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Soil- site suitability assessment of Bumnoi-mornoi watershed of Kokrajhar district using RS and GIS techniques

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Abstract
In the present study, twenty two surface samples from two physiographic units viz., Alluvial plain and Flood Plain of Bumnoi-mornoi watershed in Kokrajhar district of Assam were evaluated for their soil site suitability for growing crops like *Ahu* rice, *Sali* rice, Potato, Maize, Banana and Pineapple under rainfed condition. Physiographic units were delineated in the study area using toposheets (1:50,000) and FCC (1:25000 scale) of IRS-P6 L-3. Soil-site suitability evaluation for crops forms an essential part of land use planning programme. Several soil and site characteristics are used as parameters for assessing the suitability of land for crops. Suitability of the soils for these crops was determined by comparing different land qualities and climatic parameters with crop requirement. Based on soil moisture content, drainage, effective soil depth, texture, base saturation, soluble salt content, organic matter and CEC productivity potential were evaluated for each physiographic unit which varies from average to good in both alluvial plain and flood plain. The coefficient of improvement (CI) values indicated that with proper management practices, the productivity of alluvial plain and flood plain soils could be increased to maximum extent of 2.22 to 1.88, respectively. Soils were found to be moderately suitable (S2) to permanently unsuitable (N2) for *Sali* rice, *Ahu* rice, Potato, Maize and very suitable (S1) to permanently unsuitable (N2) for Banana. For Pineapple, the soils were found to be very suitable (S1) to moderately suitable (S3). Soil site suitability maps along with potential productivity maps of the study area were prepared using GIS techniques.

Keywords: Bumnoi-mornoi watershed, productivity potential, soil site suitability, GIS

Introduction
Food security, environment protection and prosperity of the people depend greatly on sustainable management of soil resource (Kumar *et al*., 2018) [18]. Land evaluation is the ranking of soil units on the basis of their capabilities to provide highest returns per unit area and conserving the natural resources for future use. The land suitability evaluation for field crops forms a prerequisite for land use planning (Sys *et al*., 1991). Performance of any crop is largely influenced by soil site parameters as condition by climate, topography and management level (Singh *et al*., 2017) [15]. Devi and Naidu (2016) conducted study on Land evaluation for alternate land use planning of Sugarcane growing soils of Chittoor District in Andhra Pradesh and found that Riquier's parametric approach was a good indicator for identification of production potential of these sugarcane growing soils. Meena *et al.* (2017) [10] also studied the soils of Aravali hills to assess land productivity index based on parametric approach and found that the productivity of hill and pediments soils was extremely poor for crop (1.57%), pasture (5.89%) and tree (0.12%) while the productivity of valley, pediments and plains (P3-29.43%, P4-31.07%, P5-27.62% and P6-31.07%) was average.
Remote Sensing (RS) data are used for estimating biophysical parameters and indices besides cropping systems analysis, and land-use and land-cover estimations during different seasons. However, RS data alone cannot suggest crop suitability for an area unless the data are integrated with the site-specific soil and climate data. RS data coupled with soil survey information can be integrated in the geographical information system (GIS) to assess crop suitability for various soil and biophysical conditions (Martin *et al.*, 2009) [9]
Watershed is a holistic approach for rainfed areas, which can lead to higher productivity and sustainability through conservation of soil and water resources (Patil *et al.*, 2016) [11]. Study of soils within a watershed has increasingly been attempted as it offers diverse soils to form due to the topographic variation present in a watershed (Prabhavati *et al.*, 2017) [12]. Remote sensing and geographic information system (GIS) is very useful tool for preparing a proper watershed development plan. It helps in creation of natural resource database in effective way, integration

of information with the ancillary data for generating action plan and watershed prioritization for soil conservation for the watershed (Sharada *et al.*, 2008) [14]; Kalgapurkar *et al.*, 2012) [6].

At present there is an extreme inadequacy of basic data or resources in the study area for preparation of scientifically sound watershed development plans. Keeping in view the importance of the study of suitability of soils the present investigation was undertaken in the Bumnoi-mornoi watershed of Kokrajhar district.

Materials and Methods

The study area Bumnoi-mornoi watershed is located in the western boundary of Kokrajhar district, on north western direction of the Kokrajhar town. It lies between 89° 50' E to 89°57' E longitudes and 26°25' N to 26° 31'N latitudes covering an area of 6275.35 ha. The climate of the study area is humid subtropical climate with an average rainfall of 3319 mm. The mean annual soil temperature is 26.56° C and the difference between mean summer soil temperature and mean winter soil temperature is more than 5 °C. Hence, the studied area qualifies for hyperthermic soil temperature regime. The relation among precipitation (P) and Potential Evapotranspiration (PET) are represented through the ombrothermic diagram given in Fig 1. Landforms of the study area were studied from Survey of India (SOI) Toposheet and FCC of IRS-P6 L-3. After traversing the area, based on the visual observations and variations in soil-site characteristics, twenty two surface samples upto a depth of 15cm were collected from two physiographic units *viz*., alluvial plain and flood plain for studying the soils of the watershed. Processed soil samples (<2 mm size) were analyzed for various physico-chemical properties following standard methods (Black 1965; Jackson 1973) [1, 6]. Productivity (P), Potentiality (P′) indices and Suitability of the soils were evaluated by using the formula Riquier *et al.*, 1970 [13] and Sys *et al.*, 1993 [17], respectively. The ratio of potential productivity and actual productivity determines the coefficient of improvement (CI). Soil site suitability maps along with potential productivity maps of the study area were prepared using GIS techniques.

