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Capability and quality assessment of rice growing hydric soils in Majuli river Island, Assam, India

Bhaskara Phaneendra Bhaskar and Dipak Sarkar

National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), India

Corresponding author: bhaskaraphaneendra@gmail.com

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Abstract: The wetland soils in Majuli Island is a unique ecosystem in maintaining rice ecology and geoenvironment in Brahmaputra valley of Assam due to increasing rate of bankline erosion in southern bank and expansion of channel bars on northern banks. These hydric soils in the orders of Entisols and Inceptisols are saturated throughout year as assessed from depleted matrix with hue 10YR, 2.5Y and 5Y, chroma less than 2, stratified textures, neutral to slightly alkaline reaction, low cation exchange capacity and poor exchangeable base status. The assessment of land capability and soil quality for rice production in hydric soils were conducted on twenty five soil mapping units derived from reconnaissance soil survey done on 1:50000 scale. As per land capability assessment, these soils are good (class II) to fairly good (IV) for arable use with limitations of low fertility status, moderate to severe wetness and moderate to rapid permeability. The soil quality rating with multiple variable indicator transform (MVIT) technique of twenty five hydric soil units in active and old floodplains was medium (35% to 65%) with six indicators (pH, organic carbon, base saturation, effective rooting depth, structure and texture) meeting the threshold value above 65 per cent. Thirty five per cent of the total area is suitable for rice cultivation as against the current cropped area of 7.2 % with potassium and zinc deficiencies. The determination of soil quality in relation to land capability was found useful to design best management practices for wetlands in the region to ensure sustainable land use.

Keywords: hydric soils, Majuli Island, land capability, agronomic interpretation, soil quality assessment

Introduction

Majuli, one of the largest river islands in the world, has 92460 hectares (ha) supporting the population of 15.53 per cent (135378) of Jorhat district, Assam. This island experiences seasonal floods and severe bankline erosion causing loss of 50 km^2

of land mass during 1969 to 1994 (Nayak and Singh, 1996), decline in drainage density from 0.963 km/km^2 to 0.442 km/km^2 and stream frequency of 0.346 stream/km^2 to 0.144 stream/km^2 during 1917 to 1966-72. The frequent fury of floods may be attributed to the great earthquakes of 1897 and 1950 affecting the upper Brahmaputra Valley including Majuli with severe bank erosion at the rate of 5.63 km^2/year after a period of 57 years (1915, 1245.59 km^2 to 1971) and further reducing to 645 km^2 in 1995, thereby maintaining an average rate of erosion in the order of 7.4 km^2/year (Sarma and Phukhan, 2004).

The island has low cropping intensity (ratio of total cultivated area to net sown area and multiplied with 100,102 per cent) with an average productivity of rice of 487 kg/ha in post rainy season (November-February) and 1325 kg/ha in rainy season (June - November) as against district average productivity of 1700 kg/ha. Rice is grown on wet soils during raining season and described as the "breadbasket" in the region. The conversion of wetlands to agricultural use has been subjected to higher frequency and severity of flooding, severe bankline erosion, disruption of water flow regulation and deterioration of environmental quality. Development of agriculture in the island can only be possible with assessing these wetland resources for proper land use planning (Vadivelu *et al.,* 2005 and Bhaskar *et al.*, 2010a). The wide spread of *aquepts* and *fluvents* in Brahmaputra valley with stratified textures, free carbonates and high organic carbon in surface layers was reported (Dey and Sehgal, 1997 and Bhaskar *et al.*, 2009). These lowlands are important for agricultural development but less information is available for their utilization and intensification on a sustainable basis. Therefore, the present paper will focus upon the wet land resource evaluation by way of land capability and quality assessment of soils in order to optimize the agricultural uses in Majuli island.

Materials and Methods

Study area

The Majuli island (93^o 30' - 94^o 35' E and 26^o 50' and 27^o 10' N) is situated in north of Jorhat district. The elevation on the island varies from 60 to 85 m above mean sea level. The island is bounded by three important rivers viz; Kherkutia Suti, the Subansiri in the north and the Brahmaputra river in the south (Fig. 1). The island is marked by seventy bils (local name for water bodies), which break the monotony of flat relief. The historical records mention that the Brahmaputra River was located north of Majuli during the late part of the 17th century. There is no dependable record mentioning southward migration of the Brahmaputra. The migration was probably due to frequent earthquakes and floods that occurred between 1661-1696 (Bhuyan, 1968). Since 1930, two mega (magnitude 8.7), five major (magnitude 7.0) and many smaller magnitude earthquakes have occurred in the area (Valdia, 1987). Movements along active basement faults have caused tilting of the recent alluvium leading to the shifts in the courses of many rivers (Sarma and Phukan, 2004).

The Majuli island experiences subtropical monsonal climate with aquic/udic soil moisture regime and hyperthermic soil temperature regimes. The island supports the growth of evergreen, semi-evergreen and deciduous trees, grasses and marshy vegetation (Bhagabati, 2001). The grasses in wetlands include *Phragmites karka*, *Arundo donax*, *Chrysopogon aciculatus*, *Imperata cylindrica*, *Cynodon dactylon* and *Vetiveria zizaniodes*. The marshy vegetation includes *Eichhornia crassipes*, *Pistia stratiotes*, *Nymphaea nouchali*, *Nelumbo nucifera*, *Trapa bispinosa*, *Euryale ferox*, *Cyperus rotandus*, *Alisma plantago*, *Polygonum hydropiper*, *Alpinia allughas* and *Ipomea reptans*.

Fig. 1 – Location Map of Majuli island

Rice management systems in Majuli

The climate in the island is subtropical with warm humid summer and cool dry winter with mean annual rainfall of 1900mm. According to Kopper system, this island enjoy's "CWg" as humid mesothermal gangetic type of climate (Barthakur, 2004). This island predominantly receives southwest tropical monsoons during April through October and occasional winter showers. The monsoon season receives maximum amount of rainfall (62-65% of annual rainfall) followed by pre-monsoon (20-23%), post-monsoon (6-8%) and winter (2-3%) season (Bhaskar *et al.*, 2010b). The average maximum temperature ranges from 23.6 ^{o}C to 31.7 ^{o}C and minimum temperature varies from 10.00 °C to 24.20 °C. The average minimum temperature is about 100 ^{o}C in December/January while maximum of 320 ^{o}C is attained in July/August. However, the minimum temperature drops to as low as 60 ^{o}C while maximum shoots up to 370 ^{o}C in some years. On an average, the relative humidity is more than 80% throughout the year. Even during dry winter months, the average relative humidity is never below 75% in the region.

