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Soil physiographic relationship in southeastern sector of submontane tract of Punjab

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Abstract

The soils of southeastern part of submontane tract of Punjab were studied in relation to topography by remote sensing followed by ground survey and laboratory analysis. The study demonstrated a well marked soil-physiographic relationship in the area having typical soil on each landform unit. The soils on relatively unstable landforms indicated young and immature A-C profile whereas those from stable landforms showed distinct profile development having A-Bw-C and A-Bt-C horizons sequence. Topography and parent material were found to be the major factors governing the soil characteristics specially on unstable surfaces whereas time as an additional factor on stable surfaces during which pedogenic processes were responsible for their differences in the profiles. The soils on upper piedmont plain were classified as Typic Ustorthents, 'choe' beds as Typic Ustipsamments, recent flood plain as Aquic Ustifluvents, lower piedmont as Typic Haplustepts and old alluvial plain as Typic Haplustalfs.

Additional keywords : Remote sensing, soil characteristics, genesis.

Introduction

Soils are considered as the integral part of the landscape and their characteristics are largely governed by the landforms on which they developed. Physiographic influence on soil characteristics has been recognized which ultimately leads to evolution of the soil-landscape relationship. The remote sensing technique has proved to be a useful tool to work out soil-landscape relationship and 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; Ahuja *et al.* 1992; Verma *et al.* 1998) for characterization, classification and mapping of soils.

In Punjab, a sizeable area (about 9.9% of the total geographical area) is under submontane tract (Sidhu 1992) having variety of topographic features. Though the attempts have been made to characterize and classify the soils and establish soil-physiographic relationship in central and northwestern sector of the belt (Anand *et al.* 1977; Singh 1979; Ibrahimi *et al.* 1986; Sharma *et al.* 1986) not much information is available particularly for southeastern part (Ropar district) of the tract. 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.

Materials and methods

Setting of the area : The study area lies between 30°26'35" and 31°34'14" N latitudes and 76°17'13" and 76°51'28" E longitudes in Ropar district of Punjab. Geologically, two distinct units, viz. the Siwaliks and recent deposits of the foothills were recognized. The Siwalik hills constitute sedimentary rocks such as sandstones, siltstones, conglomerates and clays (Wadia 1976) whereas foothill areas include recent deposits of alluvial and/or colluvial nature.

The climate of the area is semi-arid (sub-moist). The mean annual rainfall varies from 870 to 1060 mm whereas mean annual soil temperature remains about 25°C. As the MAST is more than 22°C and the MSST and MWST differ by more than 5°C at 50 cm depth the area qualifies for hyperthermic temperature regime. The soils remain dry for 90 and 180 cumulative days and remain moist for atleast 90 consecutive days and as such qualify for ustic moisture regime.

Methodology : Besides, the Survey of India toposheets on scales 1:50,000 and 1:250,000, Landsat TM imagery in the form of FCC (bands 2, 3 and 4) on scale 1:250,000 were used for pedogeomorphic investigation of the submontane tract of Punjab. Based on morphological (tone, texture, colour and contours) analysis, different physiographic features were identified and delineated on 1:50,000 base map.

In order to establish soil-physiographic relationship, two typical pedons from each physiographic unit, fully illustrative of the various image manifestations, were chosen and exposed for detailed profile description. The soil samples collected from various horizons of the representative profiles were analysed for physical and chemical characteristics following the procedures outlined by Klute (1994).

Results and discussion

Physiography : The area was differentiated into six physiographic units, namely Siwalik hills, piedmont plains, old alluvial plains, recent flood plains and choe beds (Table 1 & Fig. 1). The Siwalik hills form the northeastern part of the studied area and comprise of series of low altitude (<775 m), narrow, elongated northwest-southeast running parallel hills. The piedmont plains form the foothill belt to the south of Siwalik hills. The unit comprises gently to moderately steep sloping undulating/rolling plains often divided into upper and lower piedmont plains. Small seasonal rivulets ('choes') which originate from the Siwaliks and often terminate in the piedmont plains form the important feature of this area. The old alluvial plain constitutes nearly level to very gently sloping terrains to the south of the piedmont plain. This relatively stable terrain with least erosion, deposition and penetrable depth of water table, is intensively cultivated for most climatically adopted crops. Recent flood plains cover a narrow strip along the Satluj river having heterogeneous parent material with depth.