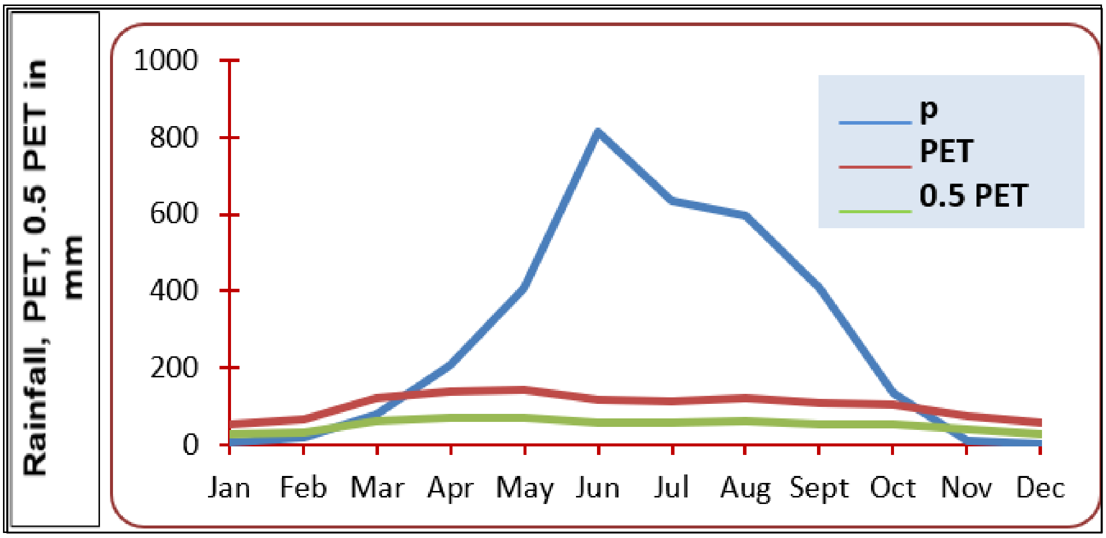

Fig 1: Monthly distribution of rainfall and potential evapotranspiration (PET) in the study area

Results and Discussions

Soil Properties

In the present study, the watershed is characterized by two physiographic units viz., alluvial plain and flood plain. Variations were observed in soil textural class ranging from sandy loam to clay loam. Sand, silt and clay contents in these soils varied from 23.3 to 56.7, 28.6 to 60.0, and 6.70to 28.1 per cent, respectively. Organic matter content in the soil varied from 3.1 to 26.5 g kg^{-1}, soil pH varied from 4.1 to 6.4. Among the exchangeable cations, Ca^{2+} was the dominant cation followed by Mg^{2+}, Na^{+} and K^{+} with few exceptions. CEC of the soils varied from 4.8 to 12.3cmol (p^{+}) kg^{-1}. Percent base saturation ranged from 23.49 to 67.43. Available N varied from 37.6 to 501.7kg ha^{-1}, available P_2O_5 varied from 23.1to 55.70 kg ha^{-1} and available K_2O varied from 110.4to 451.0 kg ha^{-1}.

Productivity and potentiality evaluation

The productivity index value presented in Table 2 and Fig. 2 showed that the alluvial soils having index values varying from 16.24 to 52.32 could be categorized under poor to good class for crop cultivation. Adopting probable improvement measures in texture and structure of root zone, base saturation, organic matter and nutrient status, the productivity of these soils could be improved to average to good class (Table 2, Fig. 3). The results were also in conformity with the findings Karmakar (1995) [7]. He also reported higher potentiality of young and less developed soils of lower Brahmaputra valley zone of Assam for crop production. Deka (1997) [1] reported that alluvial plain soils of lower Brahmaputra valley of Assam were having average rating class. The productivity index of flood plain soils ranged from 16.47 to 52.63 (Table 2) were rated as poor to average. Such soils could be improved by adopting probable measures in drainage, texture and structure of root zone, base saturation, organic matter and nutrient status. The coefficient of improvement values ranged from 1.18 to 2.22 in alluvial plain and 1.05 to 1.88 in flood plain. Gogoi *et al.* (2018) [4] found soil pH, drainage and nutrient as the major limiting factors for potential utilization of the land resources in Dorika watershed of Sivasagar District in Assam.

