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LAND IRRIGABILITY CLASSIFICATION OF SOILS IN SIMEN RIVER BASIN UNDER NORTH BANK PLAIN ZONE OF ASSAM, INDIA

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ABSTRACT

Land irrigability classification deals with evaluation of soils for their suitability to irrigation based on quantitative limits of soil characteristics pertinent to irrigation. The present study was undertaken to study land irrigation suitability of the soils under the Simen river basin located in the Northern Brahmaputra valley of Assam. The entire basin area was divided into three distinct landform units which included piedmont plain, alluvial plain and flood plain. Land irrigation suitability was evaluated based on various soil physico-chemical properties, topographic features and ground water table position. The study revealed that 97.32% areas of the studied river basin were marginally suitable (S3) for irrigation. In contrary, only 2.49% soils were moderately suitable (S2) and another 0.19% soils were currently not suitable (N1) for irrigation. Amongst the landform units the flood plain soils were found to have higher land irrigability index values (2.26-3.23) followed by alluvial plain (1.91-3.14) and piedmont plain (1.89-2.98).

Key words : River basin, Brahmaputra valley, Land irrigability, Landform units.

Introduction

The crop yields are governed by several inputs such as climate, soil, irrigation, improved seeds, fertilizers, plant protection measures etc. Out of these, irrigation is considered as one of the most important input. When rainfall is not sufficient, crops must be provided with additional water (irrigation) from other sources. Irrigation reduces the crop failure risk in a rain deficit condition and ensures the possibility of cultivating during the dry season. Therefore, peoples have been using irrigation since almost the advent of the civilization. In the development plans of India also, irrigation has been given as high productivity to ensure sustainable agriculture as well as to survive with the periods of inadequate rainfall and drought. However, mismanagement of irrigation can result in severe problems such as salinisation, alkalinisation and water logging. As such to avoid land degradation, irrigation water and techniques must be compatible with the soil properties. To decide where to apply irrigation and to choose the appropriate method, it is necessary to evaluate the suitability of land for irrigation. According to FAO (1976), land irrigation suitability is strongly related to land qualities including erosion resistance, water availability and flood hazards. Sys *et al.* (1991) suggested a parametric evaluation system for estimating land irrigation suitability which was primarily based on physical and chemical soil properties. Gizachew and Ndao (2008) used Sys's parametric evaluation systems to evaluate land suitability for surface and drip irrigation in the Enderta District, Tigray, Ethiopia. Mohammad *et al.* (2014) compared different irrigation methods in an area of 13,300 ha in the Gotvand Plain, South West Iran, using a parametric evaluation system, and generated the suitability maps for irrigation using Geographic Information System. Kumar *et al.* (2018) carried out land irrigability classification in Garakahalli micro watershed, Karnataka and evaluated the soil units for surface irrigation. Sebnie *et al.* (2020), while conducting a land irritability evaluation study in Abergelle District of Wag-Himra Zone, Ethiopia, found that 41.32% of the study area was moderately suitable and 21.95% of lands were not suitable for irrigation due to major limiting factors such as soil depth and slope. Similar studied conducted by Worku *et al.* (2024) in Zenti River catchment of Ethiopia revealed that 56% of the study areas were in the range of high irrigation potential to moderate irrigation potential for irrigation development.

In order to bring food security at national as well as household level, improvement and expansion of irrigated agriculture must be seriously considered. However, there is limited land and water resources based investigation of irrigation potential in Assam. As such the present investigation was undertaken to assess the land irrigability classes of soils of the Simen river basin located in the Dhemaji district of Assam.

Materials and Methods

The area under investigation (Simen river basin) is located in the Dhemaji district of North Bank Plain Zone of Assam, India (Fig. 1). The study area lies between 27.54^0-27.74^0 N latitude and 94.79^0 - 94.98^0 E longitude at an altitude of 104 m to 132 m above the mean sea level. The total catchment area of the basin falling in Dhemaji district of Assam (179.85 sq. km.) was delineated by taking into consideration of visually interpreted geocoded FCC of Resourcesat-2, LISS-4 data in conjunction with Survey of India toposheets (1:50,000). Based on the variations in remote sensing satellite data, three distinct landform units of the Simen basin were demarcated which includes: piedmont plain (41.32 sq. km.), alluvial plain (50.71 sq. km.) and flood plain (87.82 sq. km). The land use and land cover pattern of the Simen river basin included crop land, agricultural plantation, forest, water bodies, barren land and sandy areas. The slope of the Simen river basin varied from 0 to 10% as was estimated from Cartosat DEM 10 m resolution data. Soil depths were estimated from auger-hole observation as well as selected profile study of the studied area. Altogether 108 both bulk and core soil samples including 34 from piedmont plain, 38 from alluvial plain and 36 from flood plain were collected from the entire study area using a portable Garmin Etrex 30 GPS. The collected surface samples were air dried, grinded and passed through 2 mm sieve then stored. The samples were further analyzed for various soil physico-chemical properties parameters according to the standard procedure (Soil Conservation Service, 1972).