Table 1 - Rice growing seasons in Majuli

GROWING SEASONS	SOWING	HARVESTING	VARIETIES	FERTILIZER DOSE(KG/HA)	DURATION	REMARKS
Ahu (PreKharif rice) Area: 787ha Productivity: 2.8 t/ha	Mid February to April	June -July	Semi dwarf: Govind, IR-50, IR-36, Luit, Kopilee, Disang, Jaya Tall: Rangodoria,Banglami, Dubaichanga, Fapori, Guni, Ihajit,	20N:10P_2O_5:10K_2O	80-130	Photoperiod insensitive, early maturing, usually broadcast,
Sali (Kharif rice) Area: 15857ha Productivity: 4.5 t/ha	June-August	November-December	Ranjit,Bhadur, Luit, Pankaj, Lakshmi, Kushal, Moniram, Satya, Basundhara	40N:20P_2O_5:20K2O	150-180	Photoperiod sensitive, long duration, grown transplanted under variable water depth (0-30cm)
Boro (Summer) Area: 7875ha Productivity: 3.5t/ha	December-February	May-June	Boro1, 2, Masuri, IR-50, Jyotiprasad, Jaymoti	40N:20P_2O_5:20K_2O	180-200	Photoperiod insensitive, cold tolerant at vegetative stage, traditionally in the bils (depressions) and marshy lands with minimal or no tillage.
Bao (deep water rice) Area: 1197ha Productivity: 2.3t/ha	April-May	December/January	Panikekoa, Sabita, Bhudev, CR780-1937, CR662-2211	--	270-300	Deep water rice, normally grown as broad cast, endure water depth >100cm, sown at the time when Ahu rice is sown and harvest at the time when Sali rice is harvested

The significant rise of river bed of the Brahmaputra near Dibrugarh was responsible for severe floods along Majuli and attain aggressive nature specially after the great 1950's earthquake. The recent flood occurrence scenario reveals that floods of different order occur at least 3 to 4 times every year (Sharma and Basumallick, 1984). The erosional scenario in the island showed that the area of island (1249 km^2 in 1915) was reduced to 645.49 km^2 in 1995 with an erosional rate of 8.88 km^2/year (Sarma, 2005 and Kotoky *et al.*, 2005). This has created an increasing threat to the island and the rich natural and cultural heritage it represents. The historical records of this island says that the extensive flat to gently sloping floodplains are considered suitable for rice based cropping systems. The rice growing seasons (Ahmed *et al.*, 2011) along with varieties and general package of practices were presented (Table 1). The rice is the principle crop grown to an extent in three seasons of 787 ha in Ahu, 15857 ha in Sali and 7857 ha in Boro but area under Bao rice approximately accounts to 1197 ha. The island has 142 villages with total geographical area of 924.6 km^2. This island has 42 *chapori's* covering an area of 26315.97 ha supporting population of 21650.The chronically flood prone areas in three circles (Garmura, Kamalabari and Jenjari) of Majuli is recorded as 39298 ha with total cropped area of 47348 ha. The major rice based cropping systems are mustard, wheat with black gram. The general fertilizer dose for rice is 40N:20P_2O_5:K_2O kg/hectare. The land-climatic requirements for wetland rice (Table 2) was adopted from the criteria given by Udoh *et al.* (2011).

Table 2 - Soil-climatic requirements of wetland rice in alluvial soils

CLIMATE-SOIL PARAMEERS	UNIT	S1	S2	S3	N1	N2
Climate (c)						
* Annual Rainfall	mm	>1400	1200-1400	950-1100	850-900	<850
Soil Physical Characteristics (s)						
(a) Soil Depth	cm	>20	10-20	5-10	<5	Any
(b) Clay	%	50-25	25-15	15.5	≤5, ≥ 5	Any
Wetness (w) or Ground water table						
(a) Drainage	–	1-3	1.3	3	any	Any
(a) Flood Duration	Months	> 4	3-4	2-3	< 2; >4	Any
(a) Ground water Table	m	0-15	15-30	30-60	> 60	Any
Fertility Status (f)						
pH	–	5.5-7.5	5.2-5.5	≤5.5	≥ 5.2 -	Any
Total N	%	>0.2	0.1-0.2	0.05 -0.1	<0.05	Any
Organic carbon	%	2-3	1-2	3-4	> 4	Any
Available P	mg·kg^{-1}	> 20	15-20	10-15	< 10	Any
Exc. K	cmol·kg^{-1}	> 0.2	0.1-0.2	< 0.1	< 0.1	Any
Exc. Ca	cmol·kg^{-1}	10-15	5-10	1-5	<1; >5	Any
CEC (Soil)	cmol·kg^{-1}	> 16	10-16	5-10	<5	Any

Land Resource Evaluation

Landforms

The IRS-ID (Indian Remote Sensing Satellite) geocoded satellite imageries of 18th January, 2003 were visually interpreted (Jensen, 1986) and delineated seven geomorphic units in the floodplains of Majuli island as per the classification of Nanson and Croke (1992). The pinkish with red tones (mustard fields during winter season) in the middle of the island indicated the flat to gently sloping active floodplains whereas light blue with whitish tinge tones, fine texture and associated with dark blue tones of water bodies indicated old alluvial plains. The tall grass lands of natural levees occurring along the river course have dark red tones with regular linear feature of fine texture whereas flat featureless channel fills in low lying areas have light bluish with white tones with a laminar ripples with textural differences. The most conspicuous feature is unvegetated sand bars in the meandering reaches of island have white tones whereas tall grass lands have bright red tones. The low lying water bodies in swamps have dark blue tones whereas abandoned channels have whitish blue tones.

The soils

The detailed morphological, physical and chemical descriptions of thirteen soil series belonging to the order *Entisols* and *Inceptisols* were reported (Bhaskar *et al*., 2008). Brief description of hydric soils in fluvial landforms of Majuli Riverine Island are discussed as follows. The Kamalabari (Kb), Puranibari (Pb), Dakshinpat (Dh) and Bhakat (Bt) soil series are dominant on active floodplains covering 16.3 % of the total area. These soils have Ap-AC-C horizon sequence, dark grey (10YR4/1) A horizons, clay loam to silt loam textures with moderate, medium subangular blocky structures. The AC horizons are dark grey (10YR4/1) and loamy but changed to loamy sand textures in C horizons (Table 3). These soils are classified as *Humaqueptic Fluvaquents* (Kamalabari series, Kb), *Humic Endoaquepts* (Dakshinpat, Dh), *Typic Fluvaquents* (Bhakat, Bt) and *Fluvaquentic Endoaquepts* (Puranibari, Pb). Majuli (Mj, *Typic Fluvaquents*) and Garumara (Ga, *Typic Endoaquepts*) on sand bars (43.2 % of total area) have olive grey to dark grey A horizons, coarse loamy texture and slightly alkaline pH. The Bharaki (Bi, *Fluvaquentic Endoaquepts*) and Bongaon (Bn, *Typic Fluvaquents*) soils in swamps have dark grey and silt loam textured with weak subangular blocky structures. The cambic B horizons have dark grey matrix with silt loam to silty clay loam textures and moderate angular blocky structures with neutral to slightly alkaline pH. Adielengi (Ae) and Chilkala (Ch) are dominant soil series in old floodplains with grey matrix, silty loam to silty clay textures and dark grey B horizons followed by sandy C horizons. These soils are classified as *Typic Endoaquepts*. The Gayangaon (Gy, *Typic Endoaquepts*) and Boritika (Ba, *Fluvaquentic Endoaquepts*) soils in channel fills have