Soil-site suitability for major crops

Using limitation and parametric approaches, the land suitability for ahu rice, sali rice, maize, potato, pineapple, banana was evaluated. In limitation approach the suitability classes and subclasses were determined with regard to the number and intensity of limitations of soil and climatic parameters which vary from 0 (no limitation) to 4 (very severe limitation). In parametric method each soil and climatic parameter was rated on a scale ranging from 0-100 and the land index was calculated by multiplying these numerical rating values. These parameters include climate (c); topography or slope (t); wetness (w) like flooding (F) and drainage (D), soil physical characteristics (s) including texture (T) and soil depth (P); soil fertility characteristics (f) which include apparent CEC (A), base saturation (N), organic matter (O), pH (L) and NPK (M). The land index ratings along with the suitability classes and area for different crops are:

Ahu rice: The land index value and class of the studied soils varied from 12.6 to 72.88 (Table. 2 and Fig. 4) Based on parametric method, the soils of the studied area could be categorized as permanently unsuitable (N2) to moderately suitable (S2). Out of the total geographical area, 70.38 ha soils were moderately suitable (S2), 3635.83 ha area were found to be marginally suitable (S3), 1567.94 ha soil exhibited currently unsuitable (N1) and 1001.20 ha study area were permanently unsuitable (N2) for cultivation of *Ahu* rice. Soil pH, followed by organic matter was found to be most limiting factor in all the soils for growing *Ahu* rice. All the soils in the studied area were rated from currently unsuitable to moderately suitable expect the soil sample no. 20 of flood plain which was found to be permanently unsuitable (N2) for *Ahu* rice cultivation, due to limitations on drainage, pH and organic matter. The problem of low pH and drainage could be mitigated through liming and selection of flood resistant varieties.

Sali rice: The land index value and class of the studied soils varied from 23.47 to 65.21 (Table 2 and Fig. 5). The suitability assessment for *Sali* rice showed that the land index of alluvial soils and flood plain soils ranged from currently unsuitable (N1) to moderately suitable (S2) and permanently unsuitable (N2) to moderately unsuitable (S2) class, respectively. Out of the total geographical area, 76.42 ha soils were moderately suitable (S2) and 5,847.05 ha soils were marginally suitable (S3). On the other hand 346.29 ha soils were currently unsuitable (N1), while only 5.58 ha soils are permanently unsuitable (N2). The limiting factors of the studied soils were found to be soil pH, followed by organic matter for growing *Sali* rice. The soil of sample no. 20 in the flood plain exhibited permanently unsuitable (N2) for *Sali* rice cultivation due to the limitation in drainage, pH and organic matter. To manage low pH, low organic matter and drainage, addition of lime and organic manure along with selection of flood resistant varieties could be adopted.

Potato: The land index value and class of the studied soils varied from 18.41 to 69.23 (Table 2 and Fig. 6). The suitability assessment showed that the land index of alluvial soils and flood plain soils ranged from currently unsuitable (N1) to moderately suitable (S2) and permanently unsuitable (N2) to moderately suitable(S2). Out of the total geographical area, 2,266.20 ha soils were moderately suitable (S2) and 3,492.91 ha soils marginally suitable (S3) for cultivation of potato. In contrary, 500.43 ha were currently unsuitable (N1) and 15.80 ha soils were permanently unsuitable (N2) for cultivation of potato. The limitations of the studied area were low pH. Previous study (Vadivelu *et al.*, 2004) [18] also indicated that the alluvial plain soils of Northern Brahmaputra valley of Assam were marginally suitable (S3) to highly suitable (S1) for potato crop with major limitations of pH and fertility status. The reports were also in conformity with the findings by Dutta (2009) [3]. The soil of sample no 20 in flood plain were permanently unsuitable (N2) for potato cultivation due to the limitation in pH and organic matter. Management requirement to combat the problem of low pH and low organic matter include addition of lime, organic manure and proper fertilization.

Maize: The land index value and class of the studied soils varied from 22.65 to 76.71 (Table 2 and Fig. 7). Based on the parametric method the soils of the studied area could be categorized into permanently not suitable (N2) to moderately suitable (S2). The suitability assessment of maize for alluvial and flood plain soils fall under permanently unsuitable (N2) to moderately suitable (S2) and permanently unsuitable (N2) to marginally suitable (S3), respectively. It was found that, out of the total geographical area, 2,602.82 ha soils were currently unsuitable (N1) and 2,412.90 ha soils marginally suitable (S3). On the other hand 1,228.55 ha soils were moderately suitable (S2) and 31.07 ha soils were permanently unsuitable (N2) for cultivation of maize. Most of the soils in the flood plain were currently unsuitable (N1), due to limitations in low pH and base saturation. To combat low pH and base saturation liming and proper fertilization should be done in these soils.

Banana: The land index value and class of the studied soils varied from 16.56 to 85.73 (Table 2 and Fig. 8) for banana cultivation. Based on parametric method the studied soils could be categorized into permanently unsuitable (N2) to very suitable (S1). However, the alluvial plain and flood plain fall under currently unsuitable (N1) to very suitable (S1) and permanently unsuitable (N2) to moderately suitable (S2), respectively. It was found that only 7.08 ha soils were very suitable (S1) for cultivation of banana. On the other hand 2,391.0 ha were found to be marginally suitable (S3) and 2,178.06 ha soils were moderately suitable (S2) class. In contrary, 1,650.27 ha and 48.94 ha soils were currently unsuitable (N1) and permanently unsuitable (N2), respectively for cultivation of banana in the studied area. The major limiting factor in the studied area for banana cultivation is low pH and texture. Management practice to combat this problem includes addition of lime and improving the fertility status of soil.

