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A Remote Sensing Approach for Establishing the Soil Physiographic Relationship in the Coastal Agro Eco system of North Karnataka*

V. MINI, P. L. PATIL AND G. S. DASOG

Department of Soil Science and Agricultural Chemistry
University of Agricultural Sciences, Dharwad- 580 005, Karnataka, India
E mail: plpatiluasd@yahoo.com

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Abstract : Karnataka coastal area has a variety of topographic features. Soils of the Mirjan village (pilot site) of coastal agro ecosystem of Karnataka were studied in relation to topography by remote sensing followed by ground survey and laboratory analysis. Cadastral map of scale 1:8000 and IRS 1D LISS III+PAN fused image of the village were used for pedo-geomorphic investigations of the Mirjan village. Based on morphological (tone, texture, colour and contours) analysis, different physiographic features delineated on the base map are hills and hill ranges (254.56ha), low hills (129.28ha), midlands (88.57ha) and lowlands (80.41ha).

Key words: Remote sensing, soil physiography, coastal agro eco system

Introduction

Soils are considered as the integral part of the landscape and their characteristics are largely governed by the landforms in which they are developed. The physiographic influence of soil properties has been recognized which ultimately leads to evolution of the soil-landscape relationship. Topographic maps, aerial photographs and remote sensing data provide useful tool for geomorphic analysis of the region and help in soil survey and mapping. (Pandey and Pofali, 1982). Among these various tools, remote sensing data products owing to the synoptic view, large area coverage and amenability to record information on inaccessible terrains emerged as a superior tool for mapping the soils by aiding the physiographic delineation. The remote sensing technique is often used in conjunction with the conventional methods of soil survey and mapping. The technique has been employed successfully in different parts of the world (Gastellu - Etchegorry et al. 1990, Abd El-Hady et al. 1991) and in India (Sehgal et al., 1988) for characterization, classification and mapping of soils. In Karnataka a sizeable area (6.09 per cent of the total geographical area) is under coastal tract having variety of topographic features. The present study, thus, has been aimed at establishing soil landscape relationship in the area using remote sensing technique along with conventional field and laboratory approaches.

Material and Methods

The study area (Fig. 1) is Mirjan village and it lies between latitudes of 14^0 28' 07.42" N to 14^0 30' 18.68" N and longitudes of 74^0 25' 08.6" E to 74^0 26' 40.41" E near Kumta, Uttar Kannada district. The village covers an area of 653.92 ha. It is representative of the agro-ecological sub region 19.3 covering Karnataka coast of around 320 km. The climate of the area is characterized by high humidity nearly all the year round. The rainfall is plentiful with a mean annual rainfall of 3521.7 mm. The temperature variations are generally narrow in this zone. The maximum temperature (32.4^{0}C) is recorded in May and the minimum temperature (20.9^{0}C) in January. Detailed soil survey of Mirjan village was carried out using IRS – ID LISS – III + PAN merged image and cadastral maps as base maps during 2003-04. Based on colour, tone, texture, pattern and shadow of imagery, different physiographic features were delineated on the base map. Later the area was traversed extensively to check the physiographic boundaries. The different physiographic units identified in the study area were hills and Hill ranges, low hills, Midlands and lowlands (Fig. 2). In order to establish soil physiographic relationship, one typical pedon representative to each physiographic unit were chosen and exposed for detailed profile description. The soil samples collected from various horizons of the representative profiles were analysed for morphological, physical and chemical characteristics using methods outlined by Black (1965) and Jackson (1973).

Results and discussion

Pedogenic development corresponds to the physiography in the study area. The different physiographic units identified in the study area are (1) Hills and Hill ranges (2) Low hills (3) Mid lands (i) Midlands without vegetation and petroferric exposure (ii) Mid land paddylands (4) Lowlands (i) Nearly level paddy land with deep water table (ii) Nearly level paddy land with shallow water table and (iii) Garden lands (slightly raised). Due to thick vegetation cover in hills and hill ranges, the detailed study in its physiography was not possible.