Table 3 - Properties of soils in Majuli Island

Soil series	Textural Sequence	Particle size distribution (%)			pH	OC g·kg^{-1}	Exchangeable bases cmol (p+)kg^{-1}				CEC cmol (p+)· kg^{-1}
		Sand	Silt	Clay			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
Sonaribar(Sb)	sicl-sil-l-sil	12.9	69.9	17.2	7.6	8.5	10.0	4.2	0.50	0.5	12.7
Bharaki (Bi)	sil-sl-l-sil-sicl	28.8	54.4	16.8	7.4	3.7	5.3	4.3	0.46	0.2	13.3
Bhakat (Bt)	sil-sl-ls-sl-s	76.6	16.4	7.0	7.9	1.5	8.7	1.2	0.31	0.0	7.2
Boritika (Ba)	l-sl-sicl-s	55.5	27.9	16.6	7.4	5.2	4.3	2.2	0.34	0.1	14.4
Adielengi (Ae)	sil-sicl-sil-s	71.9	15.7	10.6	7.1	3.8	3.4	1.2	0.47	0.0	6.7
Puranibari (Pb)	sl-l-s-sl-sil-sicl	31.4	45.9	22.7	6.5	3.3	4.3	2.5	0.53	0.1	17.1
Kamalabari (Kb)	l-sil-l-ls	57.1	33.2	9.7	6.9	3.6	3.3	1.3	0.8	0.2	10.3
Chilkala (Ch)	sill,sic, sicl-s	65.8	17.8	16.4	6.9	4.0	3.0	2.4	0.7	0.1	7.1
Gayangaon (Gn)	sil-l-s	52.4	33.7	13.9	7.0	4.6	3.4	2.1	0.7	0.1	10.1
Dakshinpat (Dh)	sicl-sic-sil-s	35.4	47.4	19.7	7.1	8.9	5.5	3.5	0.7	0.1	14.4
Bongaon (Bn)	sil-l-sl-l-s	63.5	31.0	5.6	7.8	3.0	7.8	5.2	0.7	0.1	5.1
Garumara (Ga)	l-sl-s	57.9	31.2	11.9	6.1	4.7	2.4	2.0	0.8	0.1	10.1
Majuli (Mi)	ls-l-l	61.6	31.8	6.6	7.3	2.2	3.0	2.7	0.7	0.0	7.1

olive grey (5Y5/2), silty clay loam Ap horizons and dark grey (5Y3/1) or dark greyish brown (2.5Y4/2) silt loam textured and yellowish brown mottled B horizons. The Sonaribari soil series (Sb, *Typic Endoaquepts*) on natural levees have interbedding coarse to fine sediments of sand, silt and silty clay with olive grey matrix.

All soils are neutral to slightly alkaline except Kamalbari soil (P1) on active flood plains with moderately acid to neutral pH. The organic carbon varies from 9.7 g/kg (P2) to 19.5 g/kg (P3) in Ap horizons but decreased to 0.6 g/kg in C horizons of all soils (Table 3). Among exchangeable bases, calcium is dominant with values of 2.4 cmol/kg (Garumara, Ga) to 10 cmol/kg (Sonaribari, Sb). These soils have exchangeable Mg of 1.2 cmol/kg (Adielengi, Ae) to 5.2 cmol/kg (Bongaon, Bn), sodium of 0.31 to 0.8 cmol/kg and K of 0.08 to 0.5 cmol/kg. These soils have low cation exchange capacity (3.5 cmol/kg in C horizons of P2 to 20 cmol/kg in 2Bw2 (P4) with variable depth distribution. These soils have high to medium available nitrogen, low to medium available phosphorus and medium to high potassium contents. These soils are in general deficient in DTPA extractable zinc and manganese contents (Table 4). The soil data set in Majuli island (1:50000 scale) was obtained from soil resource inventory on 1:50000 scale using Indian Remote Sensing (IRS-ID) satellite imagery and corresponding toposheets of Survey of India with the emphasis on transects that cut across the segments of inland valleys from the top to the bottom (Bhaskar *et al.*, 2008).

Land capability classification

Land capability classification was used to evaluate the capability of land on a long-term sustainable basis. The system of land capability classifies land into a number of

Table 4 - Nutrient status in surface horizons of soils

Soil series	Available ($kg \cdot ha^{-1}$)			DTPA extractable ($mg \cdot kg^{-1}$)			
	N	P_2O_5	K_2O	Mn	Fe	Cu	Zn
Sonaribari (Sb)	874 (H)	46.2 (M)	584 (H)	17.3	128	10.4	0.84
Bharaki (Bi)	655 (H)	12.6 (L)	206 (M)	4.9*	110	9.7	0.46*
Bhakat (Bt)	437 (M)	8.4 (L)	172 (M)	2.3*	23.0	3.6	0.34*
Boritika (Ba)	582 (H)	37.8 (M)	275 (M)	13.3	444	6.0	0.54*
Adielengi (Ae)	509 (M)	46.2 (M)	310 (H)	5.1*	1.5	4.4	0.48*
Puranibari (Pb)	655 (H)	37.8 (M)	344 (H)	30.8	2500	3.3	0.52*
Kamalabari (Kb)	655 (H)	5.2 (L)	378 (H)	11.0	114	4.7	0.54*
Chilkala (Ch)	291 (M)	23.6 (L)	344 (H)	1.0*	156	7.5	0.58*
Gayangaon (Gn)	801 (H)	25.2 (L)	378 (H)	3.6*	101	5.7	0.36*
Dakshinpat (Dh)	1456 (H)	26.2 (L)	447 (H)	30.0	495	10.5	0.52*
Bongaon (Bn)	510 (M)	25.2 (L)	206 (M)	7.5*	82	3.9	0.30*
Garumara (Ga)	582 (H)	31.2 (M)	344 (H)	23.6	226	3.8	0.62*
Majuli (Mi)	582 (H)	25.1(L)	104 (L)	9.5	34	7.4	1.28

classes according to the land's capability to produce agricultural goods (based on broad scale grazing and cropping uses). There are generally three levels to the land capability classification: - The land capability class - which gives an indication of the general degree of limitation to use; subclass - which identifies the nature of the dominant limitation; and the unit - which groups together similar types of land requiring the same kind of management. The map units were assigned to the dominant land capability subclass as per the scheme of Grose (1999). The schematic soil-landscape diagram in the island is presented in Fig. 2.

