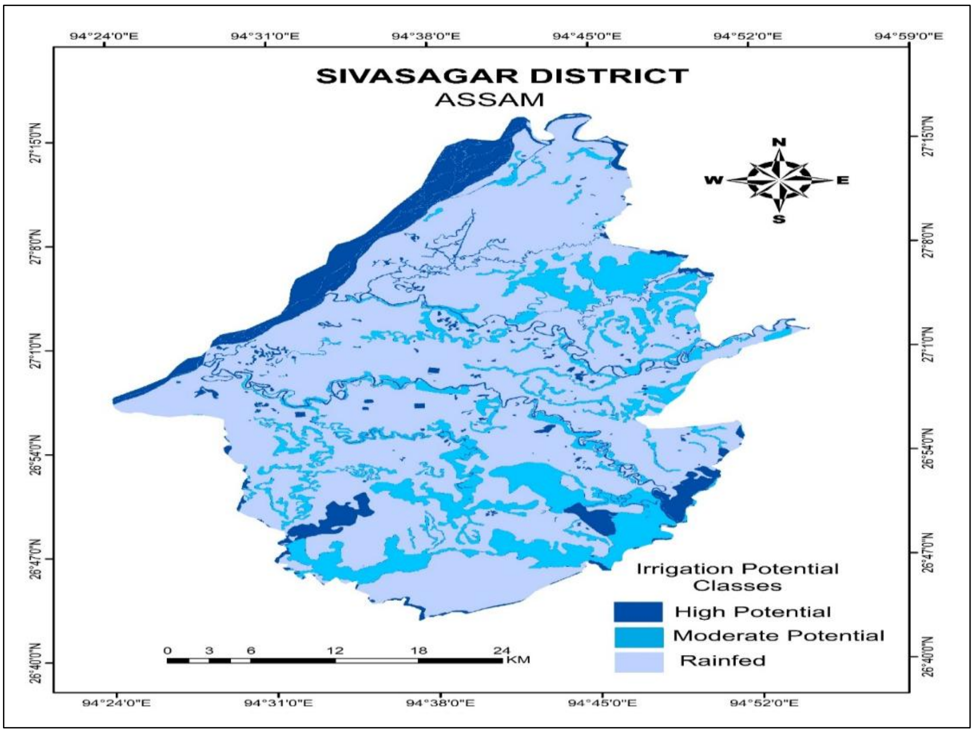

Figure 10: Irrigation Potentials

Precipitation plays a key role in decreasing drought stress and promoting plant growth. However, unpredictable or excessive rainfall can limit agricultural productivity as well. Figure 13 depicts the flood effect map, with 35% of the total lands impacted by the pre-rice season flood, which appears to be beneficial to farmers in terms of getting water resources at no cost. Rice is a key tropical and subtropical food crop that grows best in temperatures ranging from 20°C to 35°C (65°F to 95°F) (23). The Figure 9 shows the variation of temperature and stated that Sivasagar district's typical temperature ranges from 27°C to 34°C, which is ideal for rice crop growth.

