Productivity, potentiality and soil-site suitability evaluation for rice crop in the Moridhal watershed of Dhemaji district of Assam

ABSTRACT

A study was undertaken to carry out the productivity and suitability evaluation of the soils of the Moridhal watershed in Dhemaji district of Assam. Satellite image interpretation led to the recognition of four different physiographic units in the studied area which included: upper piedmont plain, lower piedmont plain, alluvial plain, and flood plain. One hundred seventy surface soil samples representing different physiographic units were collected and analyzed in the laboratory for various soil parameters. The productivity and suitability of the soils were computed and assessed by following standard procedures. The productivity index of studied soils varied from 12.13 to 62.14 could be ranked as: alluvial plain>flood plain>lower piedmont plain>upper piedmont plain. However, through adoption of proper improvement measures the soils could be improved to land index values of 41.04 to 90.25. The land index value for winter rice, autumn rice and summer rice could categorize into permanently unsuitable (N2) to moderately suitable (S2). The studied soils in terms of their suitability for winter rice, autumn rice and summer rice could be arranged in the sequence: flood plain> alluvial plain> lower piedmont plain> upper piedmont plain. The productivity and soil suitability maps as generated under GIS environment will serve as ready reckoner to farmers, planners and administrators in identifying the potential areas suitable for the major crops grown in that area.

Key words: Moridhal watershed, Land evaluation, Soil-site suitability, Remote sensing, GIS

INTRODUCTION

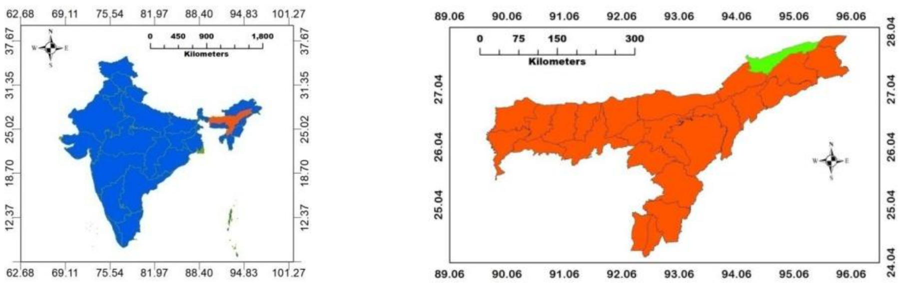
Efficient management of natural resources is essential for ensuring food supplies and sustainability in agricultural development (Amara *et al.*, 2016). Agriculture is one of the most important life-sustaining activities for people around the world. Since the beginning of civilization, humans have used land resources to meet their needs. Land degradation is a threat to the environment as it directly affects the declining productivity of both arable and non-arable land. It is estimated that about 80% of the current degradation of agricultural land worldwide is due to soil erosion caused by water (Kumar *et al.*, 2016). Land evaluation is a scientific procedure to assess the potential and constraints of a given land parcel for agricultural purposes (Rossister, 1996). Land suitability is the ability of a piece of land to tolerate agricultural production in a sustainable manner. Through analysis, the main constraints to production of a particular crop can be identified, enabling decision makers to develop crop management systems to increase the productivity of the land (Halder, 2013). The FAO defined that 'The suitability is a function of crop requirements and land characteristics and it is a measure of how will the qualities of land unit matches the requirements of a particular form of land use' (FAO, 1976). Much of the assessment work, particularly the assessment of soil suitability, has been inspired by the FAO's initiative (FAO, 1976) to develop a soil assessment framework that defines the basic concepts, principles and procedures for soil assessment, and which is generally applicable at all levels, from the global to the individual farm. Sys (1985) outlined the evaluation procedure for the soil characteristics which was subsequently refined (Sys *et al.*, 1991; Sys *et al.*, 1993). Rice is an important crop and is widely distributed as a staple food throughout the world. India is one of the world's leading rice producers, ranking second in the world. In 2016, India produced over 100 million tons of rice from over 400 lakh hectare. Rice is the staple food crop for more than two-thirds of the population in Assam and the state is among the top 10 rice producers in the country. The gross and net cropped area for rice in Assam is 3.84 and 2.75 366 million hectare (Mha), respectively. Rice is produced in three seasons in the state which includes winter (*Sali* rice), Summer (*Boro* rice) and Autumn (*Ahu* rice). Amongst these, winter rice is the most important culture with a productivity of 2.06 t ha^{-1}. However, the total rice productivity in Assam is only 1.97 t ha^{-1} as against the national average of 2.24 t ha^{-1}.