Soil quality assessment

The soil quality indicators for crop production were selected using the approach suggested by Cameron *et al.* (1998). The approach is based on the equation: A = (S, U, M, I, R) where A = acceptance score for indicators, S = sensitivity of the indicators to degradation or remediation process, U = ease of understanding of indicator value, M = ease and/ or cost effectiveness of measurement of soil indicators, I = predictable influence of properties on soil, plant and animal health and productivity, R = relationship to ecosystem processes (especially those reflecting wider aspects of environmental quality and sustainability). Each parameter in the equation was given a score of 1 to 5 based on experience. The acceptance score for indicators were derived by dividing sum of scores of an individual indicator by total score (25) and then

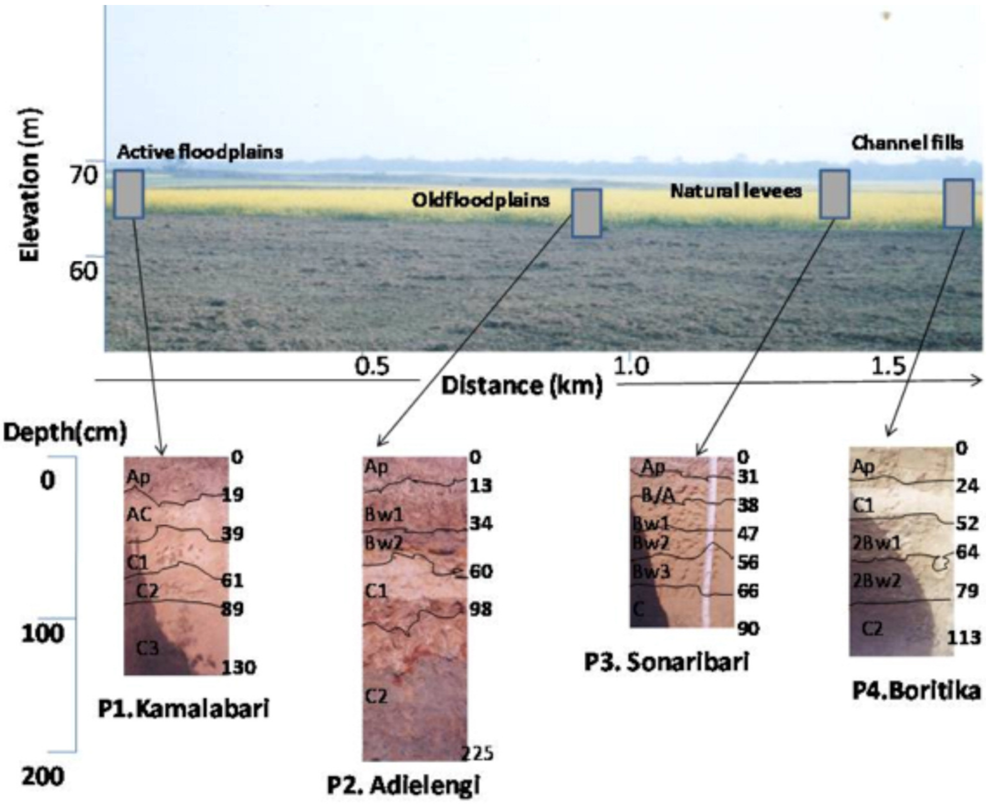

Fig. 2 – Soil-landscape relationships in Majuli island

multiplied with 100. For example, the assigned score for organic carbon was as follows (S = 4, U = 5, M = 3, I = 4 and R = 4), then the Acceptance score (A) = 20/25 x100 = 80%.

The following indicators were selected for soil quality assessment: pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases, cation exchange capacity, texture, structure, effective rooting depth and available water holding capacity as suggested by Lal (1994) in the tropical region. The quality of the hydric soils for crop production was assessed using multiple variable indicator transform (MVIT) (Smith *et al.*, 1994). The indicators were transformed on the basis of their ability to attain critical level or range was scored as 1 and anyone below critical as 0. Later these were integrated into *percentage* quality rating (%Q rating) as %Q = Number of indicators that attain critical level / total number of indicators assessed X100.These ratings were further grouped as High (% Q rating > 65), medium (% Q rating 35 to 65) and low (% Q rating <35). This methodology was applied in assessing soil quality of Idoffa in Ogun state of Southwestern Nigeria (Oluwatosin *et al.*, 2006) but not tested with reference to any crop.