Pineapple: The land index value and class of the studied soils varied from 51.47 to 85.73 (Table 2 and Fig. 9) for pineapple cultivation. Based on parametric method the studied soils could be categorized under marginally suitable (S3) to very suitable (S1). However, the soils of alluvial and flood plain soils fall under moderately suitable (S2) to very suitable class (S1). Most of the studied area fall under moderately suitable class except soil sample no. 22 which were very suitable 85.73(S1) for the cultivation of pineapple. It was found that out of the total geographical area, only 5.33 ha soils area were very suitable (S1) for pineapple cultivation. On the other hand, 5,911.76 ha soils fall under the class moderately suitable (S2) and 358.26 ha soils were marginally suitable (S3) for cultivation of pineapple. The major limitations of the area were low pH and base saturation. To combat the low pH addition of liming must be practiced. By improving the pH and fertility status most of the soils could be upgraded to very suitable (S1) class.

Conclusion

The present investigation shows that the soils of Bumnoi-mornoi watershed varied considerably in physico-chemical properties. Based on the findings it may be suggested that the farmers of Bumnoi–mornoi watershed may opt for the following crop/cropping sequences with proper soil management practices. *Ahu* rice – *Sali* rice – Maize (rabi season) and *Ahu* rice –*Sali* rice – Potato, horticultural crops like banana and pineapple can be grown in home stead gardens. It was observed that the land resource data generated by studying the soils could be integrated through GIS techniques for efficient crop planning. Land suitability evaluation of the studied rainfed areas will serve as an important piece of information for agricultural planners and decision makers for sustainable crop production. The suitability maps could also be used by extension personals and farmers to make choice of appropriate uses for specific areas. However, soil-site suitability ratings should be validated with actual field experimental data for different crops for drawing final conclusion.

Table 1: Pysico-chemical properties of the Bumnoi-mornoi Watershed.

Physiography	Sample no.	Sand %	Silt %	Clay %	Textural class	OM (gm kg^{-1})	pH	N	P_2O_5	K_2O	Exchangeable cations				CEC	PBS (%)
								Kg/ha			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		
											[cmol(p+)kg^{-1}]					
Alluvial plain	1	46.0	34.0	20.0	Sl	19.9	5.4	62.7	40.7	151.6	1.2	0.2	0.56	0.17	6.2	34.35
Alluvial plain	2	33.3	45.3	21.5	Cl	22.9	5.7	448.0	41.0	220.0	1.6	0.8	0.58	0.19	10.2	31.07
Alluvial plain	3	35.6	42.3	22.1	Cl	22.2	6.3	275.9	23.1	146.7	2.8	1.0	0.52	0.21	9.2	49.23
Alluvial plain	4	33.0	43.6	23.4	Cl	18.5	6.4	326.1	41.0	340.0	1.3	0.5	0.50	0.19	10.6	23.49
Alluvial plain	5	55.7	28.6	15.7	Sl	11.1	4.7	250.9	38.8	154.0	1.7	0.3	0.60	0.33	4.8	61.04
Alluvial plain	6	56.1	33.3	10.6	Sl	17.8	4.5	439.0	32.0	110.4	2.6	0.7	0.52	0.39	8.6	48.95
Alluvial plain	7	32.4	46.8	20.8	Cl	11.1	6.4	37.6	35.7	158.9	2.3	0.4	0.41	0.23	12.3	27.15
Alluvial plain	8	36.2	57.1	6.70	Sil	5.9	5.4	252.1	28.1	115.0	2.8	0.7	0.46	0.15	6.7	61.34
Alluvial plain	9	56.0	30.2	13.8	Sl	14.1	4.5	363.8	24.6	127.5	2.7	1.0	0.51	0.16	9.7	45.05
Alluvial plain	10	32.2	45.2	22.6	Cl	22.9	4.1	313.6	38.1	291.1	2.5	1.0	0.58	0.12	10.1	41.58
Alluvial plain	11	45.0	45.0	10.0	Sl	9.6	5.2	201.6	56.0	160.4	2.0	0.4	0.42	0.31	8.4	37.26
Alluvial plain	12	46.2	35.9	17.9	Sil	26.5	5.2	358.0	55.7	247.3	2.0	1.0	0.61	0.23	10.2	37.64
Flood plain	13	36.3	51.2	12.6	Sil	12.6	5.2	210.7	48.9	309.1	2.5	0.3	0.50	0.23	8.4	42.02
Flood plain	14	56.7	32.1	11.2	Sl	8.1	5.2	501.7	26.1	151.2	2.0	0.6	0.52	0.38	8.2	42.68
Flood plain	15	55.5	37.0	7.50	Sl	4.4	4.7	210.7	24.2	159.5	1.9	0.5	0.53	0.19	9.5	32.84
Flood plain	16	48.2	36.2	15.6	Sl	23.6	5.3	186.5	51.0	279.6	2.0	0.4	0.52	0.36	6.1	53.77
Flood plain	17	23.7	48.2	28.1	Cl	15.5	4.6	489.2	40.5	308.0	1.9	0.7	0.60	0.28	10	34.8
Flood plain	18	27.7	58.9	13.4	Sil	6.7	4.5	188.2	26.2	183.9	1.9	0.3	0.43	0.31	10.2	28.82
Flood plain	19	23.3	60.0	16.7	Sil	3.1	5.1	448.0	54.6	264.2	2.8	0.4	0.53	0.41	10.2	40.58
Flood plain	20	33.0	46.2	20.8	Cl	5.8	4.9	224.0	38.5	303.7	3.2	1.7	0.41	0.22	8.2	67.43
Flood plain	21	55.5	34.5	10.0	Sl	10.4	4.8	358.0	51.0	451.0	3.5	1.7	0.60	0.63	9.60	66.97
Flood plain	22	51.5	32.6	15.9	Sl	26.5	5.2	246.4	41.0	137.2	2.8	1.1	0.63	0.54	8.2	61.82