Land irrigation suitability classes were prepared based on soil irrigability rating modified from Palaskar and Varde (1985), Sys *et al*. (1991) and Sehgal *et al.* (1996). A total of 14 parameters were taken and each parameter was allotted a weightage based on their relative importance in the prevalent area (Table 1). All the soil samples were rated individually from 1 to 5 based on the value of each parameter as analyzed in the laboratory as well from field observation. The scores for individual parameters were multiplied by the weightage, which were then integrated. The integrated score was divided by the

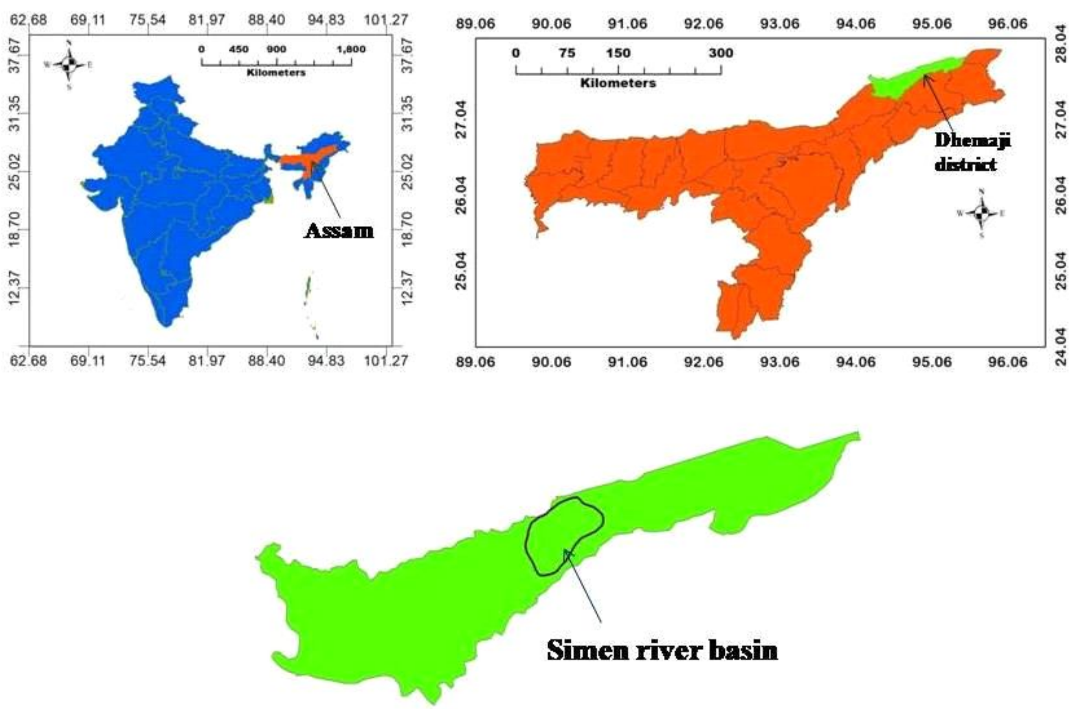

Fig. 1 : Location map of Simen river basin.

Table 1 : Weightage of various soil parameters and their classes for land irrigation suitability.