Morphological, physical and chemical characteristics : The morphological characteristics (Table 2) indicate that soils on recent flood plains and choe beds are relatively lighter in colour (brownish grey to yellowish brown) compared to the soils on Siwalik hills, piedmont plains and old alluvial plains (yellowish brown to dark brown). This may be ascribed to little available colouring matter such as sesquioxides and organic matter and their easy washing out on account of excessive drainage of the former soils.

Table 1. Spectral characteristics of different physiographic units

Physiographic unit	Spectral characteristics	Vegetation	Rock/Soil type
Siwalik hills	Dark brown, fine texture, deep gullies, dendritic to subdendritic drainage	Forest cover having bushes and shrubs	Sandstone, siltstone, conglomerate, shale and clays
Upper piedmont plains	Bright white with fine reddish brown dots, coarse texture, dendritic drainage	Sparsely cultivated and grasses	Gravel, pebbles sand, loamy sand
Lower piedmont plains	Whitish and reddish brown mixed spotty appearance, medium to coarse texture	Moderately cultivated for wheat, paddy and maize	Sandy loam, loam, silt loam
Old alluvial plains	Uniform reddish brown tone, fine texture, lack drainage lines	Intensively cultivated for wheat and paddy	Loam, silt loam, silty clay loam
Recent flood plains	Whitish or yellowish white area separated from streams/rivers by dark grey/black channel line	Thinly cultivated for some seasonal crops	Sand, loamy sand, sandy loam, silty clay
'Choe' beds	Bright white in the form of channels, fine texture, dendritic pattern	Very sparse vegetation	Sand, loamy sand

Table 2. Some important morphological characteristics of the soils*

Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Effervescence	Boundary
		Profile 1 (Siwalik hills)				
A	0–16	7.5YR 5/4	sl	f1 sbk	e	cs
C1	16–36	7.5YR 5/4	sl	m	e	cs
C2	36–66	7.5YR 5/4	scl	m	e	cs
Cr1	66–88	7.5YR 4/4	sl	m	e	gs
Cr2	88–113	7.5YR 4/4	scl	m	e	gs
Cr3	113–140	7.5YR 4/4	scl	m	es	–
		Profile 2 (Upper piedmont plains)				
A	0–12	10YR 3.5/4	ls	f1 gr	–	cs
C1	12–36	10YR 3.5/4	s	sg	–	ci

C2	36–62	10YR 4/4	s	sg	e	ci
C3	62–75	10YR 4/4	s	sg	e	ci
C4	75–102	10YR 3.5/4	s	sg	e	–
		Profile 3 (Lower piedmont plains)				
Ap	0–20	10YR 5/6	sl	m1 sbk	es	as
BA	20–42	10YR 5/4	sl	f1 sbk	es	as
Bw1	42–65	10YR 4/6	l	f1 sbk	ev	as
Bw2	65–92	10YR 4/6	l	m2 sbk	es	cs
Bw3	92–115	10YR 4/4	l	m2 sbk	es	gs
BC	115–135	10YR 4/6	l	f1 sbk	es	cs
C	135–150	10YR 5/6	sl	m	es	–
		Profile 4 (Old alluvial plains)				
Ap	0–15	10YR 4/3	sil	m1 sbk	ev	cs
Bt1	15–40	10YR 4/3	cl	m2 sbk	ev	cs
Bt2	40–75	10YR 4/4	sicl	m2 sbk	es	gs
BC1	75–91	10YR 4/4	l	m2 sbk	es	gs
BC2	91–125	10TR 5/4	sl	f1 sbk	es	gs
C	125–150	10YR 5/4	sl	m	ev	–
		Profile 5 (Recent flood plains)				
Ap	0–15	10YR 6/4	l	m	ev	cs
A12	15–30	10YR 6/4	cl	m/f1 sbk	ev	cs
C1	30–46	10YR 5/4	ls	m	es	gs
C2	46–75	10YR 5/4	ls	m	es	gs
C3	75–100	10YR 6/2	s	m	es	–
		Profile 6 ('Choe' beds)				
Ap	0–25	10YR 6/4	s	sg	es	gw
C1	25–40	10YR 6/4	s	sg	es	gw
C2	40–68	10YR 6/3	s	sg	es	gw
C3	68–79	10YR 6/3	s	sg	e	gw
C4	79–100	10YR 6/3	s	sg	e	–