Table 2: Productivity, potentiality index and suitability classes of different crops

Sample No.	p (p′)	Class	CI	Actual Land Suitability					
				Ahu rice	Sali rice	Potato	Maize	Banana	Pineapple
1.	16.24 (36.15)	4 II	2.22	52.65 (S3)	52.65(S3)	58.34(S3)	24.71(N2)	39.12(N1)	65.21(S2)
2.	38.48 (61.56)	2 II	1.60	61.95 (S2)	54.66(S3)	58.34(S3)	68.64(S2)	72.87(S2)	65.21(S2)
3.	41.55 (61.56)	2 II	1.48	72.88 (S2)	65.21(S2)	58.34(S3)	72.25(S2)	85.73(S1)	72.87(S2)
4.	19.24 (34.2)	4 III	1.77	69.23 (S2)	54.66(S3)	68.63(S2)	76.71(S2)	76.71(S2)	55.42(S3)
5.	29.07 (34.2)	3 III	1.18	39.12(N1)	41.57(N1)	27.45(N2)	61.95(S2)	36.33(N1)	72.87(S2)
6.	43.86 (64.48)	2 II	1.47	41.54 (S3)	46.46(N1)	26.08(N2)	58.34(S3)	38.58(N1)	72.87(S2)
7.	32.70 (58.14)	3 II	1.77	68.63 (S2)	41.18(N1)	65.20(S2)	68.64(S2)	68.63(S2)	61.94(S2)
8.	52.32 (61.56)	2 II	1.77	31.32(N1)	37.19(N1)	58.34(S3)	55.42(S3)	57.53(S3)	76.71(S2)
9.	37.40 (55.40	2 II	1.48	41.54 (S3)	41.57(N1)	61.94(S2)	33.77(N1)	27.61(N1)	72.87(S2)
10.	41.55 (55.40)	2 II	1.33	40.08 (S3)	48.90(N1)	65.21(S2)	43.35(N1)	64.30(S2)	40.08(S3)
11.	39.24 (61.56)	2 II	1.56	52.65(N2)	29.75(N1)	55.42(S3)	54.18(S3)	65.20(S2)	77.37(S2)
12.	41.55 (55.40)	2 II	1.33	61.95 (S2)	55.42(S3)	65.21(S2)	61.41(S2)	76.71(S2)	69.23(S2)
13.	20.78 (34.20)	3 III	1.64	52.65(N1)	55.42(S3)	55.42(S3)	43.35(N1)	65.21(S2)	77.37(S2)
14.	16.47	4	1.57	42.15(N1)	42.152(N1)	55.42(S3)	47.11(N1)	37.16(N1)	77.37(S2)

	(25.86)	III							
15.	36.33 (58.14)	2 II	1.60	29.36(N1)	46.06(N1)	43.76(N1)	22.65(N2)	16.56(N2)	54.65(S3)
16.	46.78 (51.98)	2 II	1.11	65.21 (S2)	61.94(S2)	68.64(S2)	26.01(N1)	39.12(N1)	81.45(S2)
17.	27.70 (49.25)	3 II	1.77	46.46(N2)	47.11(N1)	58.34(S3)	26.64(N1)	43.72(N1)	51.47(S3)
18.	27.62 (51.98)	3 II	1.88	23.43(N2)	48.90(N1)	55.42(S3)	26.64(N1)	36.33(N1)	61.94(S2)
19.	43.86 (58.48)	2 II	1.33	61.95 (S2)	42.15(N1)	69.23(S2)	33.77(N1)	54.15(S2)	81.45(S2)
20.	17.98 (21.16)	4 III	1.17	12.6 (N2)	23.47(N2)	18.41(N2)	32.08(N1)	32.49(N1)	65.21(S2)
21.	44.32 (49.25)	2 II	1.11	35.0 (N1)	33.25(N1)	76.71(S2)	35.86(N1)	60.56(S2)	76.71(S2)
22.	52.63 (55.4)	2 II	1.05	49.59 (S3)	52.65(S3)	76.71(S2)	55.42(S3)	68.63(S2)	85.73(S1)