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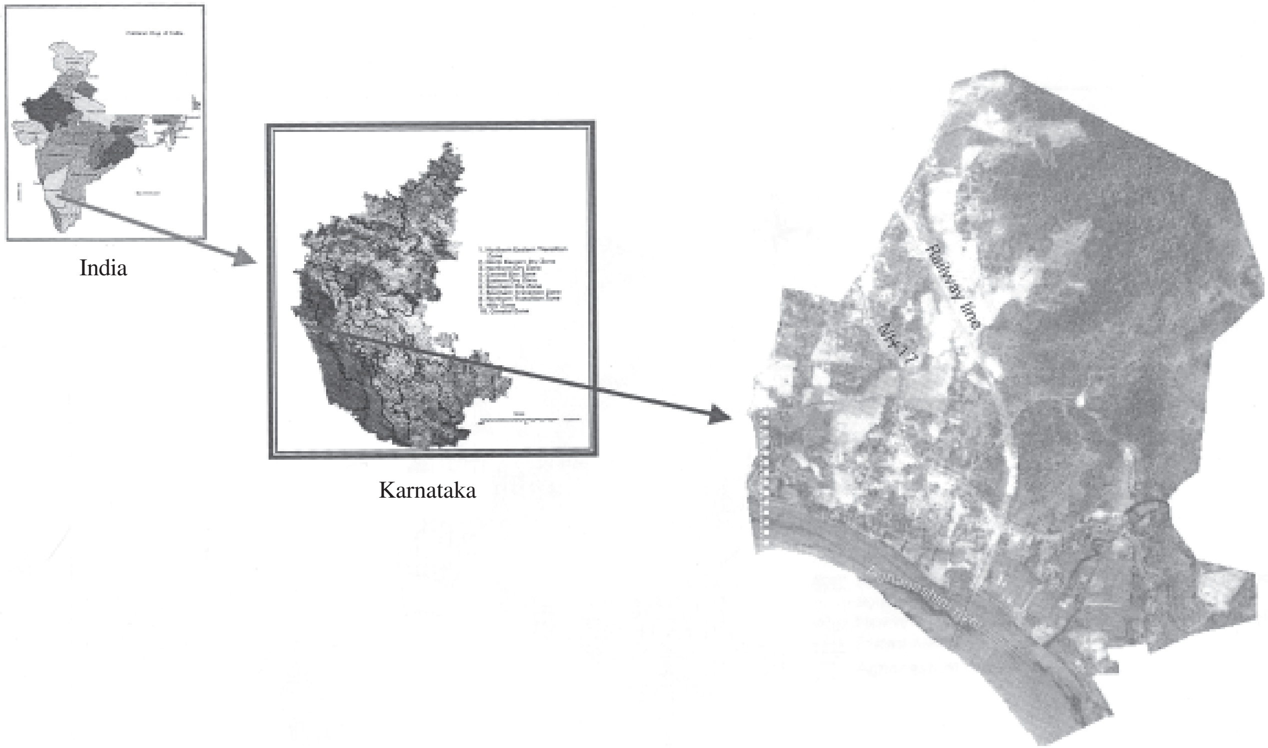