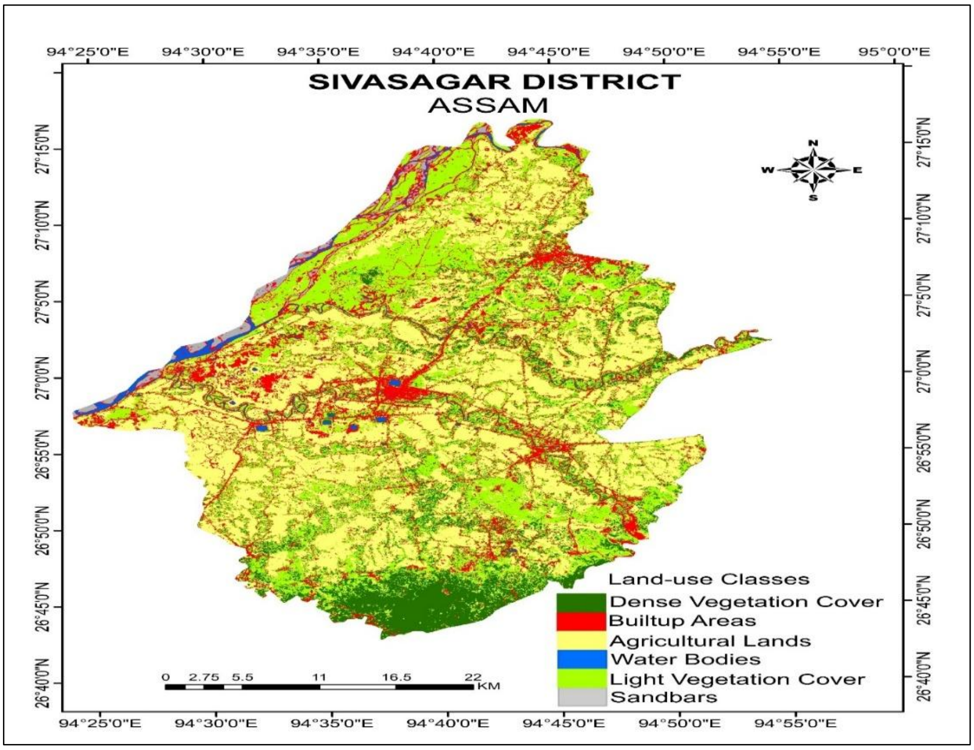

Figure 11: Land-use and Land-cover

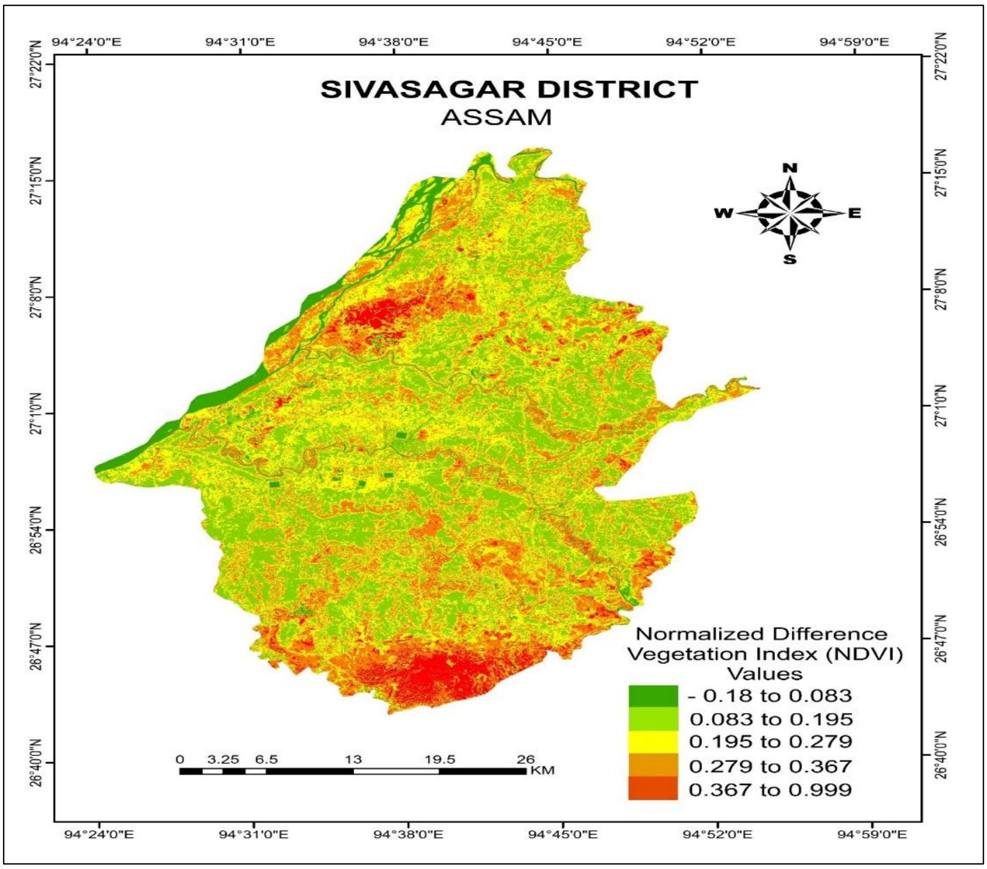

Figure 12: Normalized Difference Vegetation Index (NDVI)