*Sample no. 1-12: Alluvial Plain and Sample no. 13-22: Flood Plain

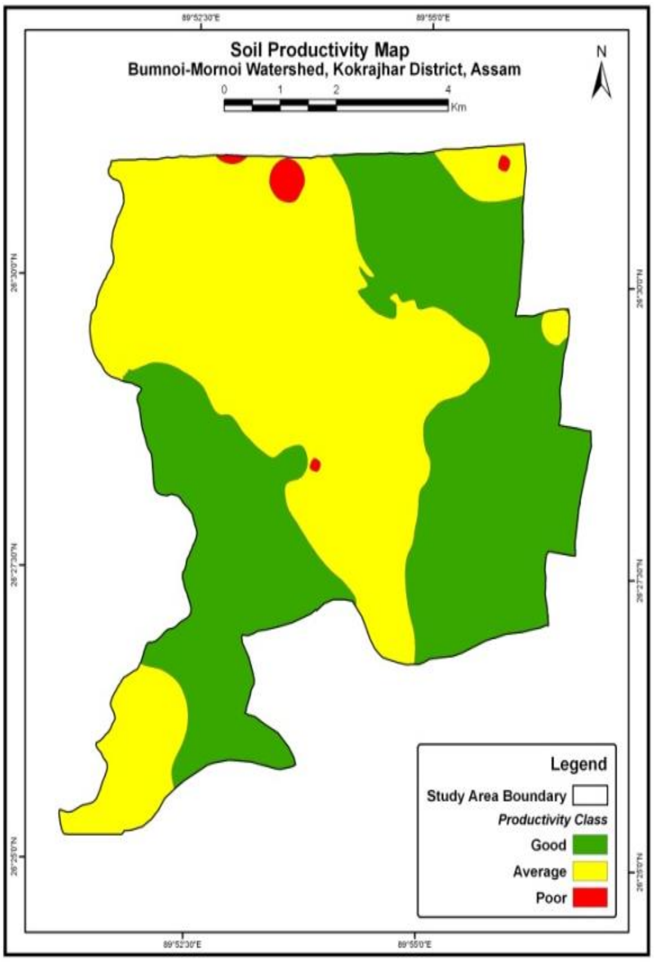

Fig 2: Productivity map of Bumnoi-mornoi watershed

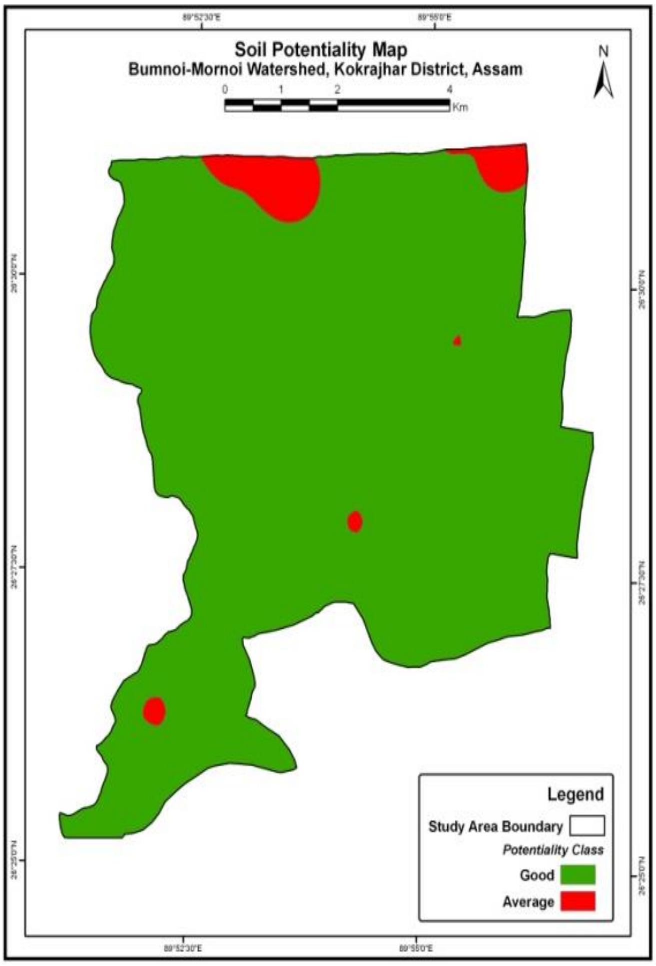

Fig 3: Potentiality map of Bumnoi-mornoi watershed