IRS 1D LISS -III image of Mirjan village

Fig. 1. Location map of the study area

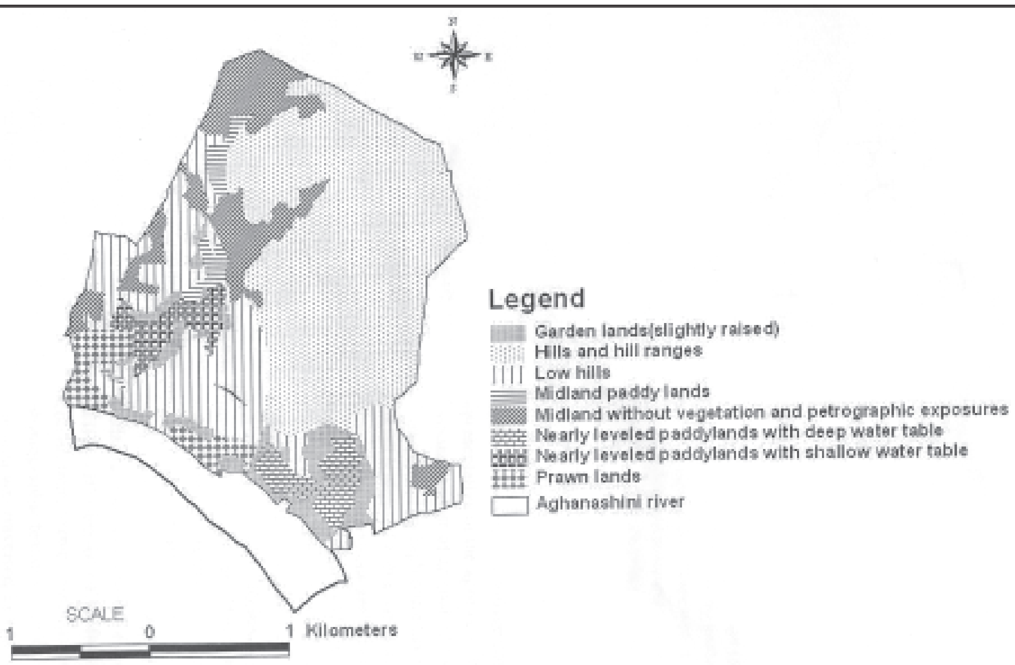

Fig. 2. Pysiographic map of Mirjan village

Hills and hill ranges, low hills and midlands were prone to moderate to severe erosion whereas lowland pedons had slight erosion.

The morphological characteristics of the soils developed on these physiographic units are described in Table 1. In the hills and hill ranges the colour of pedon 1 was yellowish red to reddish yellow in the surface horizon with a hue of 5YR. In the subsequent horizons colour was red with hue of 2.5 YR.

There was gradation in colour from reddish (5YR) colour in the higher topographic position to yellowish (10YR) colour in the lower topographic position. This is due to changing physiography and consequent changes in water table. The

Table 1. Morphological features of pedons

Horizon	Depth (cm)	Colour	Texture	Structure	Consistency			Roots	Boundary	Remarks
					Dry	Moist	Wet			
1.Hills and Hill ranges (Pedon 1)										
A_1	0- 12	5 YR 4/6	scl	m3fsbk	h	fr	ssp	mc	ds	Hard laterite layer below 80 cm
Bw_1	12- 40	5 YR 6/6	l	m2fsbk	sh	vfr	ssp	mc	ds	
Bw_2	40 –80	2.5 YR 5/7	l	very weak	vh	vfr	ssps	mc	cs	
2. Low hills (Pedon 2)										
A_1	0- 10	7.5 YR 5/6	scl	m2-3sbk	sh	vfr	ssps	mc	ds	Gravelly
Bt	10 –35	7.5 YR 5/5	cl	fm 2sbk	h	fr	ssps	mc	ds	Gravelly
BC	35- 50	7.5 YR 5/4	c	fl sbk	h	fr	ssps	mc	cs	Gravelly
3.Midland										
3.1 Midland without vegetation and Petroferric exposures (Pedon 3)										
A1	0 –13	7.5 YR 5/5	scl	fm3sbk	sh	vfr	ssps	cf	cs	Petroferric exposure on the surface
Bt1	13- 43	5 YR 5/6	l	m2 sbk	h	fr	ssps	ff	cs	
Bt2	43 – 80	5 YR 5/6	sil	f 1sbk	sh	fr	ssps	ff	ds	
3.2 Mid land Paddy land (Pedon 4)										
Ap	0-14	10 YR 5/2	sl	m2sbk	sh	vfr	ssps	cf	ds	Iron nodules were observed
Bt1	14 – 24	7.5 YR 6/8	scl	m1-2sbk	sh	vfr	ssps	cf	cs	
Bt2	24 – 53	7.5 YR 5/6	scl	fm1sbk	sh	vfr	ssps	cf	cs	
BC	53-90	5.0 YR 5/8	scl	m1sbk	s	l	ssps	-	cs	
C	90 – 120+	5.0 YR 8/8 &10.0 YR 8/8	l	very weak	l	l	ssps	-	cs	
4.0 Low lands										
4.1 Nearly level paddy lands with deep water table (Pedon 5)										
Ap	0-21	10YR6/5	sil	fm2sbk	sh	fr	ssps	cf	cs	Water table below 125 cm
A2	21-38	7.5YR6/6	sl	f1sbk	h	fr	ssp	cf	cs	
Bw1	38 –55	7.5YR5/4	c	m2sbk	vh	fr	ssp	cf	cs	
Bw2	55- 80	7.5YR5/6	sil	m2sbk	sh	fr	ssps	cf	cs	
BC	80 –112	5YR4/6	scl	m2sbk	sh	vfr	ssp	-	ds	
2C	112+	5YR4/6 & 10YR4/6	sl	massive	sh	vfr	ssps	-	cs	
4.2 Nearly level paddy lands with shallow water table (Pedon 6)										
Ap	0 –12	10 YR 3/4	c	m2sbk	vh	fr	ssp	mf	ds	Orange stains around root channels, water table below 75 cm
A2	12-24	10 YR 4/4	sic	m2sbk	h	fr	ssp	mf	ds	
A3	24– 53	10 YR 5/6, 2.5 YR5/6	c	massive	sh	vfr	ssp	-	ds	
AC	53-77+	10 YR 5/6	c	massive	s	l	ssp	-	ds	
4.3 Garden lands (Slightly raised) (Pedon 7)										
Ap	0-14	5 YR 4/4	scl	m2sbk	h	fr	ssp	cc	ds	Water table at 107 cm
A2	14 – 38	5 YR 4/4	c	m2sbk	h	vfr	ssps	cc	cs	
Bw1	38 –70	5 YR 4/6	c	m2sbk	sh	vfr	ssps	cc	cs	
Bw2	70 –98	5 YR 4/4	cl	m2sbk	sh	l	ssps	cc	cs	
BC	98 – 110+	5 YR 4/2 2.5 YR 4/6	cl	massive	sh	l	ssps		cs	