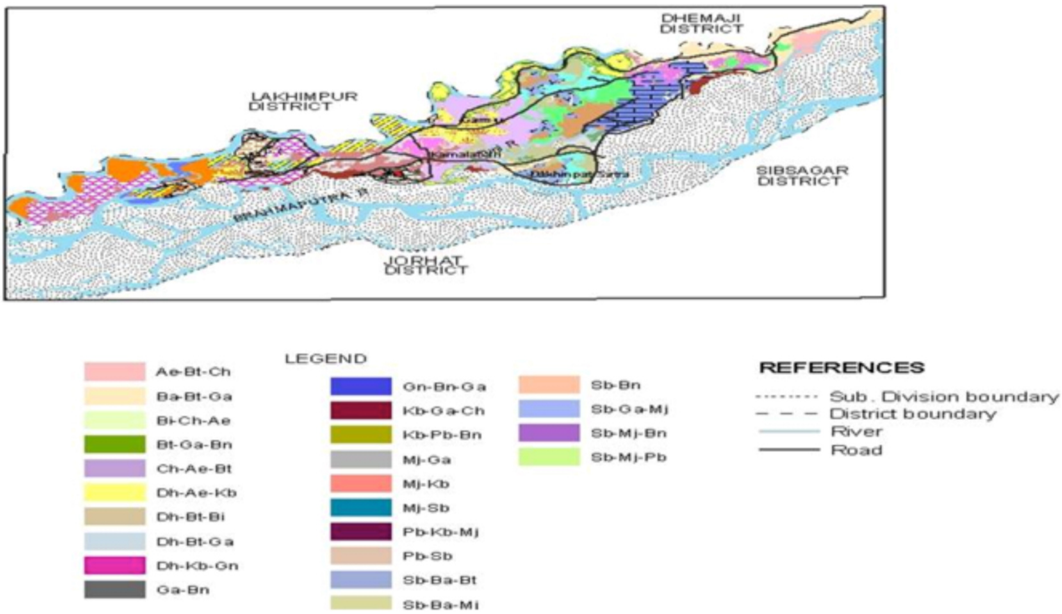

Fig 3 - Soil Map in Majuli island

Results and Discussion

Soil mapping units

Thirteen soil series were identified and twenty five mapping units as series association were derived to generate soil map using ARCINFO 8 version for GIS analysis (Fig. 3 and Table 5). These associations in the island were recognized by knowing textural sequence, flooding frequency and surface organic carbon contents. The mapping units defined here are mostly two to three series association with proportion of 60% (dominant) : 40% (subdominant) in case of two soil series association whereas 45 % (dominant) 30 % and 25% (subdominant) in case of three series association. The active floodplains covering 17991ha (16.3% of total area) have 58% of area under the three mapping units viz., 7.Dh-Bt-Bi (3456 ha), 12.Kb-Ga-Ch (3579 ha) and 18.Pb-Sb (3376 ha). The total area under sand bars is 46371 ha with eleven mapping units. Out of eleven units, only four mapping units are dominant: 10.Ga-Bn (5885 ha), 14.Mj-Ga (11789 ha), 15.Mj-Kb (16048 ha) and 24.Sb-Mj-Pb (4801 ha) covering 83.07% of sand bar area in the island. The swamps cover 14931 ha (13.6%) with sixteen mapping units wherein three units viz., 3. Bi-Ch-Ae (2022 ha), 4.Bt-Ga-Gn (2977 ha) and 23. Sb-Mj-Bn (2393 ha) have more than 2000 ha of

Table 5 - Soil mapping unit and their extent in each geomorphic units

Soil mapping unit	Area of Geomorphic units (Hectares)							Total (Hectares)
	Active flood plains	Sand bars with grass cover	Sand bars	Swamps	Old flood plains	Channel fills	Natural levees	
1.Ae-Bt-Ch	--	-	-	119	1311	-		1430
2.Ba-Bt-Ga	94	-	-	677	1022	-	-	1792
3.Bi-Ch-Ae	261	-	-	2022	1810	-	-	4093
4.Bt-Ga--Bn	1051	-	-	2977	1232	225	-	5485
5.Ch-Ae-Bt	250	-	-	39	-	1076	-	1364
6.Dh-Ae-Kb	13	-	-	1086	-	-	-	1099
7.Dh-Bt-Bi	3456	-	-	-	343	20	-	3819
8.Dh-Bt-Ga	745	-	-	-	-	595	-	1340
9.Dh-Kb-Gn	711	-	-	-	-	1549	-	2260
10.Ga-Bn	744	4539	1346	1979	-	39	-	8647
11.Gn-Bn-Ga	-	-	26	448	85	-	-	559
12.Kb-Ga-Ch	3579	-	-	59	230	640	-	4508
13.Kb-Pb-Bn	139	-	-	370	75	1816	-	2398
14.Mj-Ga	199	2629	9160	-	-	108	-	12096
15.Mj-Kb	700	1137	14911	-	86	-	5789	22623
16.Mj-Sb	30	820	4456	-	-	81	-	5381
17.Pb-Kb-Mj	1653	-	736	58	-	487	108	3042
18.Pb-Sb	3376	615	355	806	38	49	-	5239
19.Sb-Ba-Bt	62	-	926	315	179	2323	-	3805
20.Sb-Ba-Mj	241	-	-	623	-	3526	-	4390
21.Sb-Bn	-	-	-	-	536	-	178	714
22.Sb-Ga-Mj	455	-	-	961	-	421	42	1879
23.Sb-Mj-Bn	-	109	74	2393	-	-	344	2921
24.Sb-Mj-Pb	-	4441	360	-	-	-	3208	8009
25.Sb-Mj-Kb	231	112	765	-	-	--	78	1186
Total	**17991**	**14402**	**31969**	**14931**	**6946**	**12953**	**9747**	**110085**
Per cent	**16.3**	**13.1**	**30.1**	**13.6**	**6.3**	**11.8**	**8.9**	**100**

land. The old floodplains have 6.3% of study area (6946 ha) with twelve mapping units. Out of twelve units, four mapping units near by Tuni river in Kamalabari area (1.Ae-Bt-Ch-1311 ha; 2.Ba-Bt-Ga-1022 ha, 3.Bi-Ch-Ae-1810 ha and 4.Bt-Ga-Bn-1232 ha) cover 77% of the area in old flood plains. The channel fills cover 12953 ha (11.8%) with fifteen mapping units. The mapping units viz., 19.Sb-Ba-Bt and 20. Sb-Ba-Mj cover 5849 ha accounting 45%. The natural levees occupy 8.9 % of area with two dominant mapping units such as 15.Mj-Kb (5789 ha) and 24.Sb-Mj-Pb (3208 ha).

Land capability classification

The soil environmental factors in the island strongly advocate to adopt modified and simplified version of land capability classification (Grose, 1999 and Ahmad, 1996) with some similarity to USDA system (Klingebiel and Montgomery, 1961). The ground water and flood frequency are included as major factors in deciding capability class. Seven capability classes as suggested by Grose (1999) were adopted but decided not to include subclasses. Each identified soil series were mapped as associations and were considered in land capability classification. The soil units were classified in five capability classes from class II to class VI with justification (Table 6). The swamps and sand bars covering 56 per cent of total area (61302 ha) are excluded because these units were classified under class VII and are privileged sites for migratory birds and highly inaccessible places.

The class II soil units cover 17306 ha (15.72% of total area) consisting of three land forms viz., active flood plains (13338 ha, 12.03% and 8 soil units), old flood plains (2252 ha, 2.04%, 5 soil units) and channel fills (1816 ha, 1.65%, 1 soil unit). These soils are good for agriculture with ground water below 1m during rainy season with silt loam to loam textures and rapid permeability.

The class III soil units cover 16922 ha (16.88 % of total area) and geographically associated with channel fills (6.69 % with 3 soil units), natural levees (5.26%, 1 soil unit), active flood plains (2.74%, 6 soil units) and old flood plains (2.19%, 3 soil units). These soils usually occur in depressions and prone to seasonal flooding in wet season with high organic carbon.

The class IV soil units cover 9046 ha (8.22 % of total area) with limitations of frequent flooding and subjected to bankline erosion. In many places, these units are covered with grasses and in some places used for mustard cultivation. The class V and VI units in channel fills and natural levees cover 3684 ha (2.32%) with high degree of waterlogging and flooding risk (3 floods in year) which has a significant impact on workability, trafficability and crop physiological effects.