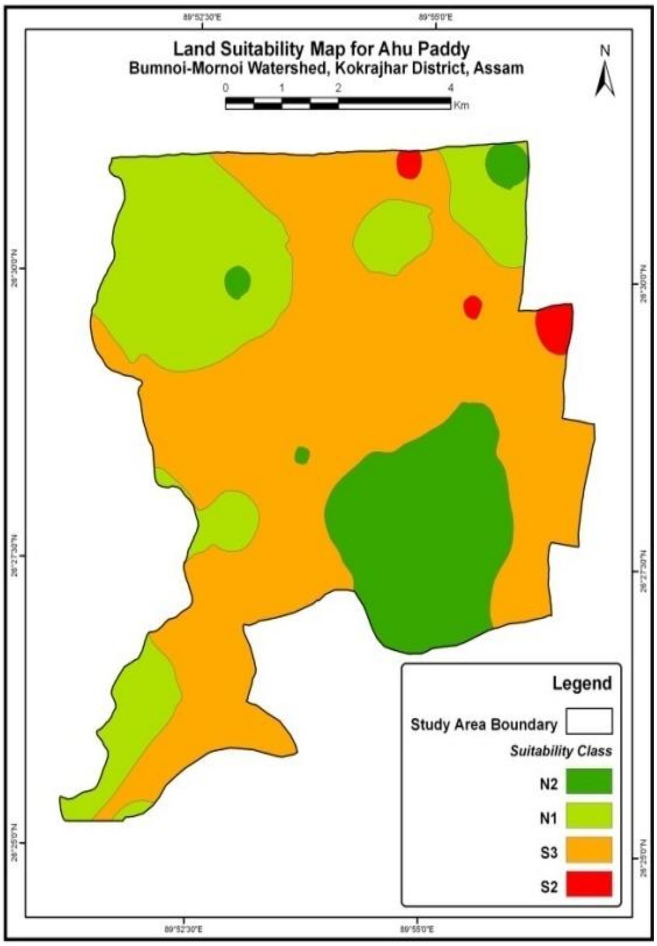

Fig 4: Suitability map of *Ahu* rice

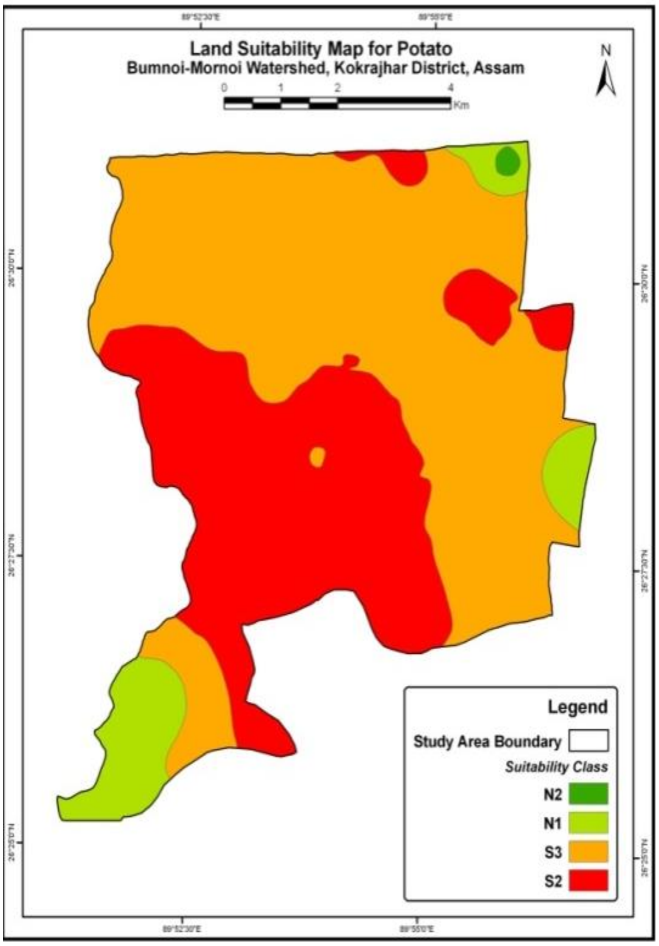

Fig 6: Suitability map of potato

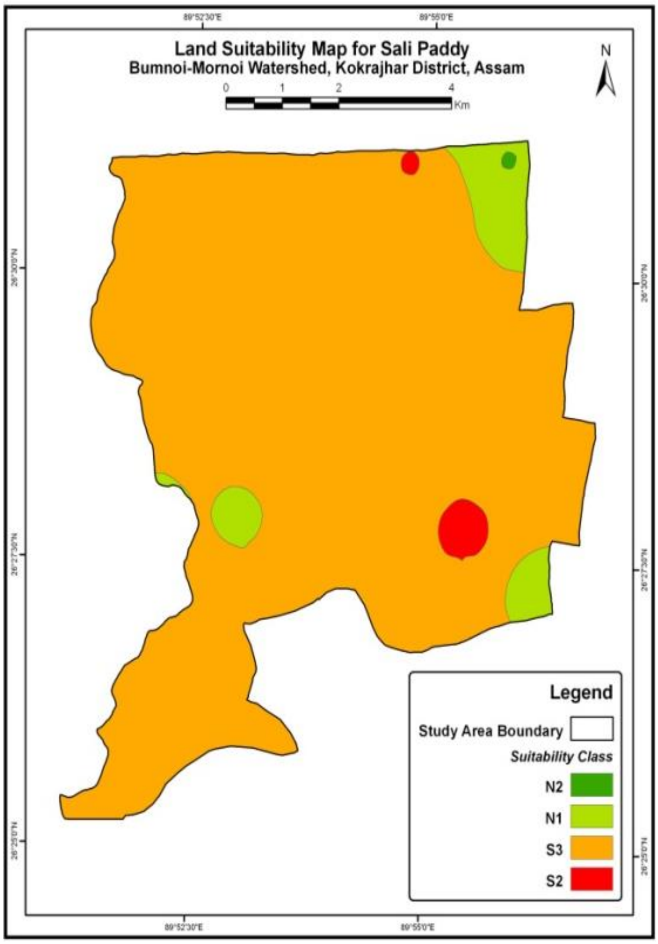

Fig5: Suitability map of *Sali* rice

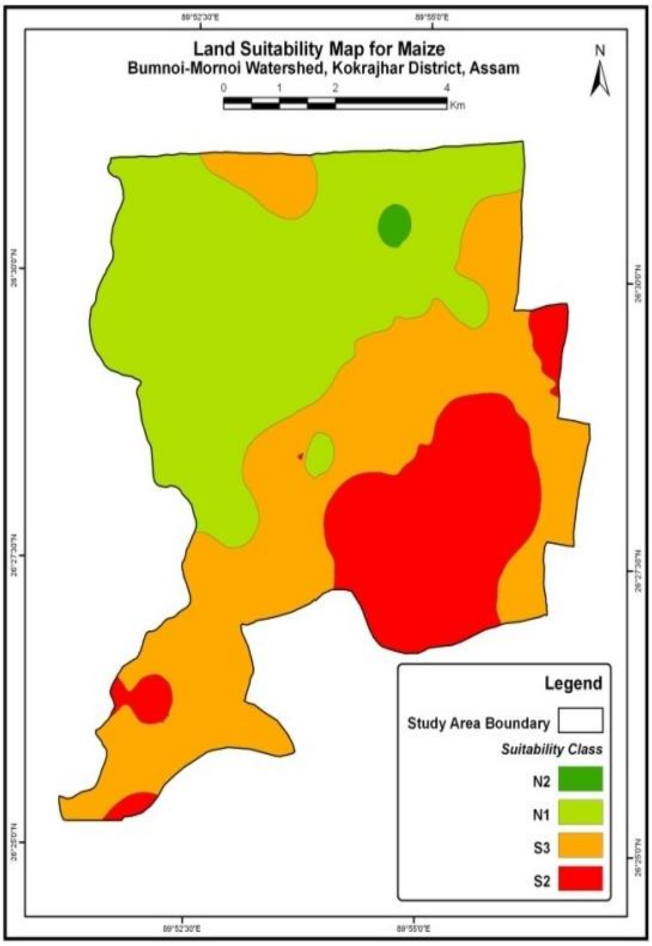