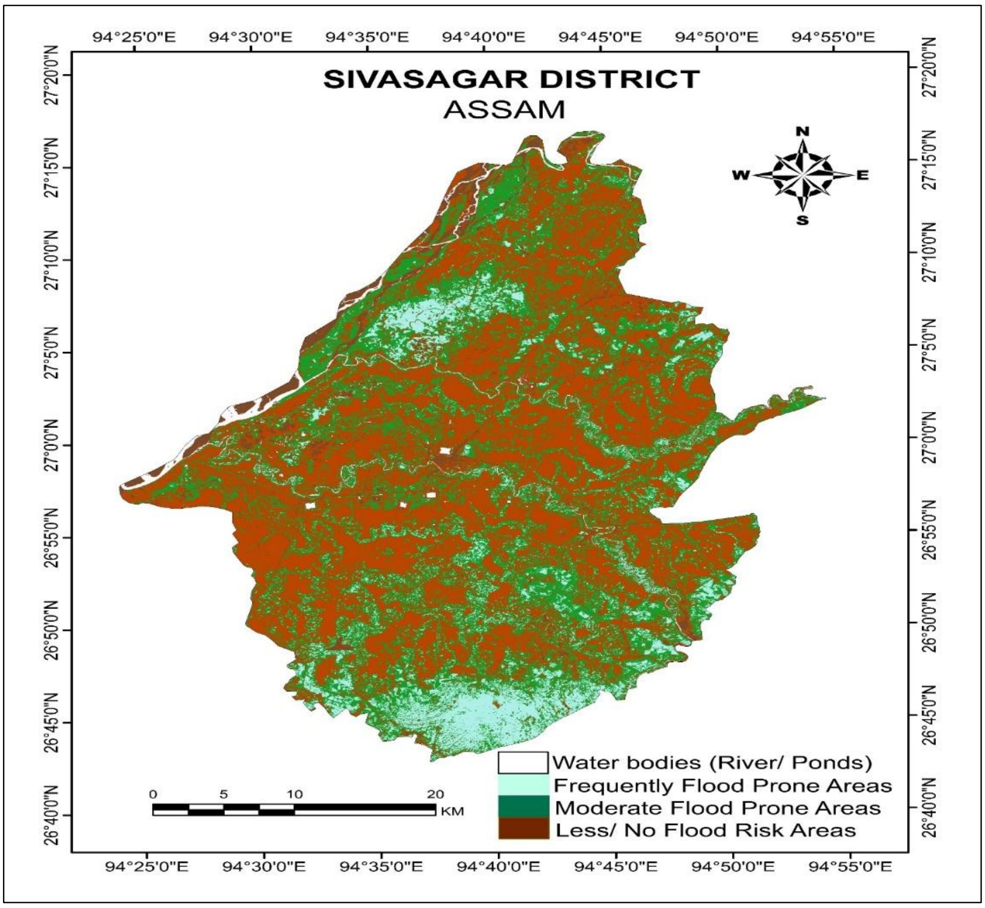

Figure 13: Flood Impact Map

The amount of irrigated water required to maintain an equilibrium between precipitation and evapotranspiration, which affects soil moisture levels. In the study, Figure 10 shows the total area of 300.64 km^2 have great potential for irrigation, 71.24 km^2 have poor potential, and the remaining 1228.39 km^2 have no irrigation arrangements since they are completely dependent on seasonal rainfall and surrounding small reservoirs. Figure 11 shows the LULC of Sivasagar district, where 632.79 km^2 of land area are used for agricultural purposes and an additional 489.56 km^2 have good potential for agriculture. The available waterbodies of 21.66 km^2 maintain the supply of water to the neighboring cultivated areas. Built-up areas cover 252.83 km^2 of total area, including major urban areas. This LULC reflects the NDVI of the Sivasagar district as the depletion and disintegration of natural vegetation have been selected as major indicators for its critical role in ecosystem functioning (31). 63.48 km^2 in the range of -0.18 to 0.083, 507.10 km^2 in 0.083 to 0.193, 573.21 km^2 in 0.193 to 0.273, 382.42 km^2 in 0.279 to 0.367, and 69.65 km^2 in 0.357 to 0.999 at the NDVI shown in Figure 12. Table 4 showing the weightage of parameters and suitability classes, has been classified with their respective percentages. Which are determined as per their impact on the overall impact of rice cultivation in the study area. The Table 5 shows, the interelationship between all the factors with a particular factor of rice cultivation. The Table 6 shows, the values are normalized for effective evaluation of the factors. The AHP technique relies heavily on the calculation of CI and CR to ensure research consistency. Table 7 reveals that the calculated CI and CR are 0.0949 and 0.0637, respectively, and according to Saaty, 1990, a CR value ranging from 0 to 0.1 is deemed consistent, and the weightage marking is accurate (41-43).

