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Pedogenic characterization and productivity of some lateritic soils developed on different geomorphic conditions

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Abstract

Typical pedons developed on various geomorphic conditions namely residual hills, denudational hills, pediments, shallow and moderately buried pediments and valley fills in Purulia district of West Bengal were studied for their morphology, physical and chemical characteristics and classification. Soils of residual hills, denudational hills and pediments are coarse-loamy whereas others are fine-loamy at family level. Soils are strongly to slightly acid except those in valley fills which are neutral in nature. The soils of residual hills, denudational hills and pediments have paralithic contact at 30 to 45 cm. Soils of moderately buried pediments are well developed and belong to Alfisols whereas soils of residual hills and denudational hills are Entisols and Inceptisols, respectively. Shallow buried pediments and valley fills have ochric epipedon and structural/cambic B horizon qualifying as Inceptisols. Soils developed on shallow buried pediments and moderately buried pediments have the highest productivity ratng index classified as good productivity class. Soils of denudational hills and pediments are rated as average and poor in productivity, respectively. Valley fills soils are placed in good productivity class.

Additional keywords : Taxonomic grouping, geomorphic unit, soil productivity

Introduction

Variations in the development of soils on varying physiographic conditions have been reported by several workers (Roy 1976; Gowaikar 1972). Characterization of soils is very essential for sustainable use and efficient management. Poor productivity of laterites and lateritic soils due to undulating topography, soil erosion and low nutrient supplying capacity poses severe limitations to crop production (Bennama 1963). In the present study, some typical lateritic soils of Banduan block, Puruliya district of West Bengal, developed on different geomorphic positions were characterized, classified and assesed for their productivity.

General description of the study area

Banduan block of Puruliya district covering an area of 351.2 sq. km. lies between 22° 42" to 22° 58" N latitudes and 86° 25" to 86° 40" E longitudes and is an extension of

the structural hills of Chhotanagpur plateau in the south, and rolling topography of undulating pediplain covered by quaternary sediments in the north. The elevation of the area ranges from 150 to 440 m above MSL. The general slope is nearly level to steep and directed towards the valley both from north to south.

The climate is sub-humid tropical with mean annual temperature of 26.3°C. The mean annual rainfall is 1322 mm of which 1056 mm (80%) received during June to September. Mean maximum summer and mean minimum winter temperature are 40.2°C and 12.4°C, respectively. The area qualifies for *Hyperthermic* soil temperature regime and *Ustic* soil moisture regime except in valley fills, which qualify for *Aquic* moisture regime as soils in control section remain moist for more than 180 days.

Materials and methods

Semi-detailed soil survey was carried out using IRS IC LISS III satellite imagery (1:50,000 scale). Satellite imagery was visually interpreted to delineate various geomorphic units. Two sample strips cutting across various geomorphic units were studied in detail and few soil profiles observed outside the sample strips. Total 42 soil profiles and 12 minipits were studied. Six typical pedons (Table 1) occurring on residual hills, denudational hills (structural hills), pediments, shallow buried pediments, moderately buried pediments and valley fills were studied for their morphology, physical and chemical characteristics and classification. The soil samples were collected horizon wise, processed and analyzed for pH, soil particle size distribution, organic carbon, CEC and exchangeable cations using methods outlined by Black (1965) and Jackson (1973). The morphological, physical and chemical properties of pedons were interpreted to assess their productivity using parametric approach described by Riquier *et al.* (1970).

Results and discussion

Pedogenic development of soils corresponds to the geomorphological types in the study area. The geomorphological units identified were residual hills, denudational hills, pediments, shallow and moderately buried pediments and valley fills (Tripathy *et al.* 1996). The parent material is quartzite - phyllite type on which soils were developed. Residual hills, denudational hills (structural hills), weathered pediments are prone to moderate to severe erosion whereas buried pediment and valley fills have nil to slight erosion.