Table 6 - Description and extent of soil mapping unit capability classification

Land capability class	Land forms	Soil mapping units	Area ha	Area (%)	Description
II	Active floodplains	3.Bi-Ch-Ae	261	0.24	Mostly soils are silt loam to silty clay loam, poorly drained, dark grey to grey, neutral to strongly acid surface horizons with ground water below 1 m. Suitable for rice during rainy season and for mustard in post rainy season in parts of north eastern and central parts of Island.
		7.Dh-Bt-Bi	3456	3.14	
		10.Ga-Bn	744	0.68	
		12.Kb-Ga-Ch	3579	3.25	
		13.Kb-Pb-Bn	139	0.13	
		16.Mj-Sb	30	0.03	The southern parts of island has light grey, loamy sands to sandy loam, moderately well drained, slightly alkaline soils, groundwater below 1.5m strongly associated with sand bars in the main stream. These soils are mostly used for mustard during post monsoon period.
		17.Pb-Kb-Mj	1653	1.50	
		18.Pb-Sb	3376	3.07	
		Total	**13238**	**12.03**	
	Old floodplains	4.Bt-Ga--Bn	1232	1.12	These soils have grey to dark grey or olive grey matrix with distinct brown mottles in solum, silty loam to loam or silty clay textures with clay less than 18% and silt more than 50%, moderately acid to slightly alkaline in reaction with ground water table below 2m and sand base usually appears below 1.5 m. These soils are intensively used for paddy-mustard system and concentrated near Tuni river .
		12.Kb-Ga-Ch	230	0.21	
		13.Kb-Pb-Bn	75	0.07	
		19.Sb-Ba-Bt	179	0.16	
		21.Sb-Bn	536	0.49	
		Total	**2252**	**2.04**	
	Channel fills	13.Kb-Pb-Bn	1816	1.65	The soils are stratic with grey to dark grey, loam/loamy sand/silty clay loam textures with clay less than 18% and silt more than 40%, slightly to moderately acid A horizons and suitable for paddy-mustard, groundwater table below 2 m, moderately well drained.
		Total	**1816**	**1.65**	
III	Active floodplains	4.Bt-Ga--Bn	1051	0.95	These soils are moderately well drained on ridges but poorly drained in low lying areas, with silt loam textures having high saturated hydraulic conductivity and sand base below 1.5 m. These soils have olive grey matrix with brown mottles in solum. Suitable for paddy cultivation.
		5.Ch-Ae-Bt	250	0.23	
		9.Dh-Kb-Gn	711	0.65	
		15.Mj-Kb	700	0.64	These are sand depositional areas in southern banks of Island with moderately well drained stratic soils having light grey matrix with loamy sand textures. Mostly covered with tall grasses. High risk zones of bankline erosion.
		19.Sb-Ba-Bt	62	0.06	
		20.Sb-Ba-Mj	241	0.22	
		Total	**3015**	**2.74**	
	Old flood plains	1.Ae-Bt-Ch	1311	1.19	These soils have grey, silt loam weak subangular blocky structures with lithological discontinuities, neutral in reaction with moderate to high saturated hydraulic conductivity and water table below 1m with distinct brown mottles. Mostly used for rice – potato and mustard.
		2.Ba-Bt-Ga	1022	0.93	
		11.Gn-Bn-Ga	85	0.08	
		Total	**2418**	**2.19**	
	Channel fills	19.Sb-Ba-Bt	2323	2.11	These soils have olive grey to dark grey, silty clay loam to silt loam textures with moderate saturated hydraulic conductivity, frequent flooding and high erosion risk zone in southern banks, moderately to poorly drained. Mostly covered with tall grasses.
		20.Sb-Ba-Mj	3526	3.20	
		22.Sb-Ga-Mj	421	0.38	
		Total	**6270**	**5.69**	
	Natural levees	15.Mj-Kb	5789	5.26	
		Total	**5789**	**5.26**	
IV	Active floodplains	8.Dh-Bt-Ga	745	0.68	These soils have dark grey silty clay loam textures with clay of 35 to 40% and gradational negative in subsequent layers to 11 per cent, low saturated hydraulic conductivity with poor internal drainage, groundwater table is below 0.5 m during rainy season but recedes to 1.5 m in winter. Mostly covered with grasses. This unit comprised of very low bars which are submerged with slight increase of inflow
		14.Mj-Ga	199	0.18	
		22.Sb-Ga-Mj	455	0.41	
		25.Sb-Mj-Kb	231	0.21	
		Total	**1630**	**1.48**	
	Old floodplains	3.Bi-Ch-Ae	1810	1.64	These soils have grey, silt loam weak subangular blocky structures with lithological discontinuities, neutral in reaction with moderate to high saturated hydraulic conductivity and water table below 1m with distinct brown mottles. Mostly used for rice – potato and mustard.These units in southern bank have loamy sand textures with high flood risk in southern banks .
		7.Dh-Bt-Bi	343	0.31	
		15.Mj-Kb	86	0.08	
		18.Pb-Sb	38	0.04	
		Total	**2277**	**2.07**	
	Channel fills	4.Bt-Ga-Bn	225	0.20	These soils are moderately well drained on ridges but poorly drained in low lying areas, with silt loam textures having high saturated hydraulic conductivity and sand base below 1 m. These soils have olive grey matrix with brown mottles in solum. These channel fills are close to northern bank of Subansiri. Mostly used for mustard cultivation.
		5.Ch-Ae-Bt	1076	0.98	
		14.Mj-Ga	108	0.09	
		Total	**1409**	**1.28**	
	Natural levees	21.Sb-Bn	178	0.16	These soils have grey to dark grey or olive grey matrix with distinct brown mottles in solum, silt loam to loam or silty clay textures with clay less than 18 % and silt more than 50%, moderately acid to slightly alkaline in reaction with ground water table below 2 m and sand base usually appears below 1.5 m. These soils are subjected to very high bankline erosion and frequent flooding every year. This is 0.5 to 3 m high in the river bed with scanty vegetation with short seasonal grass cover.
		23.Sb-Mj-Bn	344	0.31	
		24.Sb-Mj-Pb	3208	2.91	
		Total	**3730**	**3.39**	
V	Channelfills	7.Dh-Bt-Bi	20	0.02	These soils are moderately well drained on ridges but poorly drained in low lying areas, with silt loam textures having high saturated hydraulic conductivity and sand base below 1.5 m. These soils have olive grey matrix with brown mottles in solum. Suitable for paddy cultivation. These are sandbars is 3 to 5 m high over riverbed, submerged during moderate to high inflow period and holds tall grasses.
		8.Dh-Bt-Ga	595	0.54	
		9.Dh-Kb-Gn	1549	1.41	
		16.Mj-Sb	81	0.07	
		Total	**2245**	**1.01**	
	Natural levees	17.Pb-Kb-Mj	487	0.44	These units have linear channel with deposition inside the meander bends and are elongated or triangular in shape. They emerge during low flow stage. The soils are grey to greyish brown with abrupt textural sequences viz., loam, silt loam, sandy or loamy sand with prominent brown mottles and weak/ moderate, medium subangular blocky structures. These soils are subjected to very high erosion and flooding during moderate to high flow periods.
		22.Sb-Ga-Mj	42	0.04	
		Total	**529**	**0.48**	
VI	Natural levees	10.Ga-Bn	39	0.04	This unit is at least 5 to 6 m high with high bars, islands and banks with 4 to 6 m high supporting tall grasses, trees and shrubs, This is submerged during exceptionally high floods. This unit has grey to dark grey silt loam, fine subangular blocks with distinct brown mottles.
		12.Kb-Ga-Ch	640	0.58	
		25.Sb-Mj-Kb	78	0.07	
		Total	**757**	**0.69**	

