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Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau

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Abstract

Pedological investigation carried out on a soil toposequence of Chhotanagpur plateau indicated that the area was occupied by four typical Alfisols with well expressed illuvial horizons (Bt) developed in old alluvium underlain by granite-gneiss. The soils in the upper slope of the toposequence are very deep, excessive to well drained, sandy loam to sandy clay loam in texture and yellowish red to dark red in colour whereas the soils in the lower slopes are very deep, imperfect to poorly drained, silt loam to clay in texture and light brownish grey to grey in colour with characteristic redoximorphic features. The soils are moderately acidic to near neutral, low to medium in organic carbon, low to medium in CEC with medium to high base saturation. The soils are classified along the toposequence as Ultic Paleustalfs, Rhodic Paleustalfs, Aquic Haplustalfs and Aeric Endoaqualfs. All the soils were well developed however, the profile development was least at the toe end of the toposequence.

Additional key words : Soil Characteristics, reconnaissance soil survey, Alfisols

Introduction

The western part of West Bengal (Purulia district, part of Bankura and Medinipur districts) is the continuation of lower outlier of Chhotanagpur Plateau. The landform of the region is most undulating. In the region under study, the upper slope in the segment of soilscape is typified by coarse textured soils having sparse vegetal cover subject to local arid pedo-environment in contrast to the medium to fine textured soils with local humid pedo-environment along the footslope. Soils in the lower part of the slope are deeper and retain more amount of moisture. The toe-end of the slope merging with the depressions results in the hydromorphic conditions which leads to gleying in the bottomland situations. Hence for optinum and sustained utilisation of soils, their properties should be considered as key elements to assess their behaviour in terms of limitation and potential to different levels of managements. Keeping these in view, the present study was undertaken to identify the soil toposequence relationship and its impact on soil properties as reflected by morphological, physical and chemical characteristics and ultimately on landuse of the study area.

Materials and methods

The eastern outlier of Chhotanagpur plateau lies between 22°0' to 25°30' N latitudes and 83°47' to 87°50' E longtitudes, comprising gently undulating lower part of outlier. The area includes north eastern parts of the districts of Bankura (Bishnupur), Medinipur (Garbeta and Jhargram), Birbhum (Seuri and Rampurhat) and parts of Purulia district of West Bengal. The outlier represents the Tertiary and the post Tertiary peneplain surfaces of lower Chhotanagpur plateau merging into the Bengal basin in the east. The climate is hot dry tropical subhumid with '*Ustic*' moisture regime (mean annual precipitation 1350 mm) and *Hyperthermic* temperature regime. The length of growing period (LGP) ranges from 150-180 days in a year (Sehgal *et al.* 1990). The pedoclimatic environment in the area indicates well expressed alternate brief wet cycle followed by longer dry cycle characterised by strong dessication.

Table 1. Site characteristics

Pedon	Soil Series	Elevation above MSL (m)	Slope (%)	Landform	Drainage	Permeability	Parent material	Present Land Use
1	Mrigindihi	80	3–5	Gently undulating interfluves	Somewhat excessively drained	Rapid	Old alluvium	Degraded forest, rainfed vegetables/ direct seeded rice
2	Mukundapur	60	2–3	Gently sloping uplands	Well drained	Mode-rate	-do-	Thin forest and sparse vegetion
3	Teltaka	40	1–2	Very gently sloping plain	Imperfectly drained	Slow	-do-	Rice cultivation
4	Nayabasat	35	0–1	Very gently sloping plain	Poorly drained	Slow	-do-	Rice cultivation

Based on reconnaissance soil survey (1:50,000 scale), four soil series were identified in a toposequence i.e. 1) undulating interfluves, 2) gently sloping uplands, 3) very gently sloping plain and 4) very gently sloping plain. Soil morphology and horizonation of typifying

pedons were studied in the field (Soil Survey Staff 1951) and soil samples were collected, processed and analysed for laboratory analysis following standard procedure (Black 1965). Soils were characterised and classified as per Keys to Soil Taxonomy (Soil Survey Staff 1998).

Results and discussion

The site characteristics of the soils are presented in table 1. These soils have developed in old alluvium. Soils developed on the upper slopes of the toposequence are excessively to well drained with rapid to moderate permeability and are mostly covered with thin degraded forest, occasionally cultivated to direct seeded rice, rainfed vegetables and other drought resistant seasonal crops and the soils of lower slopes are imperfectly to poorly drained with slow runoff and are mostly under cultivation of rice.