The site and morphological characteristics of the soils developed on these geomorphological units are described in tables 1 and 2. The soils of residual hills, denudational hills and pediments exhibit dark brown to dark reddish brown (7.5 YR 3/4

to 5 YR 3/4) colour and are well drained. Soils developed on denudational hills, pediments and shallow buried pediments have weak, fine and sub-angular blocky structure in the sub-surface horizon indicates formation of altered B (cambic) horizon. However, pedon 4 is also associated with Fe-Mn concretions in Bw3 horizon. Soils of residual hills have massive structure and are classified as Entisols. The soils of residual hills, denudational hills and pediment have paralithic contact at 30-45 cm, above the bedrock.

Table 1. Site characteristics of typical pedons

Soils	Geomorphology	Parent material	Topography (% slope)	Effective soil depth (cm)	Drainage class	Erosion class	Present land use
Pedon 1	Residual hill (Side slope)	Quartzite	Moderately steep (15–25)	Moderately deep (29)	well	Very severe	Barren/ scrubs
Pedon 2	Denudational hill (Side slope)	Quartzite-phyllite complex	Steep Sloping (25–33)	Deep (48)	well	Moderate	Moderately dense sal mixed forest
Pedon 3	Pediments	Quartzite-phyllite, schist complex	Strongly sloping (10–15)	Moderately deep (36)	well	Moderate	Moderately dense sal mixed forest
Pedon 4	Shallow buried pediments	Quartzite-phyllite, schist complex	Gently sloping (3–5%)	Deep (84)	Moderately well	Slight	*Kharif* paddy
Pedon 5	Moderately buried pediments	Quartzite-phyllite, schist complex	Very gentle (1–3%)	Very deep (165)	Imperfect	Slight	*Kharif* paddy
Pedon 6	Valley fills	Alluvium	Nearly level (<1%)	Very deep (126)	Poor	Slight	*Kharif* & *rabi* paddy

Moderately buried pediment and valley fills have very dark greyish brown to yellowish brown (10 YR 3/2 to 10 YR 5/4) soil colour. The soils of moderately buried pediments are well developed and characterized by argillic sub-surface diagnostic horizon (Table 2).

The Ap and A1 horizons (pedon 5) indicate higher clay content than below horizon because of deposition of clay from elsewhere through runoff. It has moderate, medium, sub-angular blocky structure at sub-surface horizons. Few, fine and distinct mottles are present in sub-surface layers. The soils are very deep and moderately well drained. They belong to fine-loamy mixed hyperthermic, family of Typic Haplustalfs. They are mostly cultivated for rainfed paddy crop. The soils of valley fills are poorly drained. Common to many, fine to distinct mottles appeared in the profile below the plough layer (Ap). Moderate sub-angular blocky structure observed in the subsurface horizon confirms cambic sub-surface diagnostic horizon and the soil is classified as fine-loamy Typic Endoaquepts.