Walia and Chamuah (1992) evaluated the suitability of land for agricultural crops on the basis of limitations of moisture, erosion and acidity of soils in the flood affected area of Brahmaputra valley. Gangopadhyay *et al.* (1998) found that all the soils of the Upper Brahmaputra valley of Assam except Puranimati, Akahugaon and Dohotia were suitable for rice with highest land rating indices. Karmakar (2014) reported that the alluvial soils in the northern plains of Assam have the greatest potential for crop production and grazing, while those on flood plain could be considerably improved for commercial trees. Karmakar and Rao (1999) while evaluating the land of lower Brahmaputra valley zone of Assam found that surface texture and drainage are the main limiting factors in those soils. Dongare *et al.* (2016) carried out land suitability evaluation for rice in Tirora tehsil of Gondia district, Maharashtra through analysis of landform and soils using IRSID LISS-III and ancillary data GIS. Basumatary *et al.* (2020) found that the productivity index value of the alluvial soils of the Bumnoi-mornoi watershed of Assam varied from 16.24 to 52.32 and the soils were rated as poor to good for crop cultivation. Deka *et al.* (2021) studied the soils of Ghiladhari watershed of Assam and, thereby, found that the suitability of the soils for winter rice, and Summer/Autumn rice varied in the sequence of: old flood plain> lower alluvial plain> upper alluvial plain> lower piedmont plain> upper piedmont plain> structural hill.

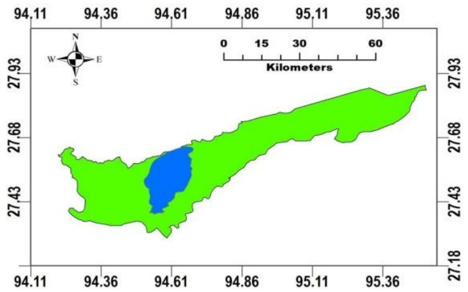
Moridhal watershed in Dhemaji district of Assam is one of the places known for intensive rice cultivation. However, there is no information on the productivity of the area and the suitability of the soil for rice cultivation. Therefore, this study was undertaken to provide this information.

MATERIALS AND METHODS

The study area (Moridhal watershed) is located in Dhemaji district of the Northern Brahmaputra Valley Zone of Assam (Fig. 1). The watershed is situated between $94^{0}52'$ E to $94^{0}69'$ E longitude and $27^{0}38'$ N to $27^{0}64'$ N latitude and it comprises 30,730 ha geographical area. The Moridhal river is formed by the combination of Ronganoi and Huliajan rivers originated at Arunachal Pradesh. The tributaries of the Moridhal watershed include Kanibil river, Korha river, Pavomari river, Telijan river, Sila river and Dangdhara river. The geology is alluvium formed in Brahmaputra arc that runs parallel to the mighty river Brahmaputra. These alluvium deposits have the time span in between upper Pleistocene to upper Holocene (Geological Survey of India, 1989). The area of the Moridhal watershed is characterized by humid climate with an average annual rainfall 3064.14 mm received during January to December. The average annual temperature, average maximum temperature and average minimum temperature are 23.6, 28.7 and 18.5, respectively. The studied area qualified for hyperthermic soil temperature and Udic moisture regime. The average relative



(a) (b)



(c)

