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Characterization, Classification and Evaluation of Soil Resources in Coastal Eco-system- A Case Study of Gosaba Block (Part), South 24 Parganas, West Bengal

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Abstract: Three representative soils of coastal ecosystem of Gosaba block (Part), South 24 parganas district of West Bengal were studied for their characterization and classification. The soils were very deep, moderately well drained to somewhat poorly drained, strongly acidic to neutral in reaction (3.2 to 7.3), moderately-saline (1.0 to 12.5 dSm^{-1}), brown to dark grey in colour, silt loam to silty clay in texture, sub-angular blocky in structure, low to high in organic carbon content (2.3 to 13.3 g kg^{-1}) and low in cation exchange capacity [11.9 to 18.2 cmol (p^+) kg^{-1}] and base saturation (45 to 80%). The soils have high amount of silt and clay fractions which do not show any trend in different depths. Among the exchangeable cations, calcium was found to be high in all soils, followed by sodium magnesium, and potassium. Based on the morphological, physical and chemical characteristics, soils were classified as Inceptisols soil order and further, classified as *Typic Halaquepts*, *Typic Endoaquepts*, and *Fluventic Endoaquepts* at sub group level. Three land capability sub-classes *viz.* IIIsw (54.15%), IIw (16.73%) and IIws (29.12%) were identified and suitable land use options were suggested.

Key words: *Soil characterization, classification, evaluation and land use*

Introduction

The coastal agro-ecosystem occupies about 10.78 million hectares (1,07,833 km^2) in India, coastal region covers a long strip along the East coast (West Bengal, Orissa, Andhra Pradesh, Pondicherry and Tamil Nadu) and West coast (Gujarat, Maharashtra, Karnataka and Kerala). It also occupies considerable area under Lakshadweep and Andaman and Nicobar group of Islands. About 20% of the population of India lives in coastal areas (FAO. 2005). The great Sundarbans (delta region of the river Ganges) occur in the coastal tracts of West Bengal and constitute a major portion of coastal region of India with wide variability in climatic, topographical and edaphic conditions (Mitran *et al.* 2014). In the coastal agro-ecosystem, with the increasing human and animal population, the competition between various land uses has become intensive. Sundarbans face the problem of salinity, water logging and drainage congestion (Bandyopadhyay *et al.* 2001) and salt affected soils stand to be one major challenge in preventing agricultural activities. Therefore, understanding of coastal soils and their properties is necessary for judicious and optimal use on suitable basis (Prasad *et al.* 2009). Hence, an attempt has been made to characterize, classify and evaluate the soil resource (Part of Gosaba block, South 24 parganas district of West Bengal) to achieve sustainable yield of crops in coastal region along with maintaining soil health.

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Materials and Methods

The study area, Gosaba block is located in the North-Eastern part of South 24 Parganas district, West Bengal and lies between 21°32'7" to 22°17'17" N latitude and 88°42'14" to 89°04'30" E longitude and covering an area of 4173 ha, comprises 15 villages (Fig. 1). Geologically the area comprises of sub-recent and recent alluvium of the Ganga river system. The major landform is very gently sloping (0-1%) and nearly level (1-3%) which have elevation less than 10 m above mean sea level. The climate is subtropical, sub humid with hot humid summers and cool winters, with mean annual rainfall of 1400 mm and mean annual temperature is 27°C. The area qualifies for *hyperthermic* soil temperature regime and *aquic* soil moisture regime. The area belongs to Agro-eco Sub Region (AESR) 18.5, which is hot subhumid

plain with length of growing period (LGP) of 180-210 days. Major land uses are *kharif* paddy followed by fallow in *rabi*. In some pockets, farmers are cultivating paddy-paddy, paddy-vegetables, paddy-pulses (bore well irrigation). Detailed soil survey was carried out on 1:10,000 scale by using base map prepared from image of remote sensing satellite data (IRS-P6 LISS IV) in conjunction with village cadastral map and Survey of India (SOI) toposheets for physiographic delineation.