Table 2. Morphological characteristics of the typical pedons

Horizon	Depth (cm)	Horizon boundary	Colour	Texture	Coarse fragments (%)	Structure	Consistence	Porosity	Mottles Colour	ASC	Clay cutans
Pedon 1 : Loamy-skeletal Typic Ustorthents											
A	0–12	cw	7.5YR4/4	sl	35–40	Massive	mfr	c,fn	–	–	–
AC	12–29	as	7.5YR5/4	scl	40–50	Massive	mfr	c,fn	–	–	–
Cr	29–65	–	7.5YR5/4	Paralithic contact							
Pedon 2 : Coarse - loamy Typic Haplustepts											
A	0–7	cw	10YR4/3	l	15–20	1fsbk	mvfr	f,f	–	–	–
Bw1	7–29	cw	7.5YR4/4	sl	30–35	1fsbk	mvfr	f,f	–	–	–
Bw2	29–48	aw	7.5 YR3/6	l	45–60	massive	mvfr	–	–	–	–
C	48+	–	–	Paralithic contact							
Pedon 3 : Loamy- skeletal Typic Haplustepts											
A	0–13	cs	7.5YR 3/4	sl	35–40	massive	dl, mvfr	–	–	–	–
Bw	13–36	aw	5YR 4/6	sl	25–35	1vfsbk	dsh, mfr	c,f	–	–	–
Cr	36–72	–	Paralithic contact								
R	72+	–									
Pedon 4 : Fine- loamy Typic Halplustepts											
Ap	0-16	cs	7.5YR 3/4	sl	–	1fsbk	dh, mfr, wpl	f,f	–	–	–
Bw1	16-41	gs	5YR 3/4	scl	–	1fbk	dh, mfr, wpl	c,vf/f	–	–	–
Bw2	41-74	cs	2.5 YR 3/6	scl	5-10	1fsbk	mfr, wpl	c,f	–	–	–
Bw3	74-84	cs	5YR 3/4	scl	15-20	1fsbk	mfr, wpl	f,f	–	–	–
Cr	84-96	as	–	Paralithic contact							
R	96+	–									
Pedon 5 : Fine - loamy Typic Haplustalfs											
Ap	0-12	cs	10YR4/3	l	–	–	mfr,wp	f,f	–	–	–
A1	12-30	gs	10YR5/4	l	–	1fsbk	mfr,wp	f,f	–	–	–
A2	30-49	cs	10YR5/3	l	–	1fsbk	mfr,wp	f,f	10YR4/4	f,f,d	–
Bw	49-80	cs	10YR5/3	l	–	1fsbk	mfr,wp	f,f	10YR4/4	f,f,d	–
Bt1	88-114	gs	10YR 3/3	scl	–	2msbk	mfr,wp	c,f/vf	10YR5/4	f,f,d	p,tn
Bt2	114-137	gs	10YR3/6	cl	–	2msbk	mfi,wp	c,f	10YR5/4	f,f,d	p,tn
Bt3	137-165	–	10YR 3/3	cl	8-10	2msbk	mfi,wvp	c,vf/f	10YR5/4	f,f,d	p,tn
Pedon 6 : Fine-loamy Typic Endoaquepts											
Ap	0-12	gs	10YR3/3	l	–	–	mfr,wp	–	–	–	–
Bwg1	12-26	cs	10YR3/2	l	–	1fn,sbk	mfr,wp	f,fn	10YR3/6	f,f,d	–
Bwg2	26-58	cs	10YR3/2	l	–	2md,sbk	mfr,wp	f,vfn	10YR3/6	c-f,d	–
Bwg3	58-72	cs	10YR3/2	sil	–	2md,sbk	mfr,wp	f,fn	10YR5/4	m-f,d	–
Bwg4	72-96	gs	10YR3/2	sil	10-15	1fn,sbk	mfr,wp	f,vfn	10YR5/4	m-f,d	–
Bwg5	96-126	-	10YR3/2	sil	15-20	1fn,sbk	mfr,wp	f,vfn	10YR5/4	m-m,d	–
126+ water appeared											

Physical and chemical characteristics of soils (Table 3) show that soils of residual hills, denudational hills, pediments and shallow buried pediments are sandy loam to sandy clay loam in texture whereas moderately buried pediments and valley fills soils are loam to clay loam in texture. Fine texture soils in moderately buried pediment and valley fills may be due to *in situ* weathering and deposition of fine particles brought by runoff water from denudational hills and pediments.

Soils of residual hills, dedudational hills and pediments are strongly to slightly acidic which may be due to removal of bases through runoff water (Chamuah *et al.* 1996). Soils of valley fills are neutral whereas soils of shallow buried pediments had moderately to slightly acidic pH. Organic carbon is low (0.42 to 0.50%) in soils of residual and denudational hills. The soils of moderately buried pediment and valley fills have medium organic carbon content. The organic carbon content decreases with depth in all soils.