Fig 7: Suitability map of maize

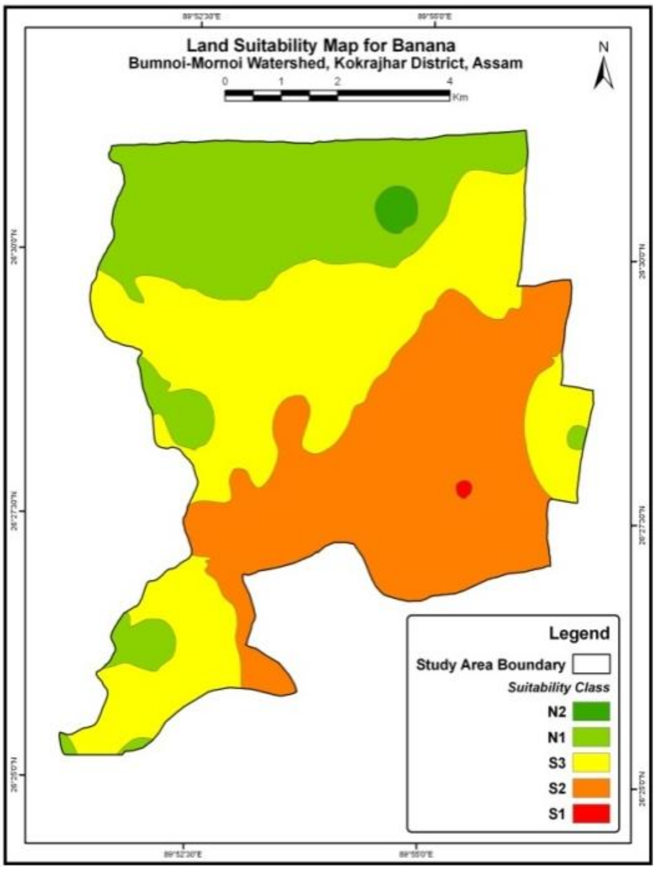

Fig 8: Suitability map of banana

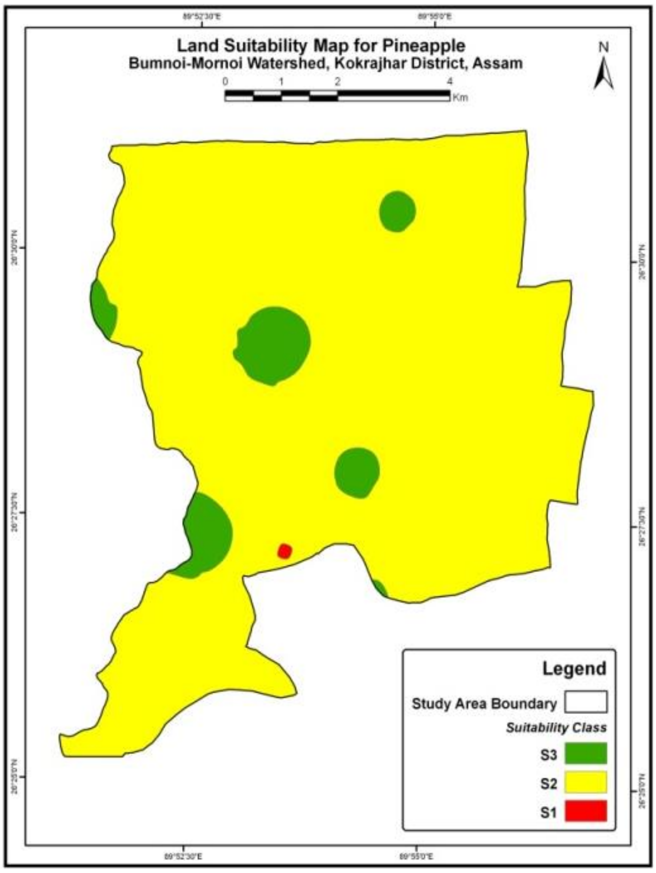

Fig 9: Suitability map of pineapple

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