Soil Characteristics	Weightage	Soil classes				
		S1 (5)	S2(4)	S3(3)	N1(2)	N2(1)
Soil depth	5	>100 Deep	75-100 Moderately deep	50-75 Slightly deep	25-50 shallow	25 very shallow
Surface texture	5	SiL, CL, L	C, SiC, SC	SL	LS	S, Si
Soil Structure	3	Crumb, Granular	Angular Sub-Angular blocky	Platy	Columnar, Prismatic	Massive, Single grained
Available water capacity in effective profile depth (cm)	5	>21	21-14	14-7	7-2	<2
Saturated hydraulic conductivity (cm/hr)	4	6-2	2-0.5	12.5-6	25-12.5 or 0.5-0.25	>25 or <0.25
Drainage	2	Well	Moderately well	Imperfect	Poor	Very poor
pH	2	6.6-7.3	5.6-6.5	4.6-5.5	4-4.5	<4
EC (ds m^{-1})	1	<1	1-1.5	1.51-2.50	2.51-3	>3
ESP (%)	1	<15	15-35	20-30	30-40	>40
$CaCO_3$ (%)	2	<0.3	0.3-10	10-25	25-50	>50
Gravels (% by volume)	2	<15	15-35	35-55	55-70	>70
Slope (%)	3	0-2 Level	2-5 Nearly Level	5-8 Very gentle	8-15 Gentle	>15 Strong
Soil erosion	3	Slight	Moderate	Severe	Very severe	Extremely severe
Ground water table depth (m)	2	>5	3-5	1.5-3.0	0-1.5	-
Total	40					

Table 2 : Land irrigation suitability classes.

Land Irrigability Classes	Land Irrigability Index	Interpretation
Highly suitable (S1)	4-5	None to slight soil limitation for sustain use under irrigation
Moderately suitable (S2)	3-4	Moderate soil limitation for sustain use under irrigation
Marginally suitable (S3)	2-3	Severe soil limitation for sustain use under irrigation
Currently not suitable (N1)	1-2	Very Severe soil limitation for sustain use under irrigation
Currently not suitable (N2)	<1	Unsuitable for irrigation

total maximum weightage and the obtained value was taken as Land irrigability index. Based on the calculated Land irrigability index, the land irrigability classes were determined following the rating chart (Table 2) suggested by Bhushan and Roy (2022). The GIS based land irrigability map was prepared under Arc GIS environment using the calculated land irrigability index values. Interpolation for the unsampled location was carried out using Inverse Distance Weighted (IDW) function and the interpolated maps were reclassified to get the map units and legends.

Results and Discussion

The estimated values of various soil physico-chemical properties, topographic features and ground water table position used in land irrigability classification of the Simen river basin are presented in Table 3.

Physical properties

The texture of the soils of the piedmont plain were dominated by sandy loam and clay loam, while the soils of flood plain were found to be mostly silty clay loam in nature. As the texture of the studied soils varied from loamy sand to silty clay loam, so the soils were assigned with scores varying from 2-5. The structures of the soils varied from single grain to sub angular blocky and accordingly the soils in different landform units received scores ranging from 0.60 to 2.24.

Hydraulic properties

The hydraulic conductivity of the studied soils were found to vary from 0.57 cm/hr to 8.70 cm/hr with a mean value of 3.21 cm/hr. Hydraulic conductivity was observed to be highest in the piedmont plain (Mean: 3.51 cm/hr) followed by alluvial plain (Mean: 3.22 cm/hr) and flood plain (Mean: 2.87 cm/hr) with range values of 0.57-8.70 cm/hr, 1.12-7.70 cm/hr and 0.82-6.45cm/hr, respectively. Based on hydraulic conductivity the studied soils were scored which varied from 2.4-4.0 in different landform units. Available water capacity of the soils of the experimental area ranged from 4.73 cm to 25.90 cm having an average value of 11.81 cm. Based on available water capacity, the soils were assigned scores which ranged from 3-5. All the soils under piedmont plain were found to be well drained and in view of this, the soils were allotted the maximum score of 2. In contrary, scores varying from 1.6 to 2.0 were assigned to the soils under alluvial plain and flood plain as they were moderately drained to well drained.

Chemical properties

The pH of the study area was found to vary from very strongly acidic to medium acidic and it ranged from 4.75 to 6.53 with a mean value of 5.58. Among the various landform units, the highest pH was observed at the flood plain (Range: 5.00-7.48) and lowest was found to be at piedmont plain (Range: 4.75-6.01) with mean values of 5.73 and 5.39, respectively. The maximum electrical conductivity (EC) was found at the flood plain (Mean: 0.117 ds m^{-1}) and minimum was found at the alluvial plain (Mean: 0.093 ds m^{-1}) with values varying from 0.035-0.475 ds m^{-1} and 0.026-0.244 ds m^{-1}, respectively. The electrical conductivity of the studied soils varied from 0.025 to 0.475 ds m^{-1}, while the exchangeable sodium percentage (ESP) ranged from 0.30 to 2.09. All the soils

Table 3 : Range values of various soil properties used in land irrigability classification.