Assessment of Soil quality

The nine soil indicators selected on the basis of Cameron *et al.* (1998) present soil quality ratings for each soil mapping unit (Table 7). The mean computed threshold values for nine soil indicators is as follows: - 50 for organic carbon, 53 for total nitrogen, 57 for structure, 59 for pH and available phosphorus, 67 for available water holding capacity, exchangeable bases and cation exchange capacity and 71 for texture. The low values are assigned to sensitivity to degradation (S), influence of properties on plant and animal health (I) and relationship to ecosystem processes (R). The soil unit wise indicators showing below threshold values in quality assessments are listed as:- the texture in 9 units, organic carbon in 15 units, total nitrogen in 11 mapping units, available phosphorus, pH, exchangeable bases and cation exchange capacity in 12 mapping units and structure and available water holding capacity in 13 units (Table 6). Six mapping units 1, 2, 3, 5, 6 and 7 have low quality rating (<35%) with 1 to 3 soil indicators meeting the threshold requirements for crop production whereas eleven mapping units 4, 8, 10, 12, 13, 15, 16, 19, 20, and 21 have 4 to 5 indicators meeting threshold values of medium quality (35 to 65%) and eight mapping units 9, 11, 14, 18, 22, 23, 24 and 25 with 6 to 8 indicators meeting high quality ratings above 65%.

The arable soil mapping units (from class II to class IV) were grouped further in accordance with landforms and soil quality (Table 8). The fourteen soil mapping units in class II (17306 ha, 15.72%), are further grouped as per quality rating into three categories such as low (2 units in active flood plains), medium (11 units) and high (1 unit). The Puranibari - Sonaribari soil mapping unit (18) has high quality of selected indicators above the threshold values except total nitrogen content whereas medium quality soils are seasonally flooded with shallow ground water tables throughout year and neutral to slightly alkaline with low Potassium reserves. The low quality rating is due to pH and total nitrogen (Bharaki – Chilkala - Adielengi, 3) and (Dakshinpat - Bhakat and Bharaki, 7).

The class III has 13 soil units covering 16.9 per cent of area but have only 1.11 per cent (1217 ha) under high quality, 7.19 per cent (7903 ha) under medium quality and 2.35 per cent (2583 ha) under low quality. The class IV has 14 units covering 8.22 per cent of area (9046 ha), of which 3.88 per cent of area is under high quality soil associations followed by 1.39 per cent of area (1541 ha) under medium quality and 2.93 per cent of area (3229 ha) under low quality. The soil quality and its relationship with capability classes implies that pH and organic matter are crucial in modifying soil structure and its influence in water retention and nutrient availability. The soil quality assessment in riverine islands with flat to gentle slopes is helpful to identify the areas subjected to ferrolysis (Brinkman, 1970) and compare units under different rice management systems of special interest such as Bao and Boro/ Ahu seasonal systems.

Table 7 - Soil quality rating for rice production function

Soil mapping unit(SMU)	Soil quality rating										Category
	pH	Organic carbon	Total Nitrogen	Available phosphorus	Exchangeable bases	CEC	Texture	Structure	AWC	Quality rating (QR,%)	
1.Ae-Bt-Ch	64(1)	47(0)	55(1)	56(0)	65(0)	64(0)	68(0)	52(0)	60(0)	22	low
2.Ba-Bt-Ga	56(0)	49(0)	57(1)	56(0)	71(1)	65(0)	64(0)	56(0)	65(0)	22	low
3.Bi-Ch-Ae	67(1)	47(0)	53(0)	53(0)	65(0)	61(0)	64(0)	51(0)	64(0)	11	low
4.Bt-Ga--Bn	59(0)	52(1)	59(1)	60(1)	64(0)	67(1	68(0)	56(0)	61(0)	44	medium
5.Ch-Ae-Bt	64(1)	47(0)	55(1)	56(0)	65(0)	64(0)	68(0)	52(0)	60(0)	22	low
6.Dh-Ae-Kb	59(0)	44(0)	51(0)	61(1)	65(0)	60(0)	71(1)	63(1)	64(0)	33	low
7.Dh-Bt-Bi	55(0)	47(0)	55(1)	56(0)	67(0)	65(0)	67(0)	55(0)	71(1)	22	low
8.Dh-Bt-Ga	57(0)	47(0)	57(1)	60(1)	64(0)	67(1	69(0)	61(1)	69(1)	56	medium
9.Dh-Kb-Gn	45(0)	43(0)	59(1)	60(1)	72(1)	61(0)	73(1)	67(1)	68(1)	67	high
10.Ga-Bn	31(0)	54(1)	58(1)	62(1)	62(0)	66(0)	73(1)	60(1)	60(0)	56	medium
11.Gn-Bn-Ga	53(0)	49(0)	61(1)	60(1)	68(1)	67(1	73(1)	61(1)	63(0)	67	high
12.Kb-Ga-Ch	60(1)	47(0)	61(1)	57(0)	67(0)	60(0)	73(1)	61(1)	65(0)	44	medium
13.Kb-Pb-Bn	52(0)	49(0)	56(1)	64(1)	68(1)	61(0)	73(1)	63(1)	64(0)	56	medium
14.Mj-Ga	68(1)	50(0)	56(1)	60(1)	60(0)	72(1	73(1)	58(1)	66(1)	78	high
15.Mj-Kb	58(0)	48(0)	54(1)	60(1)	66(0)	66(0)	73(1)	58(1)	62(0)	44	medium
16.Mj-Sb	70(1)	48(0)	44(0)	56(0)	70(1)	78(1	73(1)	52(0)	68(1)	56	medium
17.Pb-Kb-Mj	56(0)	47(0)	55(1)	69(1)	67(0)	65(0)	73(1)	61(1)	68(1)	56	medium
18.Pb-Sb	62(1)	54(1)	48(0)	60(1)	74(1)	70(1	73(1)	60(1)	78(1)	89	high
19.Sb-Ba-Bt	57(0)	54(1)	51(0)	56(0)	75(1)	69(1	65(0)	55(0)	71(1)	44	medium
20.Sb-Ba-Mj	63(1)	54(1)	47(0)	57(0)	72(1)	73(1	67(0)	56(0)	69(1)	56	medium
21.Sb-Bn	64(1)	54(1)	46(0)	58(0)	72(1)	72(1	74(1)	54(0)	62(0)	56	medium
22.Sb-Ga-Mj	69(1)	54(1)	51(0)	57(0)	73(1)	73(1	73(1)	56(0)	69(1)	67	high
23.Sb-Mj-Bn	65(1)	54(1)	47(0)	59(1)	68(1)	67(1	72(1)	53(0)	61(0)	67	high
24.Sb-Mj-Pb	64(1)	54(1)	48(0)	60(1)	69(1)	73(1	75(1)	57(1)	72(1)	89	high
25.Sb-Mj-Kb	63(1)	54(1)	49(0)	57(0)	71(1)	69(1	75(1)	56(0)	67(1)	67	high