CEC of soils of residual hills, denudational hills and pediments is low (11.7 to 16.37 cmol (p+) kg^{-1}) whereas soils of shallow and moderately buried pediments and valley fills have moderately high CEC (15.1 to 28.2 cmol (p+) kg^{-1}). Among the exchangeable bases, Ca^{2+} and Mg^{2+} are dominant followed by Na^{+} and K^{+}. Moderately buried pediments and valley fills soils have high base saturation (60–96%) indicaing there high fertility whereas the soils of residual hills, denudational hills, pediments and shallow buried pediments have moderate base saturation with low to medium fertility (Tisdale and Nelson 1975). High base saturation in valley fills soils may be due to deposition of bases carried through runoff from higher elevations. Topography and rainfall appear to be main factors in the development of these soils. Soils of hills are severely eroded due to high rains in monsoon and left coarse fragments in soils. Neutral soluble salts are removed from hills, pediments, shallow buried pediments and deposited at moderately buried pediments and valley fills resulting in high base saturation. Soils of moderately buried pediments are well developed whereas soils in valley fills lying along the drainage on both sides at the lowest elevation on concave relief keep soil saturated with water for longer period of time.

Table 3. Physical and chemical characteristics of the soils

Horizon	Depth (cm)	Particle size class			pH	EC (1:2)	O.C. (1:2)	Exchangeable cations				Base saturation
		Sand	Silt	Clay				CEC	Ca+Mg	Na	K	
		(%)					(%)	c mol(+) kg^{-1}				(%)
Pedon 1 : Loamy-skeletal Typic Ustorthents (side slope of residual hills)												
A	0–13	61.2	24.0	14.8	5.81	0.10	0.46	13.58	6.80	0.49	0.16	54.8
AC	13–29	55.2	18.0	26.8	5.95	0.10	0.50	15.10	9.00	0.59	0.34	65.7
Pedon 2 : Coarse-loamy Typic Haplustepts (side slope of denudational hills)												
A	0–7	45.2	42.0	12.8	6.51	0.15	0.35	16.27	9.20	063	0.50	63.5
Bw1	7–29	53.2	32.0	14.8	6.33	0.20	0.50	14.76	8.40	0.76	0.48	65.3
Bw2	29–48	49.8	34.0	16.2	5.82	0.10	0.41	13.40	8.20	0.69	0.38	69.2
Pedon 3 : Loamy-skeletal Typic Haplustepts (pediments)												
A	0–13	69.8	22.0	8.2	5.71	0.10	0.42	11.72	9.20	0.48	0.26	56.0
Bw	13–36	53.8	32.0	14.2	5.60	0.10	0.42	12.65	8.20	0.50	0.13	68.7
Pedon 4 : Fine-loamy Typic Haplustepts (shallow buried pediments)												
Ap	0–16	63.8	18.0	18.2	5.99	0.20	0.62	17.44	8.40	0.62	0.49	55.5
Bw1	16–41	55.8	20.0	24.2	6.38	0.15	0.31	15.11	8.20	0.64	0.49	61.7
Bw2	41–74	57.8	18.0	24.2	6.44	0.20	0.23	26.26	11.20	0.69	0.49	47.1
BC	74–84	59.8	14.0	26.2	6.40	0.20	0.15	26.47	13.20	0.67	0.48	54.2
Pedon 5 : Fine-loamy Typic Haplustalfs (moderately buried pediments)												
Ap	0–12	41.2	36.0	22.8	5.70	0.10	0.39	19.53	10.68	0.53	0.42	60.2
A1	12–30	39.2	42.0	18.8	5.85	0.10	0.39	17.58	10.00	0.60	0.43	62.7
A2	30-49	43.2	40.0	16.8	5.73	0.10	0.27	20.62	10.50	0.70	0.38	61.0
Bw	49–80	37.2	38.0	24.8	5.30	0.15	0.12	21.05	11.60	0.56	0.45	59.9
Bt1	88–114	45.2	26.0	28.8	5.69	0.10	0.08	27.13	17.20	0.62	0.49	67.4
Bt2	114–137	35.2	26.0	36.8	5.84	0.10	0.12	28.21	17.60	0.61	0.49	66.3
Bt3	137–165	39.2	28.0	32.8	6.01	0.10	0.15	22.13	16.80	0.56	0.49	80.7
Pedon 6 : Fine-loamy Typic Endoaquepts (Valley fills)												
Ap	0–12	41.2	40.0	18.8	6.67	0.50	0.97	23.00	20.00	0.82	0.44	92.4
Bwg1	12–26	35.2	40.0	24.8	7.31	0.40	0.19	21.05	18.00	0.83	0.38	91.3
Bwg2	26–58	33.2	40.0	26.8	7.54	0.40	0.19	17.58	15.20	0.83	0.39	93.4
Bwg3	58–72	25.2	52.0	22.8	7.57	0.40	0.08	19.31	15.60	0.83	0.35	86.9
Bwg4	72–96	23.2	54.0	22.8	7.63	0.35	0.19	19.53	17.80	0.71	0.34	96.5
Bwg5	96–126	26.4	52.0	21.6	7.51	0.30	0.16	18.20	14.35	0.55	0.35	83.7