S. no.	Soil characteristics	Piedmont plain	Alluvial plain	Flood plain
1	Soil depth	Slightly deep to deep	Slightly deep to deep	Slightly deep to deep
2	Surface texture	Loamy sand to Clay loam	Loamy sand to Silty clay loam	Loamy sand to Silty clay loam
3	Soil Structure	Single grain to Sub-angular blocky	Single grain to Sub-angular blocky	Single grain to Sub-angular blocky
4	Available water capacity in effective profile depth (cm)	5.43-23.14	4.73-18.14	5.14-25.89
5	Saturated hydraulic conductivity (cm/hr)	0.57-8.70	1.12-7.70	0.82-6.45
6	Drainage	Well	Moderate to well	Moderate to well
7	pH	4.75-6.01	4.83-6.31	5.00-7.48
8	EC (ds m^{-1})	0.025-0.245	0.026-0.244	0.035-0.475
9	ESP (%)	0.30-2.09	0.33-1.88	0.36-1.52
10	$CaCO_3$ (%)	0.13-2.30	0.11-2.10	0.10-2.33
11	Soil stoniness (% by volume)	15-20	<15	<15
12	Slope (%)	8-10	6-8	1-5
13	Soil erosion (t ha^{-1} yr^{-1})	0.75-45.60	0.55-43.08	0.04-23.37
14	Ground water table depth (m)	4-5	4	3-4

Table 4 : Land irrigability scores of Simen river basin soils under different physiographic units.

S. no.	Soil characteristics	Piedmont plain	Alluvial plain	Flood plain
1	Soil depth (m)	3-5	3-5	4-5
2	Surface texture	2-5	2-5	2-5
3	Soil Structure	0.60-2.24	0.60-2.24	0.60-2.24
4	Available water capacity in effective profile depth (cm)	3-5	3-5	3-5
5	Saturated hydraulic conductivity (cm/hr)	2.4-4.0	2.4-4.0	2.4-4.0
6	Drainage	2.0	1.6-2.0	1.6-2.0
7	pH	1.2-1.6	1.2-1.6	1.2-1.6
8	EC (ds m^{-1})	1.0	1.0	1.0
9	Soil sodicity (ESP)	1.0	1.0	1.0
10	$CaCO_3$ (%)	1.6-2.0	1.6-2.0	1.6-2.0
11	Gravels (% by volume)	1.6-2.0	2.0	2.0
12	Slope (%)	1.2	1.8	2.4-3.0
13	Erosion	0.6-2.4	0.6-3.0	1.2-3.0
14	Depth to water level from ground (m)	1.6-2.0	1.6-2.0	1.2-1.6
	Land irrigability score and class	1.89-2.98 (N2-S3)	1.91-3.14 (N2-S2)	2.26-3.23 (S3-S2)

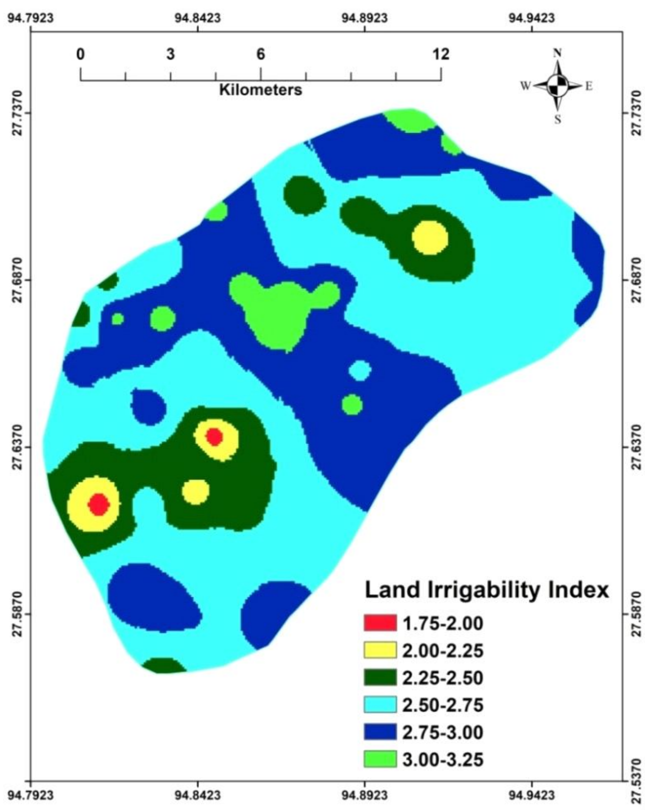

Fig. 2 : Land irrigability index map of Simen river basin.

under different physiographic units had EC less than 1 ds m^{-1} and exchangeable sodium percentage less than 15% and hence, the soils were assigned a score of 1 against each of these two properties. The calcium carbonate in the study area varied from 0.10 % to 2.33% and it showed an increasing trend from piedmont plain towards flood plain. Based on $CaCO_3$ content the soils were assigned with scores, which ranged from 1.6 to 2.0.