soils of low land pedons exhibited aquic characateristics like mottles (Venugopal and Koshy, 1985). Soil developed on hills and hill ranges had very weak, fine and sub-angular blocky structure in the sub-surface horizon indicating formation of altered B (cambic) horizon. The soils of low lands (pedon 5) had massive structure in all the horizons. The consistency of soils did not vary much among the pedons. The Hills and Hill ranges, low hills and Midland soils were relatively coarser in texture (Sandy loam to sandy clay loam) than lowland pedons (clay loam to clay) as a result of sorting of sediments and translocation of fine particles from overlying areas (Sawhney, 2000).

The coarse fragments (Table 2) were high in Hills (54.80 %) and midlands (29.77%). It is due to landscape setting which is highly sloping that facilitated erosion of soil. In low land the gravel content was less (4 – 44%) that may be due to the accumulation of sorted soil material at low lands. The speed of runoff water reduces by the time it reaches to foot slope in the hilly area, as a result finer eroded materials reach to low lands. The heavy rainfall of the study area and the combined effects of the site differences and slope are responsible for the down slope transport of materials by soil creep and surface wash. The formation of low land soils with low gravel content can be attributed to these processes (Rengaswamy *et al.*, 1978).

The accumulation of high amount of clay (Table 2) in the lower layers of pedon 4 and 5 is due to geomorphic setting. The intense rainfall in the area and consequent erosion processes from the slope have resulted in movement of clay from the slopes and deposition in the lowlands and subsequent intense leaching and eluviation through the upper layers of the profile has resulted in deposition in the lower layers near the water table. The soils are acidic in reaction. (pH 4.26 to 5.88) having lower pH values in the surface horizons compared to subsurface horizons (Table 2). Conductivity was very low indicating that the soils are free from salinity hazard. In low lands slightly higher EC was recorded compared to other pedons due to accumulation of salts at the low lands. The organic carbon content of surface soil was greater than the subsurface soils in most of the pedons (Table 2). This can be attributed to high amount of litter and crop residues at the surface. In pedon 3 (midland), organic carbon content was low throughout the profile except a slight increase in intermediate layer (0.26 to 0.55%) due to sparse vegetative cover and very rapid oxidation of organic matter facilitated by high temperature prevailing in the regions (Bhargava *et al.,* 1973).

The geographical setting influenced the exchangeable acidity also which was high in hills and hill ranges (16.18 to 21.20 c mol (p+) kg^{-1}) and was low in lowland pedons (9 to 19.60 c mol (p+) kg^{-1}). The fluvial processes are responsible for the distribution of exchange acidity in varying amounts in different horizons of pedon 6. The exchangeable bases were also more in lowland pedons and as a result base saturation was also high in low land pedons (Table 3).