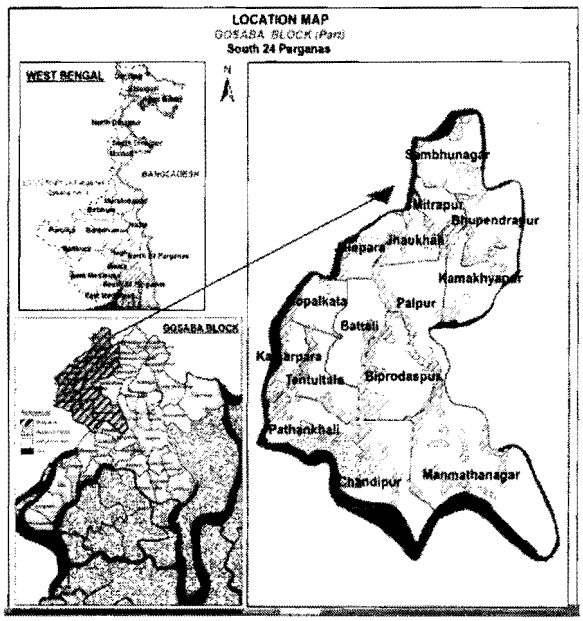
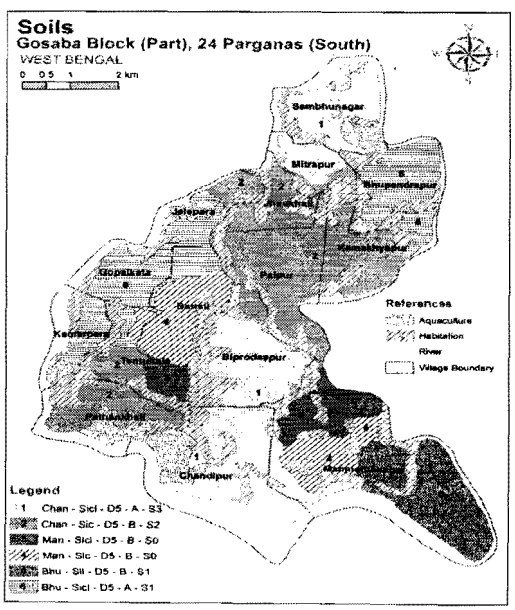


Fig. 1 Location map of study area

Profile observations and auger samplings were done to cover all the major landform units. Totally, 12 representative pedons were studied. After final correlation, three soil series (Chandipur, Manmathanagar and Bhupendrapur) with six mapping units were established (Fig. 2). The horizon-wise soil samples were collected, processed and analyzed for various physical and chemical properties *viz.* pH, EC, ECe, organic carbon, mechanical analysis, cation exchange capacity (CEC), exchangeable bases, base saturation and soluble salts using standard methods (Black 1965; Jackson 1973; Page *et al.* 1982). The soils were classified as per guidelines given in Key to Soil Taxonomy (Soil Survey Staff 2010). Land Evaluation of the identified soil series was carried out through Land Capability Classification (AISLUS. 1970 and Sys *et al.* 1991).



Chan- Chandipur soils, Man- Manmathanagar soils, Bhu-Bhupendranagar soils; sic-silty clay, sicl-silty clay loam, sil-silt loam; D5-very deep; A-slope (0-1%), B-slope (1-3%); S3- severe salinity, S2-moderate salinity, S1-slight saline, S0-very slight saline.

Fig. 2 Soil map of the study area

Results and Discussion

Soil Morphology

Brief morphological features of representative pedons of soil series are presented in Table 1. The pedons of coastal plain under study area are very deep. Soils had their Munsell colour notation in the hue of 10YR and 2.5YR with value 5 to 4 and chroma 3 to 1. Soils of Chandipur and Manmathanagar series had greyish brown colour (10YR5/2) in surface soils and grey to dark grey (10YR4/1) colour in sub surface horizons. In Bhupendrapur series surface soil colour was grey (10YR5/1) and dark greyish brown (2.5YR4/2) in sub soil. Chandipur series has sporadic distribution of jarosite mottles (conir) in after 15 cm of soil depth, which have fine common nodules, colour varying from yellowish brown (10YR5/6) to olive brown (2.5YR5/4) which may be due to presence of sulphuric materials (Sarkar *et al.* 2001). Manmathanagar and Bhupendrapur series do not have any clear jarosite mottle, but Fe concretion was observed in lower horizons; it may be due to aquic moisture conditions. Soil texture varied from silt loam to silty clay. The textural variation might be due to parent material deposition during different periods, (transported by the river). The structure of soils was sub angular blocky type. The dry consistency is observed only in surface layer slightly hard, moist consistency is friable, slightly sticky to slightly plastic. Based on clay content, CEC and base saturation, it was observed that, all the series do not have any specific characteristic to qualify for a particular diagnostic horizon and therefore qualify for *ochric* epipedons. However, the lower horizons are physically and chemically altered due to the alteration of texture, structure and colour, hence qualifying for *cambic* endopedons.