Fig 1: Location map of moridhal watershed

(a) Assam in india

(b) Dhemaji district in assam

(c) Moridhal watershed in dhemaji district

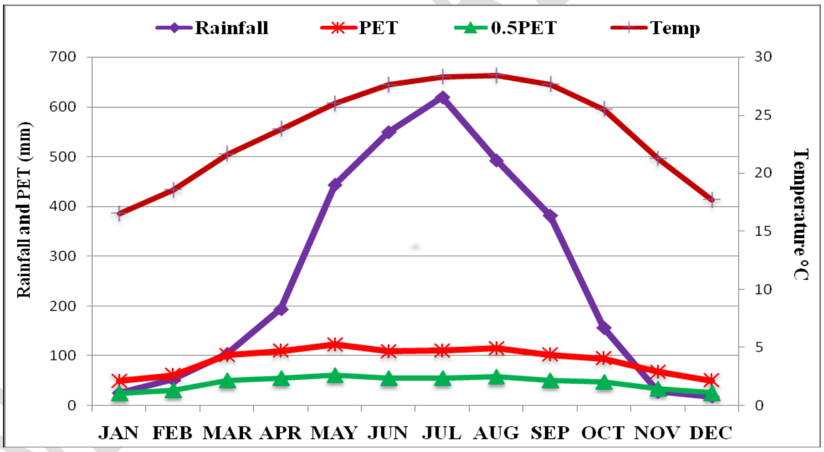


Fig 2: Ombrothermic diagram of moridhal watershed

humidity in the area is 82.58 per cent. The relation amongst precipitation (P), Potential evapotranspiration (PET) and temperature (T) are represented through the ombrothermic diagram (Fig. 2).

Major land units identified in the studied area include agricultural land, agricultural plantation, forest, forest plantation and tea estate. Visual image interpretation of Geocoded FCC of resourcesat-2, Liss-4 data in conjunction with Survey of India toposheets (1:50,000) led to the recognition of four distinct physiographic units which include upper piedmont plain, lower piedmont plain, alluvial plain, flood plain. Altogether, 170 representatives' surface soil samples representing different landscape units were collected for analysis. The samples were analyzed in the laboratory for various parameters according to the standard procedure (Soil Conservation Service, 1972).

The productivity of soils were computed and assessed by following the procedures described by Riquier *et al*. (1970). The Riquier's system suggests nine factors for the calculation of productivity index, *viz.*, Soil moisture content (H), drainage (D), effective soil depth (P), texture and structure (T), base saturation (N), soluble salt content (S), organic matter content (O), mineral exchange capacity/ nature of clay (A) and mineral reserve (M).

$$\text{Productivity index (P)} = H \times D \times P \times T \times N \text{ x } S \times O \times A \times M$$

Each factor was rated on a scale from 0-100 and the soils were rated in the light of above properties. The actual factor-wise scores expressed in percentage were multiplied to derive the final index. The productivity index (P') was calculated after careful consideration of the probable improvement measures. Based on the land index values, five classes of productivity and potentiality indices were categorized which include: Excellent (1/I): 65-100, Good (2/II): 35-64, Average (3/III): 20- 34, Poor (4/IV): 8-19 and extremely poor (5/V): 0-7. The Coefficient of Improvement (CI) values were computed by taking the ratio of potential productivity and actual productivity. Suitability of the soils for winter and Summer/Autumn rice were determined by comparing different land qualities and climatic parameters with crop requirement following the criteria outlined by Sys *et al*. (1993). Based on limitations the soils were classified into five groups *viz.* S1: very suitable, S2: moderately suitable, S3: marginally suitable, N1: actually unsuitable and potentially suitable, N2: unsuitable. Using the index values, the productivity, potentiality as well as rice suitability maps were created using GIS techniques.