The CEC of lowland pedons (8.80 to 11.44 c mol (p+) kg^{-1} were more than hills and hill ranges (9.04 to 17.72 c mol (p+) kg^{-1}). This difference is due to topographical setting. The percent base saturation by CEC-S was high in low land pedons whereas it was low in hills and hill ranges (Table 3). The high base saturation in low lands may be due to deposition of bases carried through runoff from higher elevations. Neutral soluble salts are removed from higher topographic positions and deposited at lowlands (Suresh Kumar *et al.,* 2001). The profile development was good in most of the pedons. The pedons on hills and hill ranges were with A-Bw horizon sequence whereas, low hills and midland pedons were with A-Bt-BC horizon sequence.

The role of parent material in formation of these soils is clearly seen in soil properties although it is largely governed by topography, also by climate and to a certain extent by vegetation. The general acidic character of these soils is due to the prevalence of acidic igneous rocks like granite and gneiss. Since all the soils under study are selected from coastal zone characterized by high rainfall and high temperature, their influence on different soil properties are seen to some extent. Low Base saturation and low CEC noticed in all the pedons was due to intensive leaching as a result of high intensity rainfall. At certain places of hills, the forest vegetation has modified the soil weathering processes leading to the better development or weathering of soils. Structural development was good at the surface layers due to binding action of organic material. Rate of

Pedons	Physiography	Classification
Pedon 1	Hills and Hill ranges	Typic Dystrustepts
Pedon 2	Low Hills	Typic Haplustalfs
	Midlands	
Pedon 3	(i) Midland without vegetation and petroferric exposures	Inceptic Haplustalfs
Pedon 4	(ii) Midland paddy land	Ultic Haplustalfs
Pedon 5	(i) Nearly level paddy lands with deep water table	Aquic Dystrustepts
Pedon 6	(ii) Nearly level paddy lands with shallow water table	Aquic Ustifluvents
Pedon 7	Garden lands	Oxic Dystrustepts

soil formation (Time) has also played an important role, since some of the soils of the study area are in an advanced stage of weathering. The soils of low lands of alluvial environments belong to Entisols without clear horizonation. Frequent fluvial and estuarine processes deposit new materials thus inhibiting the soil development. Soil classification : The soils were classified according to the criteria outlined in Keys to Soil Taxonomy (Anon., 1998). At subgroup level, the pedons under study are classified as follows.

Pedon 1, 5 and 7 were classified into Dystrustepts at great group level owing to the presence of cambic horizon and base saturation of less than 60 percent in all horizons at a depth between 25 and 75 cm from the mineral soil surface. At subgroup level pedon 5 was classified as Aquic Dystrustepts because of