Physical characteristics

The particle size class data (Table 1) indicated that sand, silt and clay content of soils varied from 0.1 to 76.8%, respectively. Granulometric data revealed that the clay content varied from 21.2 to 45.6%. The irregular distribution of clay is observed in all the series, which may be due to river water fluctuations during different periods. In subsequent horizons, the clay content gradually increased and then decreased. Silt content in all pedons was high (53.8-76.8%) and exhibited an irregular trend with depth. Sand content is very limited like most coastal soils and are mostly heavy textured and vary widely from place to place depending on their physiographic locations, climatic conditions and soil parent materials (Bandyopadhyay *et al.* 2003; Maji *et al.* 1998).

Chemical characteristics

Chemical characteristics of the soils are shown in Table 2. The pH of soils varied from 3.2 to 7.3. All the series were very strongly acidic to neutral in soil reaction while electrical conductivity (EC) of the soils ranged from 0.26 to 3.32 dSm^{-1} and higher EC values were observed in Chandipur and Bhupendrapur series. Salinity content (ECe) of these soils was found to be slight to severe and varied from 1.0 to 12.5 dSm^{-1} Higher salinity was observed in lower horizons of Bhupendrapur series. Kalyan and Sarkar (2009) also reported on nature of acidity of some coastal acid soils of Sundarbans of West Bengal and found extremely acidic soils with pH value marginally above 4.0. Highly acidic soils with abundance of appreciable amount of sulphate at surface/ sub-surface soil horizons were reported in coastal areas of Kerala, West Bengal, Odisha and Andaman and Nicobar group of Islands (Bandyopadhyay and Bandyopadhyay 1984; Bandyopadhyay and Maji 1995). The percent organic carbon content of the soils was found to be high in surface soils and low in sub surface soils except Bhupendrapur series. The organic carbon content showed irregular distribution with depth. In some pockets of study area lower horizons of the profiles contained high amount of organic carbon which could be due to mixing of degraded wooden materials with soils (Joshi and Kadrekar 1987). CEC and base saturation varied from 11.9 to 18.2 cmol (p^+) kg^{-1} and 45 to 80%, respectively, whereas exchangeable bases were distributed in the order of $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ on the exchange complex of soils. Exchangeable cations were found in traces, it may be due to heavy rainfall although calcium is slightly higher. The exchangeable acidity varied from 0.1 to 10.4 cmol (p+) kg^{-1}. The acidity of the Bhupendrapur soil is more in lower horizons possibly due to exchangeable Al^{3+} contributing towards more acidity in subsurface layer than in the surface. Low exchangeable acidity could be due to, efficient recycling of basic cations that facilitates the soil to maintain a higher pH and low exchange acidity (Patton *et al.* 2007).