* Symbols from Soil Survey Manual (Soil Survey Staff, 1951)

The hill soils (P1) show sandy loam texture in surface horizon and sandy loam to sandy clay loam in subsurface horizons primarily due to variation in parent material. The upper piedmont plain soils are relatively coarser in texture (sand to loamy sand) than lower piedmont plain soils (sandy loam to loam) as a result of sorting of sediments. The old alluvial plain soils (P4) are relatively finer textured in subsurface horizons (clay loam to silty clay loam) compared to overlying and underlying horizons which may be ascribed to translocation of finer particles from overlying horizons by the percolating water. The flood plain soils (P5) are stratified due to periodic deposition of new sediments much faster than the soil development (Chakrabarty *et al.* 1979).

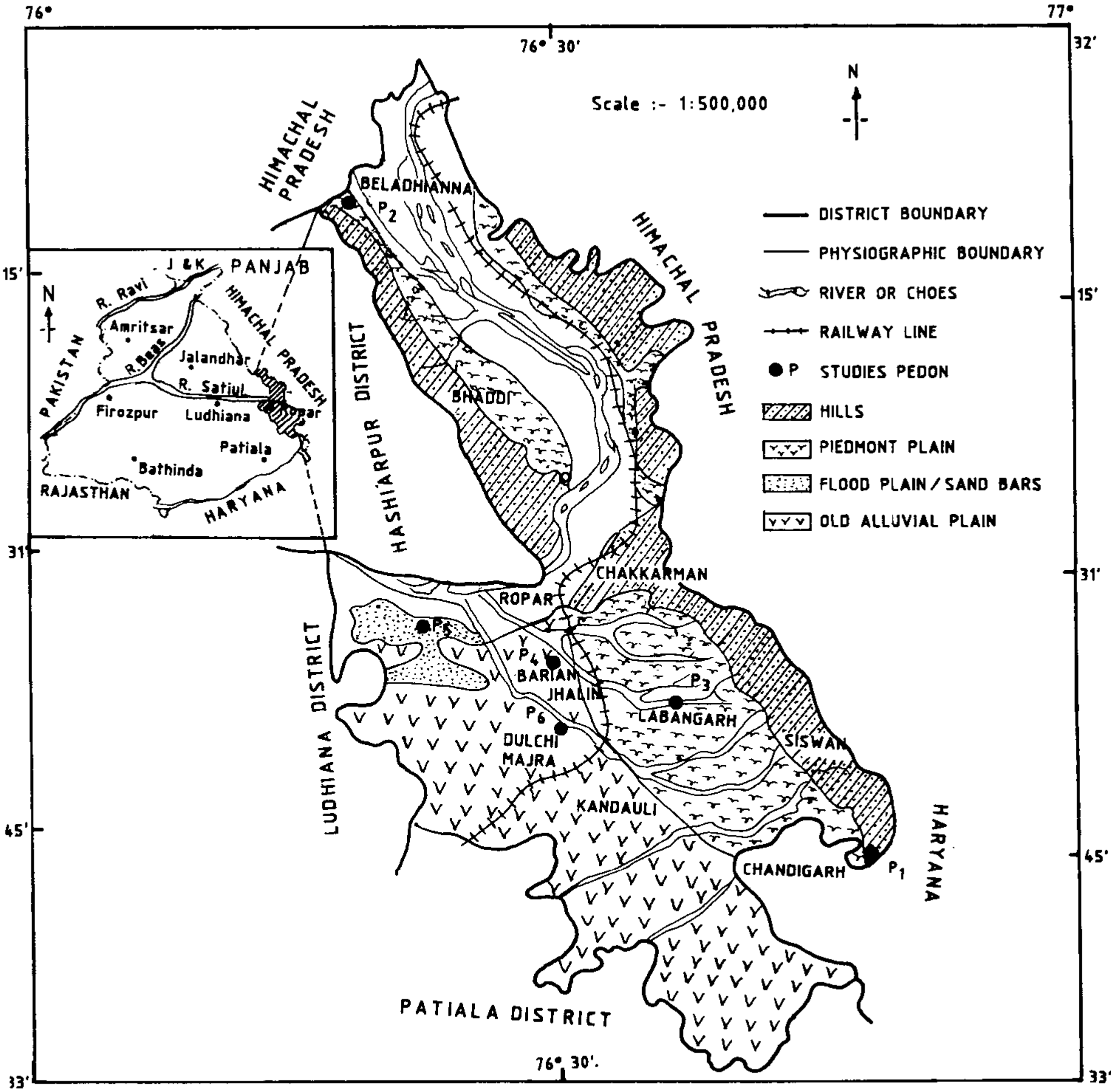

Fig. 1. Location and physiographic map of study area.

The soils on Siwaliks (P1), upper piedmont plains (P2), recent flood plains (P5) and 'Choe' beds (P6) lack aggregation except weakly developed peds in surface horizon of some of these soils (P1 and P2). The soils are generally structureless (massive or single-grained) possibly due to coarser texture having low contents of silt, clay and organic matter (Deka *et al.* 1996). The lower piedmont plain (P3) and old alluvial plain (P4) soils, however, show weak to moderate, fine to medium, subangular blocky structure throughout the solum which might be due to their fine texture and sufficient exposure to pedogenic processes.

The soils are invariably alkaline in reaction (pH 7.1-9.1) having lower pH values in the surface horizons compared to subsurface horizons (Table 3). The electrical conductivity varies from 0.04 to 0.26 dS m^{-1} indicating that the soils are free from any salinity hazard. The soils are