Morphological characteristics

The morphological characteristics of the soils (table 2) indicate that the soils are deep with significant variation in soil colour both in the surface and sub-surface layers indicating the release of iron oxides and their occurrence in various hydrated forms due to variation in internal drainage of soils as influenced by toposequence. The soils of the upper slopes of the toposequence (Mrigindihi and Mukundapur series) are yellowish red (5YR 4/6) in colour in the surface layer and dark red (2.5YR 4/6) in the lower layers with value 3.5 to 4 and chroma 3 to 6 indicating better drainage condition. The dark reddish colour could be attributed to the formation of non-hydrated iron oxide (Gerrad 1981). The soils of the lower slopes of the toposequence (Teltaka and Nayabasat series) are light brownish grey to light grey in surface horizon and grey in the lower layers with values 5 to 7 and chroma <2 indicating the prevalence of aquic conditions owing to mobilization of Fe/Mn (redox depletions). The presence of mottles and Fe-Mn concretions in the soils of lower slope of the toposequence also reflects impeded drainage in the subsoil. The texture of the soils of upper slopes of the toposequence (Pedon 1 and 2) varies from sandy loam to sandy clay loam whereas on the lower slopes it varies from silty loam to clay. The structure of all the soils are subangular blocky. The consistence of the soils is slightly hard to hard (dry), friable (moist) except in pedon 3 where it is firm due to high clay content and slightly sticky to very sticky and non-plastic to very plastic (wet) depending on clay content. Clay skins/cutans are present in the lower layers of all the pedons.

Table 2. Some morphological properties of the soils

Hori-zon	Depth (cm)	Colour (moist)		Texture	Structure	Consitence	Clay cutans	Fe and Mn concretion
		Matrix	Mottles					
Pedon 1 : (Mrigindihi series)								
A	0-15	5YR 4/8	–	sl	fl sbk	sh fr sspo	–	–
AB	15-33	5YR 4/6	–	sl	m1sbk	sh fr ssps	–	–
Bt1	33-59	5YR 4/6	–	scl	m2sbk	sh fr ssps	t tn p	–
Bt2	59-87	5YR 4/6	–	scl	m2sbk	sh fr sp	t tn p	–
Bt3	87-114	5YR 4/6	–	scl	m2sbk	sh fr sp	t mtk p	–
BCt1	114-141	2.5YR 3.5/6	–	scl	m2sbk	h fr sp	t mtk p	–
BCt2	141-160	2.5YR 3.5/6	–	scl	m2sbk	h fr sp	t mtk p	–
Pedon 2 (Mukundapur series)								
A	0-14	5YR 4/5	–	sl	fl sbk	sh fr ssps	–	–
BA	14-32	2.5YR 4/5	–	sl	m1sbk	sh fr ssps	–	–
Bt1	32-70	2.5YR 3/3	–	scl	m2sbk	h fr sp	t tn p	–
Bt2	70-115	2.5YR 3/6	–	scl	m2sbk	h fr sp	t tn p	–
BC	115-140	2.5YR 3/6	–	scl	m1sbk	h fr sp	–	–
Pedon 3 (Teltaka series)								
Ap	0-10	10YR 6/2	–	sil	m1sbk	sh fr ssps	–	–
BA	10-28	10YR 6/2	–	sil	m2sbk	sh fr ssps	–	–
Bt1	28-46	10YR 7/2	–	cl	m2sbk	h fr sp	t tn b	f f
Bt2	46-78	10YR 5/1	7.5YR 5/6	cl	m2sbk	h fr sp	t tn b	f m-c
Bt3	78-102	10YR 5/1	7.5YR 5/6	cl	m2sbk	h fi sp	t mtk p	f m-f
Bt4	102-150	10YR 6/1	7.5YR 5/6	c	m2sbk	h fi vsvp	t mtk c	f f
Pedon 4 (Nayabasat series)								
Ap	0-9	10YR 6/1	–	sil	m1sbk	sh fr ssps	–	–
BA	9-21	2.5Y 5/2	–	sil	m2sbk	sh fr ssps	–	–
Bt1	21-48	2.5Y 6/1	10YR 5/6	sil	m2sbk	sh fr ssps	t tn b	f m-c
Bt2	48-75	2.5Y 6/1	10YR 5/4	sicl	m2sbk	h fi sp	t mtk p	f m-m
Bt3	75-114	2.5Y 6/1	10YR 5/4	sicl	m2sbk	h fr sp	t mtk p	f m-f
BC	114-150	2.5Y 6/1	–	sicl	m1sbk	h fi sp	–	–