Table 1. Morphological and physical characteristics of the soils

Horizon	Depth (cm)	Colour (Moist)	Mottle colour	Drainage	Sand (2.0-0.05)	Silt (0.05 - 0.002)	Clay (<0.002)	Texture	Structure	Consistency
					(mm)				S G T	D M W
Pedon 1. Chandipur series- Nearly level (0-1% slope) plains										
Ap	0-15	10 YR5/2	-		0.9	61.3	37.8	sicl	puddled	sh fr ss/sp
Bw	15-42	10 YR 5/3	10 YR5/6		0.6	56.5	42.9	sic	m 2 sbk	- fr ss/sp
Bwg1	42-62	10 YR 5/1	2.5 Y 5/6	Somewhat	0.6	65.3	34.1	sicl	m 2 sbk	- fr ss/sp
Bwg2	62-95	10 YR 5/1	2.5 Y 6/6	poorly drained	3.9	53.8	42.3	sic	m 2 sbk	- fr ss/sp
Bwg3	95-114	2.5 Y 5/1	2.5 Y 5/4		1.6	66.7	31.7	sicl	m 2 sbk	- fr ss/sp
Bwg4	114-130	2.5 Y 5/1	2.5 Y 5/4		0.8	70.3	28.9	sicl	f 2 sbk	
Pedon 2. Manmathanagar series- Very gently sloping (1 -3% slope) plains										
Ap	0-16	10 YR5/2	-		0.1	65.9	34.0	sicl	puddled	sh fr ss/sp
Bwg1	16-35	10 YR 4/1	-	Moderately	0.2	54.2	45.6	sic	m 2 sbk	- fr ss/sp
Bwg2	35-66	10 YR 4/1	-	well drained	0.2	60.8	39.0	sicl	m 2 sbk	- fr ss/sp
Bwg3	66-90	10 YR 4/1	-		2.6	57.0	40.4	sic	m 2 sbk	- fr ss/sp
Bwg4	90-140	10 YR4/1	10 YR5/6		3.7	72.0	24.3	sil	f 2 sbk	- fr ss/sp
Pedon 3. Bhupendrapur series- Very gently sloping (1 -3% slope) plains										
Ap	0-13	10 YR5/1	-		0.4	64.5	35.1	sicl	puddled	sh fr ss/sp
Bwg1	13-37	10 YR 5/1	-		0.4	76.8	22.8	sil	m 2 sbk	- fr ss/sp
Bwg2	37-67	10 YR 5/1	10 YR5/4	Somewhat	0.8	62.4	36.8	sicl	m 2 sbk	- fr ss/sp
Bwg3	67-101	10 YR 4/1	2.5Y 5/6	poorly drained	7.6	56.3	36.1	sicl	m 3 sbk	- fr ss/sp
Bwg4	101-132	10 YR 4/2	2.5 Y 6/6		8.7	70.1	21.2	sil	m 3 sbk	- fr ss/sp
Bwg5	132-150	2.5 Y 4/1	-		3.4	66.3	30.3	sicl	m 2 sbk	- fr ss/sp

Texture: sic – silty clay, sicl – silty clay loam, sil – silt loam.

Structure: Size (S) f – fine, m – medium,; Grade (G) -2 – moderate, 3 – strong; Type (T) - sbk – sub-angular blocky.

Consistence: Dry : sh – slightly hard, Moist : fr – friable, Wet : ss – slightly sticky, sp – slightly plastic

Table 2. Chemical characteristics of soils

Horizon	Depth (cm)	pH (1:2.5)		EC	ECe	OC	Exchangeable acidity	Exchangeable cations cmol (p+) kg^{-1}				Sum	CEC	BS	ESP
		H_2O	1N KCl	(dSm^{-1})		($g\ kg^{-1}$)		Ca	Mg	Na	K			(%)	
								(*1 N* NH_4OAc, pH 7.0)							
Chandipur series: Fine, mixed, hyperthermic *Typic Halaquepts*															
Ap	0-15	4.9	4.4	3.04	9.2	9.0	0.65	4.0	1.3	2.8	0.8	8.9	15.8	56	17.7
Bw	15-42	6.3	5.4	1.17	4.4	2.6	0.25	4.6	1.3	3.0	0.9	9.8	14.5	68	20.7
Bwg1	42-62	5.5	4.6	1.33	5.0	2.3	0.20	4.2	1.3	2.8	0.8	9.1	15.2	60	18.4
Bwg2	62-95	4.6	3.9	1.46	5.5	2.6	0.85	4.3	1.3	2.2	0.6	8.4	14.9	56	14.8
Bwg3	95-114	6.3	5.5	1.50	5.6	2.8	0.10	4.8	1.3	2.5	0.7	9.3	14.0	66	17.9
Bwg4	114-130	7.1	6.2	1.24	4.7	2.4	0.10	6.1	1.4	3.0	0.8	11.3	14.1	80	21.3
Manmathanagar series: Fine, mixed, hyperthermic *Typic Endoaquepts*															
Ap	0-16	5.4	4.1	0.29	1.1	6.7	0.30	6.0	1.4	2.5	0.8	10.7	18.2	55	13.7
Bwg1	16-35	7.0	5.5	0.28	1.1	4.3	0.10	7.4	1.6	3.4	1.0	13.4	18.0	74	18.9
Bwg2	35-66	7.3	5.7	0.26	1.0	4.3	0.10	7.0	1.6	3.6	1.2	13.4	17.4	77	20.7
Bwg3	66-90	5.7	4.5	0.39	1.5	5.8	0.10	5.6	1.4	1.8	0.5	9.3	15.0	62	12.0
Bwg4	90-140	4.5	3.5	0.30	1.1	4.3	1.80	3.8	1.3	1.4	0.5	7.0	12.5	56	11.2
Bhupendrapur series: Fine silty, mixed, hyperthermic *Fluventic Endoaquepts*															
Ap	0-13	4.6	3.8	0.73	2.7	8.7	0.75	4.2	1.3	2.2	0.5	8.2	16.4	50	13.4
Bwg1	13-37	6.9	5.6	0.32	1.2	2.6	0.10	7.2	1.5	2.8	0.7	12.2	16.7	73	16.8
Bwg2	37-67	5.3	4.2	0.39	1.5	3.4	0.20	5.5	1.3	2.9	0.7	10.4	18.0	58	16.1
Bwg3	67-101	4.0	3.3	1.04	3.9	9.7	5.85	3.2	1.3	2.4	0.5	7.4	16.3	45	14.7
Bwg4	101-132	3.6	3.3	2.27	8.5	13.3	5.45	2.8	1.1	1.6	0.3	6.8	11.9	49	13.4
Bwg5	132-150	3.2	2.8	3.32	12.5	4.4	10.4	3.8	1.2	1.5	0.3	6.8	13.2	51	11.4