Soil depth and stoniness

Based on auger-hole observation and profile description of soils, the soil depths at all sampling points of the Simen river basin were estimated. It was found that the soil depth varied from slightly deep to deep and accordingly the studied soils were assigned scores from 3 to 5. Soil stoniness refers to percentage of gravel/stone content within the top productive soil depth. Soil stoniness reduces infiltration capacity in soil and germination capacity of crops. Also, it reduces surface area of land suitable for irrigation and as such stoniness is considered as not suitable for agronomic practices. In the studies area, soil stoniness was found to be less than 15% in alluvial plain and flood plain and as such a score of 2 was allotted to all the soils under these two landform units. However, few soils of piedmont plain exhibited stoniness more than 15% and accordingly values ranging from 1.6-2.0 were assigned to the soils under this group.

Slope

The slope of the piedmont plain varied from 8-10%, while in alluvial plain and flood plain it ranged from 6-8%

and 1-5%, respectively. Due to the slope constraint the piedmont plain and alluvial plain soils were assigned score of 1.2 and 1.8, respectively. In contrary, scores ranging from 2.4-3.0 were allotted to the soils of flood plain.

Soil erosion

The estimated soil loss in the Simen river basin varied from 0.04 t $ha^{-1} yr^{-1}$ (very slight) to 45.60 t $ha^{-1} yr^{-1}$ (very severe) with a mean value of 16.09 t $ha^{-1} yr^{-1}$. Amongst the landform units, the annual soil loss exhibited a decreasing trend from piedmont plain followed by alluvial plain and flood plain. The soil loss in the piedmont plain, alluvial plain and flood plain ranged from 0.75 - 45.60 t $ha^{-1} yr^{-1}$, 0.55 - 43.08 t $ha^{-1}yr^{-1}$ and 0.04 - 23.37 t $ha^{-1}yr^{-1}$, respectively. Based on soil loss value the piedmont plain, alluvial plain and flood plain scores were assigned scores ranging from 0.6-2.4, 0.6-3.0 and 1.2-3.0, respectively.

Ground water table depth

The depths of water table were observed to be more in piedmont plain, followed by alluvial plain and flood plain. Based on depth of water table the piedmont plain and alluvial plain soils were given more scores (1.6-2.0), than that of flood plain (1.2-1.6). The land irrigability scores was found to be highest in flood plain which varied from 1.89-2.98.

Evaluation of land suitability for irrigation

Based on calculated land irrigability index values, the studied soils were classified into different classes. There are five land irrigability classes recognized for evaluation of soils for flow irrigation and arable cropping which varies from S1 to N2 (Table 4). The suitability assessment for irrigation revealed that the studied soils varied from S2 to S3 with the absence of S1 and N2 Classes. Soil texture, structure, pH, hydraulic conductivity and depth of ground water table were found to be the major limiting factors in the study area for irrigation. The land irrigability map of the experimental site was prepared by taking into consideration of the computed land irrigability index values which is presented in Fig. 2. From the map, it is evident that, 2.49% areas (4.47 sq. km) of the studied river basin fall under moderately suitable (S2) class with severe soil limitation for sustained use under irrigation. There were only 0.19% areas (0.34 sq. km), which fall under N1 class (Currently not suitable) revealing that these soils had very severe soil limitation for sustain use under irrigation. In contrary, major portion of the soils of the Simen river basin (97.32%) were found to be under marginally suitable (S3) class. Amongst the landform units the flood plain soils were found to have higher land irrigability index (2.26-3.23) followed by alluvial plain (1.91-3.14) and piedmont plain (1.89-2.98).

Conclusion

In this study, land irrigation suitability of Simen river basin was evaluated through assessment of various soil physico-chemical properties, topographic features and ground water table position. The study revealed that 97.32% areas of the studied river basin were marginally suitable (S3) for irrigation. In contrary, only 2.49% soils were moderately suitable (S2) and another 0.19% soils were currently not suitable (N1) for irrigation. The main limiting factors associated with irrigation were found to be soil texture, structure, pH, hydraulic conductivity and depth of ground water table.

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