Physical and chemical characteristics of soils

The physical and chemical characteristics of the soils are presented in table 3. The particle size distribution of the soils reflects the dominance of sand in the soils of upper

slopes whereas silt is the dominant constituent in the soils of the lower slopes of the toposequence. However, the gradual increase in clay content with depth in all the pedons associated with clay skins/coatings on the ped faces (table 2) indicates the illuviation of clay from the surface horizons and in turn resulting in the development of argillic horizons. The soils occurring on the upper slopes of the toposequence (Pedons 1 and 2) are moderately to slightly acidic (pH 4.5 to 6.1) whereas the soils of lower slopes are slightly acidic to near neutral (pH 6.0 to 7.0). The higher pH values in the soils of lower slope may be due to deposition of illuvial bases from the surrounding upper slopes. Organic carbon content in the soils of upper slope varies from 0.9 to 2.8 g kg^{-1} whereas in the soils of lower slope, it varies from 0.5 to 5.0 g kg^{-1}.

The higher value of organic carbon in the surface layer of the lower slopes may be due to the deposition of organic materials from the surrounding upper slopes. However, the organic carbon content in soils generally decreases with depth except in the soils of Teltaka series (Pedon 3) where an irregular distribution of organic carbon is observed. CEC of these soils varies from 2.0 to 18.0 cmol (p^+) kg^{-1}. The cation exchange capacity of the soils of the lower slope of the toposequence (Pedons 3 and 4) are comparatively higher than that of the soils of upper slopes (Pedons 1 and 2) due to increase in clay content in the lower layers of the soils of lower slope of the toposequence. The CEC of the soils bears a positive significant correlation with the clay content of soils ($r = 0.85$). The CEC/clay ratio of these soils indicate mixed mineralogy class. Among the exchangeable bases, Ca^{2+} is the dominant cation followed by Mg^{2+}, Na^+ and K^+. Exchangeable Ca^{2+} and Mg^{2+} content of these soils show an increasing trend with soil depth. Base saturation of these soils varies from 49 to 77 per cent. The soils of lower slopes are more base saturated than the soils of upper slopes of the toposequence.

Soil Classification

All the soils under study have ochric epipedon i.e. light in colour and low in organic carbon content, the illuvial horizon contains 1.2 times more clay than the eluvial horizon in all the soils, thus qualifying for argillic subsurface diagnostic horizon and high base saturation (Table 3) confirming their placement under Alfisol order. Since the study area qualifies for ustic soil moisture regime, these soils can be placed under Ustalfs at suborder level except the soils of Nayabasat series (Pedon 4) which is under aquic soil moisture regime as evident from the characteristics of wetness and presence of mottles and Fe-Mn concretions, confirming their placement under Aqualfs at the suborder level.