Soil productivity rating index (Table 4) indicates that the soils of residual hills (pedon 1) are shallow, have low moisture holding capacity and coarse texture with lowest productivity rating index (3.16) are classified under extremely poor productivy class and are suited to grass and tree plantations to check severe erosion. The soils developed on side slopes of denudational hills (pedon 2) and pediments (pedon 3) are rated as productivity class of average (21.15) and poor (13.21), respectively. Moderately deep rooting depth, coarse texture with poor structure and low moisture holding capacity are the main limitations for vegetative growth. These soils are under sal forest which faces severe problem of deforestation by tribals causing soil erosion. Soils developed on shallow buried pediments (pedon 4) and moderately buried pediments (pedon 5) have productivity index of 46.65 and 54.40, respectively and qualify for good productivity class. These soils have minor limitations of internal drainage and low base saturation.

Table 4. Land productivity index (rating class with assigned ratings) of the pedons.

Soils	Soil moisture (H)	Drainage (D)	Effective soil depth (P)	Texture/ struc (T)	Base saturation (N)	Soluble salts tion (S)	Organic matter (O)	Nature of clay (A)	Mineral reserves (M)	Productivity class (index)
Pedon 1	H3c (70)	D4 (100)	P2 (20)	T1b (50)	N4 (80)	S1 (100)	O1 (85)	A1 (90)	M1 (85)	Extremely poor (3.16)
Pedon 2	H4a (80)	D4 (100)	P4 (80)	T1c (60)	N4 (80)	S1 (100)	O1 (85)	A1 (90)	M2a (90)	Average (21.15)
Pedon 3	H4a (80)	D4 (100)	P3 (50)	T1c (60)	N4 (80)	S1 (100)	O1 (85)	A1 (90)	M2b (90)	Poor (13.21)
Pedon 4	H4b (90)	D3a (90)	P4 (80)	T7 (100)	N4 (80)	S1 (100)	O2 (90)	A3 (100)	M3c (100)	Good (46.65)
Pedon 5	H4c (100)	D2b (80)	P6 (100)	T7 (100)	N4 (80)	S1 (100)	O1 (85)	A3 (100)	M3c (100)	Good (54.40)
Pedon 6	H5 (100)	D1b (40)	P6 (100)	T7 (100)	N5 (100)	S1 (100)	O2 (90)	A3 (100)	M3c (100)	Good (36.00)

These soils have the highest productivity index among all the soils. Valley-fill soils (pedon 6) have productivity rating index of 36.0 and have been placed in good productivity class. The main limitation for successful crop production is poor internal drainage of these soils. Although, these soils are well suited for paddy cultivaton as it requires poor drainage conditions. But soil productivity rating (Require *et al.* 1970) assess soil potential in general not for specific crop.

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