Table 4: Weighting of Parameters

Sl. No	Factors	Unit	Class	Suitability Class Rating	Weight (%)
1	Type of Soil	Type	Aeric Fluvaquents	5	13.8
			Typic Dystrochrepts	4	
			Aquic Udifluvents	3	
			Aeric Haplaquents	2	
			Typic Paleudalfs	1	
2	Elevation	Meter	56-96	5	9.7
			96-136	4	
			136-175	3	
			175-215	2	
			215-255	1	
3	Slope	Percentage	<1% to 3%	5	8.7
			3% to 8%	4	
			8% to 15%	3	
			15% to 21%	2	
			Above 21%	1	
4	Precipitation	cm/year	185-192	5	12.6
			192-197	4	
			197-200	3	
			200-205	2	
			205-214	1	
5	Groundwater	Meter below ground level	Below 0.86 m	5	5.3
			0.86-1.28 m	4	
			1.28-1.70 m	3	
			1.70-2.13 m	2	
			Above 2.13 m	1	
6	Temperature	Degree Kelvin	28.84°C-29.34°C	5	11
			29.34°C-29.80°C	4	
			27.32°C-28.84°C	3	
			29.80°C-30.63°C	2	
			30.63°C-32.63°C	1	
7	Irrigation	Level	High potential	5	9.7
			less potential	3	

			No irrigation	1	
8	LULC	Level	Agricultural lands	5	8.6
			Light vegetation covers	4	
			Dense vegetation covers	3	
			Waterbodies	2	
			Sandbars	1	12.2
9	NDVI	Level	0.193-0.273	5	
			0.083-0.193	4	
			0.279-0.367	3	
			-0.18-0.083	2	
			0.367-0.999	1	
10	Flood Impact	Level	Very high impact	5	8.4
			High impact	4	
			Moderate impact	3	
			Less impact	2	
			No impact	1	

Table 5: Pair-Wise Comparison Matrix

Matrix	Type of Soil	Elevation	Slope	Precipitation	Groundwater	Temperature	Irrigation	LULC	NDVI	Flood Impact
Type of Soil	1	1	1	1	3	3	1	3	1	1
Elevation	1	1	1	1	2	1	1	1	1	1
Slope	1	1	1	1	1	1	0.5	1	1	1
Precipitation	1	1	1	1	3	1	2	1	1	3
Groundwater	0.33	0.5	1	0.33	1	1	0.33	0.33	0.33	1
Temperature	0.33	1	1	1	1	1	3	3	0.33	1
Irrigation	1	1	2	0.5	3	0.33	1	1	1	1
LULC	0.33	1	1	1	3	0.33	1	1	1	1
NDVI	1	1	1	1	3	3	1	1	1	1
Flood Impact	1	1	1	0.33	1	1	1	1	1	1
Sum	8	9.5	11	8.17	21	12.67	11.83	13.33	8.67	12

Table 6: Normalized Pair-Wise Comparison Matrix

Matrix	Type of Soil	Elevation	Slope	Precipitation	Ground water	Temperature	Irrigation	LULC	NDVI	Flood Impact
Type of Soil	0.125	0.105	0.091	0.122	0.143	0.237	0.085	0.225	0.115	0.083
Elevation	0.125	0.105	0.091	0.122	0.095	0.079	0.085	0.075	0.115	0.083
Slope	0.125	0.105	0.091	0.122	0.048	0.079	0.042	0.075	0.115	0.083
Precipitation	0.125	0.105	0.091	0.122	0.143	0.079	0.169	0.075	0.115	0.250
Groundwater	0.042	0.053	0.091	0.041	0.048	0.079	0.028	0.025	0.038	0.083
Temperature	0.042	0.105	0.091	0.122	0.048	0.079	0.254	0.225	0.038	0.083
Irrigation	0.125	0.105	0.182	0.061	0.143	0.026	0.085	0.075	0.115	0.083
LULC	0.042	0.105	0.091	0.122	0.143	0.026	0.085	0.075	0.115	0.083
NDVI	0.125	0.105	0.091	0.122	0.143	0.237	0.085	0.075	0.115	0.083
Flood Impact	0.125	0.105	0.091	0.041	0.048	0.079	0.085	0.075	0.115	0.083