Table 8 - Mapping unit wise soil quality ratings in relation to landforms and capability class

Soil quality rating	Landforms	Land capability class II: Soil mapping unit	II Area HA	II Area %	III: Soil mapping unit	III Area HA	III Area %	IV: Soil mapping unit	IV Area HA	IV Area %
Low (<35%)	Active floodplains	3.Bi-Ch-Ae 7.Dh-Bt-Bi	3717	3.38	5. Ch-Ae-Bt	250	0.23	-	-	-
	Old flood plains	--	--	--	1.Ae-Bt-Ch 2.Ba-Bt-Ga	2333	2.12	3.Bi-Ch-Ae 7.Dh-Bt-Bi	2153	1.95
	Channel fills	--	--	--	--	--	--	5. Ch-Ae-Bt	1076	0.98
	Natural levees	--	--	--	--	--	--	--	--	--
Medium (35-65%)	Active floodplains	10.Ga-Bn 12.Kb-Ga-Ch 13. Kb-Pb-Bn 16. Mj-Sb 17. Pb-Kb-Mj	6145	5.59	4.Bt-Ga—Bn 15.Mj-Kb 19.Sb-Ba-Bt 20.Sb-Ba-Mj	2054	1.88	8.Dh-Bt-Ga 14.Mj-Ga	944	0.86
	Old flood plains	4.Bt-Ga--Bn 12.Kb-Ga-Ch 13. Kb-Pb-Bn 19. Sb-Ba-Bt 21. Sb-Bn	2252	2.04	---	--	--	15.Mj-Kb	86	0.08
	Channel fills	13.Kb-Pb-Bn	1816	1.65	19.Sb-Ba-Bt 20.Sb-Ba-Mj	5849	5.31	4.Bt-Ga-Bn 14.Mj-Ga	333	0.29
	Natural levees	--	--	--	15.Mj-Kb	5789	5.26	21.Sb-Bn	178	0.16
High (>75%)	Active floodplains	18.Pb-Sb	3376	3.07	9.Dh-Kb-Gn	711	0.65	22.Sb-Ga-Mj 25.Sb-Mj-Kb	686	0.62
	Old flood plains	--	--	--	11.Gn-Bn-Ga	85	0.08	18.Pb-Sb	38	0.04
	Channel fills	--	--	--	22.Sb-Ga-Mj	421	0.38	--	--	--
	Natural levees	--	--	--				23.Sb-Mj-Bn 24.Sb-Mj-Pb	3552	3.22

Table 9 - Distribution and extent of modifiers in fertility capability units of wetlands

FCC modifiers	Extent of area (ha)			Total area	
	Active flood plains	Oldflood plains	Channel fills	(ha)	(%)
g* (pergleyic, soil profile saturated for more than 200 days)	11195 (42.6%)	3565 (13.6%)	11525 (43.9%)	26285	78.6
k-low reserves of potassium and weatherable minerals	16015 (47.9%)	5911 (17.7%)	11525 (34.45%)	33451	100
b-basic reaction(pH>7.3)	1751 (57.18%)	1311 (42.82%)	-	3062	9.2
e-Low cation exchange capacity	2540 (21.48%)	1022 (8.64%)	8260 (69.86%)	11822	35.3

Agronomic interpretation

The soils in the island are saturated for more than 200 days per year with matrix chroma less than 2 and moderate structural B horizons. The fine loamy soils have mean clay content of 18 to 27 per cent in Puranibari (Pb), Dakshinpat (Dh) but in other soils, the clay content is less than 16 per cent. It is ascertained from the literature that clay textures are superior to silt and sand textures for rice production (Moormann and Dudal, 1964). These soils are slightly acid to neutral with stratified layers and soft nodules of Fe and Mn oxides near the zone of fluctuating water tables (Vespraskas, 2000). These soils are subjected to ferrolysis due to repeated regular cycles of oxidation and reduction leading to silicate clay destruction with abrupt textural changes and leaching of exchangeable bases resulting to poor cation exchange capacity. The modifier "g*" is used as a special modifier to designate prolonged water logging (Table 9) and gleying in these soils with an additional modifier "e" for nitrogen management and "k" for nutrient imbalance such as Ca, K and Mg. All soils are deficient in available potassium where as 9.2 % of soils are basic mostly occurring on channel fills with Fe deficiency when aerobic, Zn deficiency when waterlogged and high volatile N losses from broadcast N application. 35.3 per cent of soils have low cation exchange capacity, less gradual N release and potential Fe toxicity if adjacent uplands have Fe rich soils (Table 7). The flooded rice grown on these soils have high iron favouring deficiencies of phosphorus, potassium (Akagare type -1) and Zn deficiency (Tanaka and Yoshida, 1970). The soil mapping units in active and old floodplains have potassium deficiency (Bhaskar *et al.*, 2010b) as the ratio between exchangeable calcium and magnesium to exchangeable potassium is more than 100 (Tandon and Sekhon, 1988) and also have K saturation less than 1.5 per cent (Dobermann and Fairhurst, 2000)

Conclusions

The wet land soil resource information of Majuli Riverine Island with thirteen soil series and twenty five soil mapping units was used to assess soil quality and capability with special consideration to rice production systems dominant over years. The island had 43 per cent of arable land with 12.39 per cent of soil units under medium quality, 8.66 per cent of soil units under low quality and 8.1 per cent of soil units with high quality. Flood frequency and erosion risk hazard were two important factors influencing land capability whereas soil organic matter, pH, available phosphorus and exchangeable bases are soil quality controlling factors. The soil mapping units in channel fills have low cation exchange capacity and low potassium reserves as compared to active and old flood plains. The rice grown on these soils (8.22 % of total area) have high iron with deficiencies of phosphorus, potassium and zinc. Hereby concluded that the land capability and soil quality assessment are jointly responsible for workable solutions to rice production under different management systems in the island.

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