Table 2. Particle size distribution, pH, EC and OC of soils

Horizon	Particle size distribution (%)							Chemical properties			
	Depth (cm)	Coarse fragments >2mm	Coarse sand 2-0-2mm	Fine sand0.2-0.05mm	Total sand 2-0.05mm	Silt 0.05-0.002mm	Clay <0.002mm	pH (1:2.5 water)	pH (1:2.5 KCI)	EC dSm^{-1}	O.C %
1.Hills and Hill ranges (Pedon 1)											
A1	0-12	54	26.4	3.3	29.7	33.8	36.5	5.35	4.15	0.05	2.04
Bw1	12-40	80	23.9	10.0	33.9	46.1	20.0	5.31	4.12	0.03	0.67
Bw2	40-80	66	31.6	8.8	40.3	37.8	21.9	5.38	4.15	0.03	0.53
2. Low hills (Pedon 2)											
A1	0-10	70	31.9	26.9	58.8	21.4	19.8	5.51	4.37	0.09	2.10
Bt	10-35	58	23.8	4.9	28.6	40.3	31.1	5.42	4.21	0.10	0.79
BC	35-50	66	30.2	10.4	40.6	16.8	42.5	5.41	4.17	0.20	0.82
3. Mid land											
3.1 Mid land without vegetation and petroferric exposures Pedon 3											
A1	0-13	42	35.3	24.5	59.8	20.1	20.1	5.20	4.14	0.23	0.26
Bt1	13-43	37	25.7	18.5	44.2	30.68	24.12	5.25	4.15	0.02	0.55
Bt2	43-80	63	24.2	12.0	36.2	52.5	11.3	5.19	4.02	0.02	0.26
3.2 Mid land Paddy land (Pedon 4)											
Ap	0-14	39	41.0	34.8	75.8	6.4	18.0	4.98	4.19	0.14	2.70
Bt1	14-24	39	29.7	27.5	57.2	21.1	21.6	5.61	4.13	0.10	0.99
Bt2	24-53	29	31.6	21.3	52.9	13.7	33.4	5.62	3.66	0.07	0.91
BC	53-90	77	38.2	21.8	60.0	15.1	24.9	6.04	5.19	0.07	0.03
C	90-120+	43	23.7	19.1	42.9	36.9	20.2	6.07	5.32	0.08	0.91
4. Low lands											
4.1 Nearly level Paddy lands with deep water table (Pedon 5)											
Ap	0-21	10	13.4	17.1	30.6	54.5	14.9	5.33	4.32	0.12	1.58
A2	21-38	44	22.2	18.6	40.8	27.9	31.4	5.26	4.44	0.09	0.96
Bw1	38-55	06	13.6	17.4	31.0	21.4	47.7	4.31	3.75	0.12	0.91
Bw2	55-80	06	18.1	9.4	27.5	21.1	51.4	4.15	3.70	0.25	0.26
BC	80-112	12	28.6	15.9	44.5	22.8	32.8	4.12	3.62	0.14	0.44
2C	112+	12	37.0	19.3	56.3	29.7	14.1	3.93	3.57	0.31	1.89
4.2 Nearly level Paddy land with shallow water table (Pedon 6)											
Ap	0-12	7	23.0	9.8	32.9	21.6	46.1	5.20	4.26	0.68	3.24
A2	12-24	11	6.1	4.4	10.6	47.6	41.9	5.39	4.62	0.08	2.75
A3	24-53	4	5.0	4.9	9.8	35.3	54.9	5.54	5.22	0.14	1.05
AC	53-77+	6	10.9	5.4	16.3	34.3	49.4	5.34	5.26	0.24	0.20
4.3 Garden lands (slightly raised) (Pedon 7)											
Ap	0-14	57	43.6	12.8	56.4	5.4	28.5	5.93	5.31	0.08	2.10
A2	14-38	60	2.8	16.5	19.3	16.9	63.8	5.80	5.25	0.04	0.68
Bw1	38-70	44	19.5	10.6	30.1	28.7	41.2	5.81	4.80	0.04	0.45
Bw2	70-98	55	20.9	11.2	32.2	31.6	36.3	5.80	4.71	0.06	0.97
BC	98-110+	25	14.0	6.1	20.2	45.1	34.7	5.65	4.57	0.05	1.28

the presence of redox depletions with chroma of 2 or less in more than one horizon within 75 cm of the mineral surface. In pedon 7, CEC of less than 24 c mol (p+) kg^{-1} was observed in more than 50 per cent of the soil volume between a depth of 25 to 100 cm from the mineral soil surface, qualifying this as Oxic Dystrustepts at subgroup level. Pedon 1 was keyed out as Typic Dystrustepts.

Pedon 2, 3 and 4 have argillic subsurface diagnostic horizon and do not have natric, oxic, cambic, petrocalcic horizons, plinthite and duripan. Therefore they key out as Haplustalfs at

Table 3. Exchangeable cations, exchangeable acidity, cation exchange properties and base saturation of soils