Table 7: Calculation of CR

Factors	Vp	Cp	D	E
Type of Soil	1.39	0.135	1.472	10.915
Elevation	1.07	0.104	1.052	10.119
Slope	0.933	0.091	0.951	10.511
Precipitation	1.34	0.130	1.375	10.618

Groundwater	0.539	0.052	0.568	10.877
Temperature	1	0.097	1.197	12.341
Irrigation	1	0.097	1.066	10.983
LULC	0.896	0.087	0.950	10.927
NDVI	1.25	0.121	1.299	10.744
Flood Impact	0.896	0.087	0.914	10.510
Sum	10.31			108.544
λ max= 108.544/10=10.85		CI= 0.0949	CR= CI/RI = 0.0637	

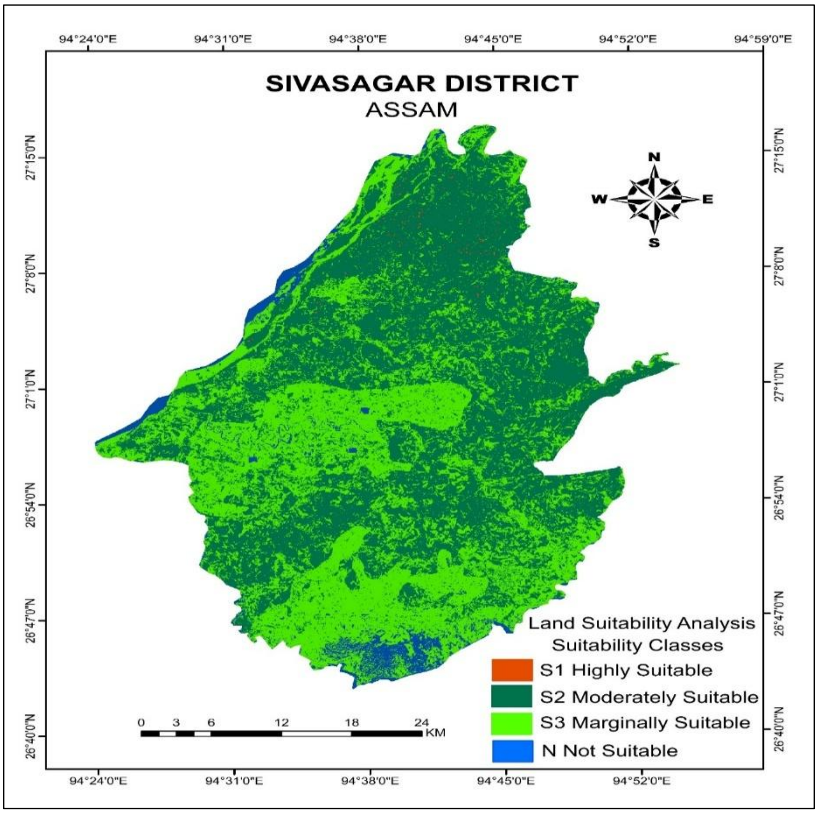

Figure 14: Land Suitability Analysis Map

Table 8: Land Suitability Assessment Classes

Sl. No.	Suitability Classes of LSA	Area (Km²)	Area (%)
1	S1- Highly Suitable	13	0.81
2	S2 -Moderately Suitable	1008	63.03
3	S3 -Marginally Suitable	516	32.27
4	N -Not Suitable	62	3.87
	Total Area	1599	100

The LSA multi-criterion decision-making process takes into account both biophysical and sociocultural aspects (50). The overlay analysis of ten parameters showing the final AHP generated agricultural suitability map has been classified into four different classes as per the Food and Agricultural Organization (51). The suitability classes (S) are subdivided into three classes, including highly suitable (S1), moderately suitable (S2), and marginally suitable (S3). In the study region, the areas with very less suitability have been classified as Not Suitable (N) (7). According to research done by Sathiyamurthi S. *et al.*, the Krishnagiri district in Tamil Nadu, India, has a 21.4% highly suitable class (S1), a large portion of 43.3% are moderately suitable (S2), 17.2% are marginally suitable (S3), and 18.1% are not suitable for agricultural purposes (10).