Soil Classification

Based on morphological characteristics physical and chemical properties of the typifying pedons, the soils were classified upto the family level according to Keys to Soil Taxonomy. Soil pedons of study area, having *ochric* horizon with ochric epipedon were classified under Inceptisols. The most common horizon sequence of Inceptisols is an ochric epipedon over a cambic horizon, with or without an underlying fragipan. All three soil series have aquic conditions for some time in normal years and also presence of matrix colour, chroma 2 or less within 50 cm of the mineral soil surface. Chandipur series has exchangeable sodium percentage (ESP) of 15 or more and lower ESP values with increasing depth below 50 cm. Manmathanagar series had irregular decrease in organic-carbon content with depth and hence classified as Fluventic subgroup (Soil Survey Staff, 2010). Based on the characteristics, these coastal soils were classified at family level *viz.* Fine, mixed, hyperthermic *Typic Halaquepts* for Chandipur, Fine, mixed, hyperthermic *Typic Endoaquepts* for Manmathanagar and Fine silty, mixed, hyperthermic *Fluventic Endoaquepts* for Bhupendrapur.

Land Capability Classification

The land capability classification is an interpretative grouping of different soil units and plays an important role in land use planning to show the relative suitability of soils for cultivation of major crops (agriculture and horticulture) in addition to focusing the problems which need preventive conservation measures. This also provides clues to the management and improvement of different soil units for increasing production. Based on the number and severity of several limitations the soils of coastal Gosaba block have been classified into three land capability sub-class (Table 3). The Chandipur series (54.15%) was placed in the land capability class IIIsw with major limitations of soil salinity and imperfect drainage, whereas the Manmathanagar and Bhupendrapur series were placed under in IIw (16.73%) and IIws (29.12%) with slight limitations of improper drainage and soil salinity. The detailed description of land capability classes with potentials, limitations and suggested land use is given in series wise (Table 3). By adopting suggested land use in the respective areas sustained crop production can be achieved as it helps in the management of soil and water besides the reclamation of salt affected soils.

Soil series	Land capability class with limitations	Description	Major limitations	Suggested land use
Chandipur	IIIsw	Moderately good cultivable land for sustainable agriculture	Soils having moderate limitations of soil salinity and improper drainage.	Suitable for paddy based cropping system with proper drainage system. Soil reclamation required for salinity control. These lands can be used for paddy in *kharif* - *rabi* season and other salt tolerant crops *viz.* vegetables and fruit crops can be grown in *rabi* season.
Manmathanagar	IIw	Good cultivable land for sustainable agriculture	Soils have slight limitations of improper drainage.	Suitable for paddy in *kharif* and other crops like pulses (black gram, green gram and cowpea) and vegetables (tomato, brinjal, bhendi, cabbage, and chilli) can be grown in *rabi* season.
Bhupendrapur	IIws	Good cultivable land for sustainable agriculture	Soils having slight limitations of improper drainage and soil salinity.	Suitable for paddy, vegetables, pulses and some fruit crops with proper drainage systems . Soil reclamation required for salinity and better nutrient and water management. Paddy-paddy and paddy-vegetables are better option in both seasons.