Horizon	Depth (cm)	Exchangeable cations: Na	K	Ca	Mg	Exchangeable acidity: $BaCl_2$-TEA Acidity	KCl acidity: Total	Exch. Al	Exch H	CEC -7	CEC -sum	BS (%)
		c mol (p+) kg^{-1}										
1. Hills and Hill ranges (Pedon 1)												
A1	0-12	0.22	0.17	5.8	2.6	21.20	0.66	0.25	0.41	10.20	29.99	29
Bw1	12-40	0.19	0.07	5.2	2.2	19.00	0.60	0.28	0.32	9.36	26.66	29
Bw2	40-80	0.35	0.04	4.8	2.4	16.80	0.30	0.13	0.17	8.8	26.39	29
2. Low Hills (Pedon 2)												
A1	0-10	0.30	0.06	5.8	3.0	17.00	0.65	0.20	0.45	10.48	26.16	35
Bt	10-35	0.21	0.04	5.2	3.2	17.40	0.58	0.25	0.33	10.40	26.05	33
BC	35-50	0.12	0.03	5.6	2.8	16.80	0.45	0.15	0.30	10.32	25.35	34
3. Mid land												
3.1 Mid land without vegetation and petroferric exposure (Pedon 3)												
A1	0-13	0.25	0.03	5.8	2.6	12.00	0.90	0.40	0.50	10.08	20.68	42
Bt1	13-43	0.29	0.03	6.0	2.2	12.20	0.8	0.35	0.45	9.64	20.72	41
Bt2	43-80	0.17	0.03	5.2	1.6	12.00	0.5	0.15	0.35	8.60	18.80	38
Pedon 4												
Ap	0-14	0.25	0.03	5.6	3.0	23.60	0.55	0.25	0.30	10.44	32.48	27
Bt1	14-24	0.28	0.03	6.0	2.8	17.20	0.45	0.20	0.25	10.12	26.36	35
Bt2	24-53	0.26	0.03	5.8	2.4	11.40	0.45	0.20	0.25	10.16	19.93	43
BC	53-90	0.37	0.07	4.8	1.8	6.80	0.35	0.10	0.20	8.36	13.84	51
C	90-120+	0.28	0.05	3.6	1.2	7.40	0.35	0.15	0.20	6.96	12.53	41
4. Low lands												
4.1 Nearly level Paddy lands with deep water table (Pedon 5)												
Ap	0-21	0.25	0.03	5.8	4.4	9.00	0.45	0.15	0.30	11.40	19.33	54
A2	21-38	0.18	0.01	5.8	4.2	13.00	0.40	0.12	0.28	11.44	21.68	47
Bw1	38-55	0.17	0.03	6.0	3.8	19.40	0.35	0.11	0.24	11.12	29.45	34
Bw2	55-80	0.12	0.04	5.6	3.2	19.60	0.45	0.15	0.30	10.44	28.51	31
BC	80-112	0.16	0.04	5.4	2.8	13.40	0.50	0.20	0.30	10.12	21.75	39
2C	112+	0.21	0.04	5.0	1.2	17.80	0.65	0.25	0.40	8.80	24.90	26
4.2 Nearly level Paddy land with shallow water table (Pedon 6)												
Ap	0-12	0.24	0.05	6.0	3.8	20.40	0.55	0.20	0.35	11.36	30.49	33
A2	12-24	0.41	0.03	5.6	3.4	16.20	0.45	0.15	0.30	10.20	25.64	37
A3	24-53	0.42	0.05	5.2	3.8	12.20	0.42	0.13	0.29	10.48	21.67	44
AC	53-77+	0.43	0.05	5.2	3.2	10.40	0.40	0.15	0.25	10.04	19.28	46
4.3 Garden lands (slightly raised) (Pedon 7)												
Ap	0-14	0.45	0.16	5.8	2.6	12.00	0.35	0.10	0.25	10.64	21.09	43
A2	14-38	0.48	0.05	5.6	3.0	11.60	0.35	0.10	0.25	10.16	20.73	44
Bw1	38-70	0.33	0.07	5.4	2.8	11.20	0.25	0.05	0.20	9.96	19.8	43
Bw2	70-78	0.44	0.09	5.0	2.4	15.40	0.25	0.05	0.05	9.2	23.33	34
BC	98-110+	0.41	0.10	4.8	1.2	14.00	0.20	0.05	0.15	7.64	20.51	32

great group level. The presence of an argillic horizon of less than 35 cm thick qualified pedon 3 to be classified as Inceptic Haplustalfs. Pedon 4 of midland has an argillic horizon with a base saturation of less than 75 percent throughout. Therefore it keys out as Ultic Haplustalfs at subgroup level. Pedon 6 was qualified for Aquic Ustifluvents because of the irregular decrease in organic carbon content and reducing conditions that prevail for one month or more during the year. (Sawhney, *et al.,* 2000). Redox depletions with chroma of 2 or less along with aquic condition was present within 50 cm of the mineral soil surface in this pedon.

The presence of better developed soils *viz.,* Alfisol in the unstable land forms like hills is due to the effect of vegetation which might have modified the weathering process (Patil and Dasog, 1999). Pedons of midlands also showed a better development. The soils of alluvial nature in the lowlands are young soils and lack any diagnostic horizon.

The study reveals that soil properties like profile development, texture, structure, colour, acidity, cation exchange capacity, base saturation *etc* are related to land form. There is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography causing erosion, leaching, sedimentation and other pedogenic processes modified by water table.

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