RESULTS AND DISCUSSION

Productivity potential evaluation

The productivity index of studied soils varied from 12.13 to 62.14. The potentiality index of studied soils varied from 41.04 to 90.25. Among the physiographic units, the flood plain soils having productivity index values from 14.73 to 62.14 (Mean 38.74) (Table 1) were rated as poor to good classes for cultivation of crops. Adopting probable improvement measure in drainage, texture, structure of root zone, base saturation, and mineral reserve, the productivity of these soils could be improved to good to excellent classes (Mean 68.86). The productivity rating class of alluvial plain (Mean 45.14) was also average to good (Range 32.92 to 55.56) which could be further improved to good and excellent (Mean 80.72) by adopting improvement measures in texture and structure of root zone, base saturation, organic matter, and nutrient status. The results were also in conformity with the findings of Karmakar (1995) and Deka *et al*. (2021) who reported higher potentiality of young and less developed soils of lower Brahmaputra valley zone of Assam for crop production. Basumatary *et al*. (2020) also reported that alluvial plain soils Bumnoi-Mornoi watershed of Kokrajhar district of Assam were having poor to good class for production of crop. The productivity index of average to good rating of lower piedmont plain soils can be increased from a mean value 28.87 to a 49.18. The upper piedmont soils had poor to average productivity (Mean 24.84) due to acidic pH, low organic matter, base saturation, mineral reserve and coarse texture being the major limiting factors for crop production. The judicious application of organic manures, lime and proper management practices can improve the productivity rating of these soils to good classes (Mean value 49.86).

The coefficient of improvement values of studied soils varied from 1.11 to 4.69. The upper piedmont plain (Mean 2.10) and flood plain (Mean 1.91) soils had more potentiality as compared to alluvial plain (Mean 1.84) and lower piedmont plain (Mean 1.81) soils. The higher potentiality for improvement in productivity of young and less developed soils of Brahmaputra valley of Assam was also reported by Karmakar (1995).

The productivity index values with reference to their spatial distribution and extent are shown in Fig 3. It was observed that the studied area had 212 ha (0.69 per cent) poorly rated soils and 15,049 ha (48.97 per cent) average rated soils. In contrary, the watershed had 15,469 ha (50.34 per cent) good rating soils from productivity point of view.

The potentiality index values with reference to their spatial distribution and extent are shown in Fig 4. It was found that the studied area had 13,431 ha (43.70 per cent) soils which could be rated as potentiality good. In addition, the watershed had 17,299 ha (56.30 per cent) soils which were found to be potentiality excellent.

Soil-site suitability for rice crops

Using parametric approaches, the land suitability for winter rice, summer and autumn rice was evaluated. 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 status (M). Based on the possible improvement measures of the soil parameters potential land suitability classes were determined.

Sali rice (winter):

The suitability index value of the watershed area varied from 19.2 to 76.2 (Mean 44.4). Among the physiographic units, the flood plain and alluvial plain soils were found to be permanently unsuitable (N2) to moderately suitable (S2) for *sali* rice cultivation (Table 1). On the other hand, the suitability index of the lower piedmont plain soils varied from 21.2 to 58.8 (Mean 40.8) and it fall under marginally suitable (S3) class. The upper piedmont plain soils were categorized as permanently unsuitable (N2) and currently unsuitable (N1) class due to acidic soil, coarse texture and undulating topography. The major limiting factors of the unsuitable and marginally suitable areas for producing *sali* rice were found to be coarse texture, low fertility status, wetness parameter like excessive flooding and poor drainage, and undulating topography. To manage low ph, low organic matter, drainage, the addition of liming and organic manure along with a selection of flood-resistant varieties could be adopted. Poor drainage, coarse texture poses severe limitation in Damodar command area in west bengal (Bera *et al*., 2017) and Haradanahalli micro watershed in Karnataka (Anil kumar *et al.*, 2019). In a similar study in Dorika watershed in Assam, Gogoi *et al.*, (2018) observed that the alluvial plain and flood plain soils of Assam were more suitable for *sali* rice as well as for *ahu* rice than that of piedmont plains. Considering this, we recommend growing of rice in flood plain and alluvial plain while upper piedmont plain may be converted to Agroforestry based systems. Maps for individual parameters are integrated in GIS environment and overlaid into a accurate and reliable suitability map for rice crop which revealed that out of the total watershed area only 0.01% land was moderately suitable (S2) and 12.3% land was marginally suitable (S3) for *sali* rice cultivation. In contrary, 61.9% was currently unsuitable (N1) and 25.7% area was permanently unsuitable (N2) for growing *sali* rice (Fig 5).