low in organic carbon content due to rapid decomposition of biomass under prevailing hyperthermic temperature regime. All the soils show presence of calcium carbonate at some depth in the solum. The soils, however, do not show calcretes possibly due to leaching condition of the soil. The free carbonate in the soils appears to be from the parent materials contributed from the Siwaliks.

Table 3. Some important physical and chemical characteristics of soils

Horizon	Sand	Silt (%)	Clay	pH (1:2)	EC dS m^{-1}	$CaCO_3$ g kg^{-1}	OC g kg^{-1}	CEC cmol (p+) kg^{-1}
			Profile 1 (Coarse-loamy, Typic Ustorthents)					
A	64.6	18.8	16.6	7.6	0.21	9.5	2.7	8.8
C1	62.8	20.7	16.5	7.9	0.17	8.5	1.1	8.3
C2	57.5	22.0	20.5	8.0	0.17	9.5	0.9	9.1
Cr1	66.4	17.3	16.3	8.1	0.14	8.5	0.3	6.9
Cr2	67.6	9.8	22.6	8.3	0.13	9.0	0.6	10.0
Cr3	64.8	13.1	22.1	8.5	0.26	11.5	0.5	9.1
			Profile 2 (Typic Ustipsamments)					
A	84.6	11.6	3.8	7.1	0.04	-	1.8	4.5
C1	91.4	6.2	2.4	7.5	0.05	-	1.1	2.8
C2	94.5	3.6	1.9	8.4	0.08	3.0	0.8	2.0
C3	95.7	2.5	1.8	8.5	0.08	4.0	0.8	1.8
C4	96.0	2.4	1.6	8.5	0.08	5.7	0.6	1.8
			Profile 3 (Fine-loamy, Typic Haplustepts)					
Ap	53.9	31.4	14.7	8.6	0.17	15.8	1.2	9.0
BA	52.3	32.5	15.2	8.7	0.19	18.0	0.9	9.6
Bw1	40.7	41.7	17.6	8.7	0.15	22.5	0.8	10.9
Bw2	29.8	48.2	22.0	8.8	0.08	18.5	0.8	12.2
Bw3	29.3	46.2	24.5	8.9	0.13	18.5	0.8	14.2
BC	30.5	49.0	20.5	8.9	0.12	18.0	0.7	9.3
C	62.8	23.2	14.0	8.9	0.11	17.0	0.7	8.2
			Profile 4 (Fine-loamy, Typic Haplustalfs)					
Ap	25.3	51.5	23.2	8.3	0.25	44.7	2.5	14.9
Bt1	21.3	50.2	28.5	8.7	0.10	26.7	1.0	16.6
Bt2	15.8	52.7	31.5	9.3	0.12	19.0	1.2	17.5
BC1	38.8	44.0	17.2	9.0	0.11	15.5	1.1	11.4
BC2	61.0	24.5	14.5	8.9	0.12	20.0	1.2	10.2
C	64.5	23.7	12.7	8.9	0.12	22.5	1.2	8.8
			Profile 5 (Coarse-loamy, Aquic Ustifluvents)					
Ap	42.3	38.0	19.7	8.3	0.23	30.0	1.8	12.5
A12	21.3	43.4	35.3	8.4	0.15	45.5	1.5	20.2