Conclusions

Coastal Gosaba soils were strong acidic to neutral in reaction, saline and low to medium in organic carbon. The CEC and base saturation values were low and exchange complex was dominated by Ca^{2+} and Na^{+}. The soils were classified as *Typic Halaquepts*, *Typic Endoaquepts* and *Fluventic Endoaquepts*. Based on the soil properties, three land capability classes were established. These lands can be used for paddy in *kharif* and other salt tolerant crops *viz.* pulses (black gram, green gram and cowpea) and vegetables (tomato, brinjal, bhendi, cabbage, and chilli) can be grown in *rabi* season. Hence, soil salinity reclamation, ensuring suitable drainage system and better nutrient management is advocated as the key to achieving sustainable crop yields and maintaining soil health.

References

AISLUS. (1970). Soil Survey Manual. Department of Agriculture, Govt. of India, IARI Campus, New Delhi.

Bandyopadhyay, B.K. and Bandyopadhyay, A.K. (1984). Effect of application of farmyard manure on soil properties and yield of crops in coastal saline soil. *Journal of Indian Society of Coastal Agricultural Research* **2(3)**, 63-73.

Bandyopadhyay, B.K. and Maji, B. (1995). Nature of acid soil of Sundarban delta and suitability of classifying them as acid sulphate or potential acid sulphate soils. *Journal of Indian Society of Coastal Agricultural Research* **43**, 103-107.

Bandyopadhyay, B.K., Sen, H.S. and Maji, B. (2001). *Saline and Alkali Soils and their Management,* Monograph Series 1. Indian Society of Coastal Agricultural Research. Central soil salinity Research Institute, Canning Town, West Bengal, India, 1-66.

Bandyopadhyay, B.K., Maji, B., Sen, H.S. and Tyagi, N.K. (2003). *Coastal Soils of West Bengal- Their Nature, Distribution and Characteristics.* Bull. No. 1/2003. Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal, India, pp 1-62.

Black, C.A. (1965). Methods of Soil Analysis. Part 1&2. American Society of Agronomy, Inc., Madison, Wisconsin.

FAO. (2005). Report of the regional workshop on salt-affected soils from sea water intrusion: strategies for rehabilitation and management, 31 March to April, 2005, Bangkok, Thailand. RAP Publication 2005, 11.57 p.

Jackson, M.L. (1973). Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi.

Joshi, R.G. and Kadrekar. S.B. (1987). Fertility status of coastal salt affected soils of Maharashtra. *Journal of Indian Society of Coastal Agricultural Research* **5(1)**, 111-116.

Kalyan, S. and Sarkar, D. (2009). Studies on chemical properties and nature of acidity of coastal acid soils of West Bengal. *Journal of Interacademicia* **13(1)**, 23-27.

Maji, B., Bandyopadhyay, B.K., Sarkar, D. and Chatterji, S. (1998). Morphological and chemical characterization of soils of Sagar Island of the Sundarbans, West Bengal. *Journal of the Indian Society of Soil Science* **46(1)**, 99-103.

Mitran T., Mani P.K., Basak N., Mandal B. and Mukhopadhyay, S.K. (2014). Soil Fertility Constraint Assessment Using Spatial Nutrient Map at Three Selected Villages of Coastal Sundarbans. *Journal of Soil Salinity and Water Quality* **6(1)**, 1-8.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of Soil Analysis, Part 2, 2nd Edition, Soil Science Society of America, Madison, USA.

Prasad, J., Ray, S.K., Gajbhiye, K.S. and Singh, S.R. (2009). Soil of Selsura research farm in Wardha district, Maharashtra and their suitability for crops. *Agropedology* **19**, 84-91.

Patton, S., Sharma, S.K. and Singh, P.K. (2007). Characterization of the Acidity of Soils under Different Land Use Patterns in Nagaland. *Journal of the Indian Society of Soil Science* **55(2)**, 134-138.

Sarkar, D., Sahoo, A.K., Sah, K.D. and Gajbhiye, K.S. (2001). Coastal soils of eastern India-their charactersistics, potentials and limitations towards alternate land use. *Journal of Indian Society of Coastal Agricultural Research* **19(1&2)**, 80-83.

Soil Survey Staff. (2010). 'Keys to Soil Taxonomy', Eleventh Edition. (U.S.D.A.: Washington, D.C.).

Sys, C., Van Ranst, E. and Debaveye, J. (1991). Land Evaluation, Part-II, *Methods in Land Evaluation,* Agricultural Publications No.7, GADC, Brussels, Belgium.

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