Ahu rice (autumn):

Ahu rice is one of the principle crops in the study area. In the studied watershed (17.7%) area was marginally suitable (S3), 59.8% land currently unsuitable (N1) and 22.5% land permanently unsuitable (N2) for cultivating *ahu* rice (Fig 6). The mean suitability index value for the entire watershed was found to be 48.9. Based on the values of suitability index the flood plain (range 37.2 to 80.7) and alluvial plain (range 31.6 to 65.2) soils fall under marginally suitable (S3) to moderately suitable (S2) class primarily due to unsuitable drainage. The lower piedmont plain soils fall under marginally suitable (S3) class. The upper piedmont plain soils were permanently unsuitable (N2) to currently unsuitable (N1) for *ahu* rice cultivation (Table 1). The major limiting factors for *ahu* rice cultivation in the studied areas were found to be precipitation in the early period of crop growth, coarse texture, acidic soil and unsuitable drainage condition.

Boro rice (summer):

The production of *sali* rice in Assam is drastically affected due to its vulnerability to natural disasters like flood, submergence and even drought. Due to its dismal performance, farmers of the region are leaning toward more risk free crops like summer rice (*boro*), rapeseed and mustard etc. Due to lack of assured irrigation in the studied area, majority of the area (59.9%) was currently not suitable, 30.8% area was permanently not suitable while remaining 9.3% area was found to be marginally suitable for growing *boro* rice (Fig 7). Among the physiographic units, the highest values of suitability index were found in the soils of flood plain (Mean 47.5) followed by alluvial plain (Mean 41.1) which were marginally suitable (S3) to moderately suitable (S2) for *boro* rice cultivation (Table 1). The upper piedmont plain soils were permanently unsuitable (N2) to currently unsuitable (N1) for the cultivation of *boro* rice. The data obtained indicated that the major limiting factors of the studied areas for producing *boro* rice were low fertility status and low ph, which could be managed through the addition of organic manure, fertilizer and lime. Similar findings were also reported by Deka *et al*. (2021) for a part of the north bank plains zone of Assam.

Table 1: Mean value of productivity index, potentiality index and soil-site suitability index for rice crops in the Moridhal watershed

	Upper piedmont plain	**Lower piedmont plain**	**Alluvial plain**	**Flood plain**	**Overall Mean**
Productivity index	24.84	28.87	45.14	38.74	35.22
Potentiality index	49.86	49.18	80.72	68.86	62.71
***Sali* rice (winter)**	31.50	40.82	43.92	50.14	44.36