Table 3. Some physico-chemical characteristics of soils

Hori Zon	Depth (m)	Particle-size distribution (%)			pH H_2O (1:2.5)	O.C g kg^{-1}	CEC	Exchangeable bases				B.S (%)	CEC Clay
		Sand	Silt	Clay				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		
								- - - - cmol (p+) kg^{-1} - - - -					
Pendon 1 : (Mrigindihi series) : Ultic Paleustalfs													
A	0-0.15	69.9	16.0	14.1	4.9	2.7	5.8	2.0	0.8	0.3	0.2	57	0.41
AB	0.15-0.33	67.9	17.7	17.0	4.8	2.3	6.2	2.5	0.8	0.2	0.2	60	0.35
Bt1	0.33-0.59	64.8	15.2	20.4	5.2	1.3	7.6	2.9	1.2	0.2	0.2	59	0.38
Bt2	0.59-0.87	60.0	16.9	23.1	5.0	1.2	8.0	2.3	1.2	0.2	0.2	49	0.34
Bt3	0.87-1.14	62.3	14.1	23.6	5.1	1.2	8.8	3.3	1.2	0.3	0.3	58	0.39
BCt1	1.14-1.41	60.6	16.4	23.0	4.9	1.0	9.2	3.6	1.6	0.3	0.3	63	0.40
BCt2	1.41-1.65	57.4	17.4	25.2	4.5	0.9	9.6	4.5	2.0	0.3	0.4	75	0.38
Pedon 2 : (Mukundapur series) : Rhodic Paleustalfs													
A	0-0.14	57.9	30.4	11.7	5.5	2.8	4.2	2.0	0.6	Tr	Tr	61	0.56
BA	0.14-0.32	58.0	22.8	19.2	5.6	1.4	4.4	2.0	0.8	Tr	Tr	63	0.37
Bt1	0.32-0.70	59.5	16.5	24.0	5.9	1.7	5.0	2.0	1.0	0.1	0.1	64	0.26
Bt2	0.70-1.15	52.2	22.4	25.4	6.0	1.5	5.7	2.0	1.2	0.4	0.2	60	0.27
BC	1.15-1.60	47.1	25.0	27.9	6.1	1.5	8.8	2.3	2.2	0.4	0.2	58	0.35
Pedon 3 : (Teltaka series) : Aquic Haplustalfs													
Ap	0-0.10	44.0	50.4	5.6	6.7	3.0	5.0	2.6	0.8	0.1	0.1	72	0.90
BA	0.10-0.28	19.0	68.2	12.8	6.8	0.9	7.3	4.0	1.2	0.1	0.1	74	0.57
Bt1	0.28-0.46	29.0	43.2	27.8	6.2	0.5	13.6	6.0	3.0	0.2	0.3	70	0.48
Bt2	0.46-0.78	36.2	30.1	33.7	6.4	2.3	12.0	5.0	2.6	0.6	0.4	71	0.31
Bt3	0.78-1.02	30.7	30.0	39.3	6.8	2.0	17.6	7.0	4.2	1.6	0.6	76	0.44
Bt4	1.02-1.55	24.4	35.6	40.0	6.9	1.2	18.0	8.0	4.0	1.0	0.6	75	0.45
Pedeon 4 : (Nayabasat series) : Aeric Endoaqualfs													
Ap	0-0.09	32.0	52.5	15.5	6.0	5.0	2.0	0.8	0.5	Tr	Tr	65	0.13
BA	0.09-0.21	23.3	58.7	18.0	6.2	3.0	3.0	1.3	0.8	Tr	Tr	70	0.16
Bt1	0.21-0.48	15.3	58.3	29.6	7.0	0.8	11.6	4.8	3.6	0.4	0.2	77	0.40
Bt2	0.48-0.75	12.1	58.3	29.6	7.0	0.8	11.6	4.8	3.6	0.4	0.2	77	0.40
Bt3	0.75-1.14	14.0	55.5	30.5	6.8	0.9	12.8	5.4	3.8	0.4	0.2	76	0.41
BC	1.14-1.60	16.2	54.4	29.4	6.8	0.9	12.8	5.4	3.8	0.4	0.2	76	0.43

The soils of Mrigindihi series (Pedon 1) has an argillic horizon within 150 cm of the mineral soil surface and with increasing depth no clay decrease of 20 per cent or more from the maximum clay content was observed. Hence, the soils are classified as Paleustalfs at great group level. Again, the argillic horizon has base saturation value of less than 75 per cent qualifying the soil as Ultic Paleustalfs at subgroup level. The soils of Mrigindihi series are classified at family level as fine-loamy, mixed, hyperthermic Ultic Paleustalfs.

The soils of Mukundapur series (Pedon 2) are very deep with argillic horizon that has no clay decrease of 20 per cent or more from the maximum with the increase in depth. Hence, this soil is placed as Paleustalfs at the great group level. Again, the argillic horizon has colour hue of 2.5YR with value 3 suggesting that the soil can be classified as Rhodic Paleustalfs at subgroup level. Thus, the soil is classified at the family level as fine-loamy, mixed, hyperthermic Rhodic Paleustalfs.

The soils of Teltaka series are also very deep and and have argillic horizon with colour hue of 10YR, suggesting the soil as Haplustalfs at the great group level. Although, soil moisture regime, in general, is ustic, the seasonal aquic nature of moisture regime in subsoil is under reduced condition resulting in low Eh-pH relationship. Hence, the soils of Teltaka series is classified at the family level as fine-loamy, mixed, hyperthermic, Aquic Haplustalfs.

The soils of Nayabasat series are found to occur in still further lower situation under aquic soil moisture regime and have the ochric epipedon. They are classified as Aqualfs at suborder level. Due to endosaturation of the soil, it qualifies for Endoaqualfs at the great group level. The colour hue of 10YR or yellower with value 3 or more keyout the soil as Aeric Endoaqualfs. Hence, the soils of Nayabasat series are classified at the family level as fine, mixed, hyperthermic Aeric Endoaqualfs.

It may be concluded that variation in soil properties is the reflection of toposequence and these variations may be taken while evaluating the soils for suitabilities under different crops.

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