In the Sivasagar district, the suitability classes have been divided into four categories as per the above Figure 14 and Table 8, highly suitable (S1) with an area of only 13 km², moderately suitable (S2) with a large portion of the area having 1008 km^2, marginally suitable (S3) with 516 km^2, and 62 km^2 of total areas are not suitable for cultivation or agricultural activities. Sandbars, built-up areas, and water bodies are classified as not suitable and marginally suitable. As a result, there is a strong chance for highly productive rice farming because all the necessary factors have a positive correlation. It undoubtably depends on the farmer's decision to cultivate rice, and it also has the potential to be upgraded to the highly suitable class (S1) through the use of sustainable and ecologically appropriate inputs and an efficient irrigation system.

Application of the Study

Farmers having the necessary knowledge about their agricultural fields will be able to achieve higher results and productivity. So, agricultural land suitability studies are an essential tool for this, and the latest digital technologies encourage us to do so. Farmers have greater options by managing these agricultural conditioning elements more efficiently, and they will pursue land suitability management tactics such as obtaining irrigation facilities, rainwater gathering technologies, applying soil quality-enhancing fertilizers and manures, and so on. This study will raise farmers' understanding of the importance of maintaining an equilibrium between agricultural conditioning factors and resource management. Farmers may be able to implement technology to combat climate change by adopting climate-smart agricultural technologies, which also aid in the selection of climate-resilient crop varieties. This will encourage long-term improvement in agricultural methods, thereby improving food security. The concerned agricultural state authorities will be aware of the many sorts of soil suitability classes and will be able to improve farmers' conditions by giving financial and technological help. This will aid in the implementation of updated and mechanized agricultural instruments, as well as improving the investment decisions of both public authorities and farmers.

Limitation of the Study

Expert judgement in AHP is expressed using numerical values. In many real implementations, confusion may result from the impossibility of making such exact comparisons of decisions (12). Nevertheless, the employment of AHP or fuzzy set approaches alone in this research produced particularly inadequate outcomes when it came to managing the weights of land attributes and determining the land suitability score (13). Certain current ecological statuses of agricultural areas, such as pH, organic carbon, and other chemical qualities, are missing from this GIS-based AHP study. Also, certain errors may arise in GIS-based AHP analysis as a result of misclassified pixels, the presence of cloud covers, incorrect sample selection made by the user, etc. Some of the qualitative criteria might not be used because there is insufficient information on certain features, like behavioral and psychological aspects.

Conclusion

The agricultural land suitability evaluation in Sivasagar, Assam shows that just 0.81% of the total area is classified as highly suitable, with moderately suitable classes accounting for 63.03% of the land area and marginally suitable classes accounting for 32.27%. Hilly land and waterbodies make up the least suitable class, accounting for 3.87% of total land area. The many features are in favor of excellent agricultural practices, as all ten of the selected factors contribute equally to the agricultural process. The analysis shows that water availability and weather conditions dominate rice cultivation since rice is the most water-intensive crop. The moderately and marginally appropriate classes have the potential to be upgraded to high suitable classes through the use of modernized technology and tools, particularly the irrigation system. Farmers must be technologically advanced in order to produce the desired results. Aside from soil biological characteristics and other ecological aspects, a farmer's socioeconomic situation influences the affordability and accessibility of resources and technologies. This could also be a source of incompatibility between crop requirements and available agricultural land. The state authorities must focus on providing the necessary support framework to farmers in order to achieve sustainable agriculture.

Abbreviations

AHP: Analytic Hierarchy Process, FAO: Food and Agricultural Organization, GIS: Geographic Information System, LSA: Land Suitability Analysis, LST: Land Surface Temperature, LULC: Land-use and Land-cover, NDVI: Normalized Difference Vegetation Index, NDWI: Normalized Difference Water Index.

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Author Contributions

Sole author contribution.

Conflict of Interest

Author declares there is no conflict of interest

Ethics Approval

This study does not require any ethics approval.

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