***Ahu* rice (Autumn)**	30.90	42.98	47.68	57.93	48.94
***Boro* rice (summer)**	28.15	37.75	41.09	47.50	41.49

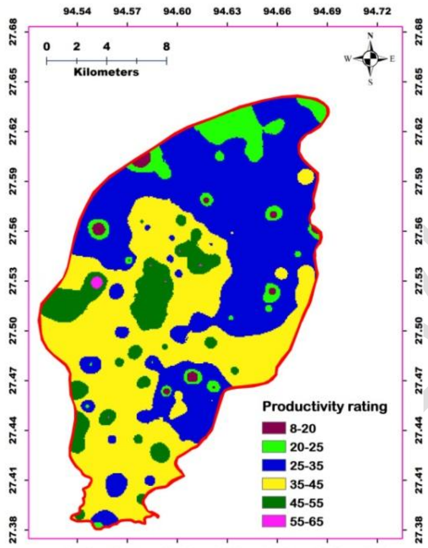


Fig 3. Productivity map

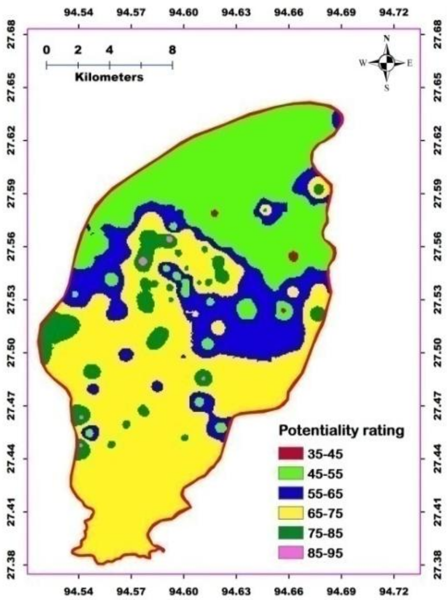


Fig 4. Potentiality map

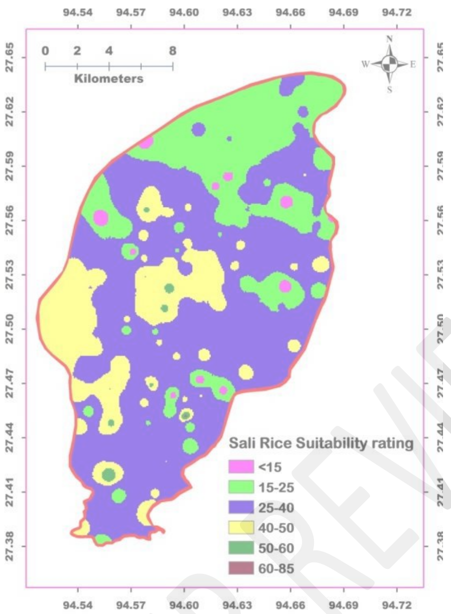


Fig 5. *Sali* rice suitability map

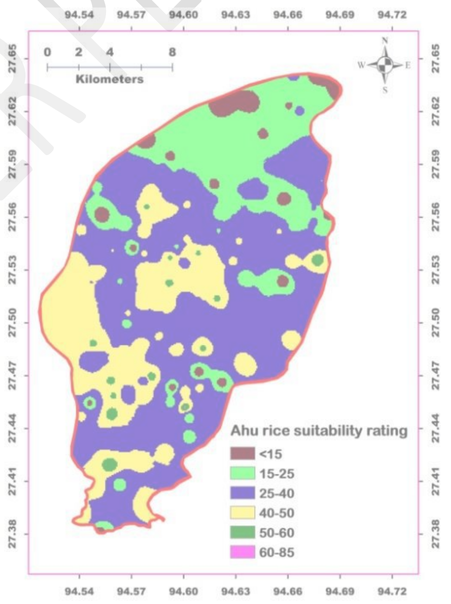


Fig 6. *Ahu* rice suitability map

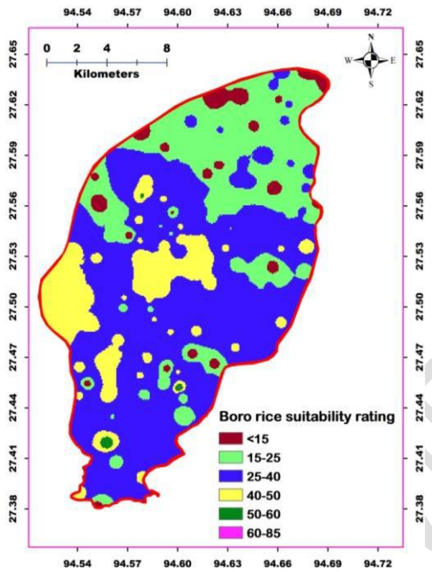


Fig 7. *Boro* rice suitability map

CONCLUSION

The assessment of land suitability has immense importance in agriculture in order to help decision makers and agriculture development planners. Land suitability tools have been extensively applied to identify better management practices in agricultural areas. The assessment of the soils of Moridhal watershed exhibits various limitations in terms of productivity as well as rice suitability. However, it is possible to overcome some of these limitations through improved management practices which eventually can lead to higher productivity .

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