C1	86.0	5.5	8.5	8.8	0.19	12.5	1.9	5.2
C2	79.0	10.8	10.2	8.8	0.13	17.5	0.3	5.9
C3	92.4	4.0	3.6	9.0	0.13	17.5	0.3	2.4
			Profile 6 (Typic Ustipsamments)					
Ap	93.1	3.4	3.5	9.1	0.09	12.0	0.3	2.0
C1	92.2	4.0	3.8	9.0	0.06	13.0	0.3	2.2
C2	91.1	4.6	4.3	8.9	0.12	12.0	0.2	2.7
C3	93.3	3.7	3.0	8.9	0.09	10.0	0.1	2.1
C4	93.6	3.4	3.0	9.0	0.10	9.0	0.1	2.1

The cation exchange capacity (CEC) varies widely in the pedons ranging from 1.8 to 20.2 cmol (p+) kg^{-1}. The higher CEC values were observed in old alluvial plain soils (P4) whereas lower CEC values in soils of upper piedmont plains (P2), flood plains (P5) and 'Choe' beds (P6) which may be primarily due to variation in clay content in these soils. The soils on upper piedmont plains (P2) show relatively higher CEC/clay ratio compared to other soils which may be due to the dominance of smectite in clay fraction of the former soils (Jassal and Sidhu 1991). Calcium and magnesium are the dominant cations on the exchange complex followed by potassium and sodium.

Influence of soil forming factors : The young soils from unstable landforms (Siwaliks, upper piedmont plains, recent flood plains, 'choe' beds) show little alteration and translocation in originally deposited parent material and as such profile development is limited. The properties of these soils thus largely determined by the nature of parent material which have been derived from highly variable geological formation of the Siwaliks. Soil variation as a result of depositional difference in sediments in the Indo-Gangetic plains was also reported by Holmes and Western (1969).

The soils from hills (P1), in some area, show influence of the underlying rocks. The flood plain soils (P5) show abrupt changes in properties with depth due to heterogenous or stratified nature of parent material. The soils on upper piedmont plains and 'Choe' beds (P2 and P6), on the other hand, do not show variation in property with depth due to uniform nature of parent material.

A transect from the Siwaliks to the river Satluj (Fig. 2) shows the physiographic control over kind and properties of soils. The Siwalik hills, being on steep slopes, allow more surface runoff than percolation of water and as such little profile development. The flood plain and 'Choe' bed soils suffer severe erosion, reworking of older sediments and deposition, and hence had little time for pedogenic processes to act upon parent material. Moreover, the coarser texture dominated by resistant quartzitic sand (Sawhney *et al.* 1992) has restricted the horizon differentiation. The soils on lower piedmont plains (P3) and old alluvial plains (P4) have undergone to a certain degree of transformation and translocation of soil material due to their relatively stable landscape positions and thus show development of cambic and argillic subsurface horizons.

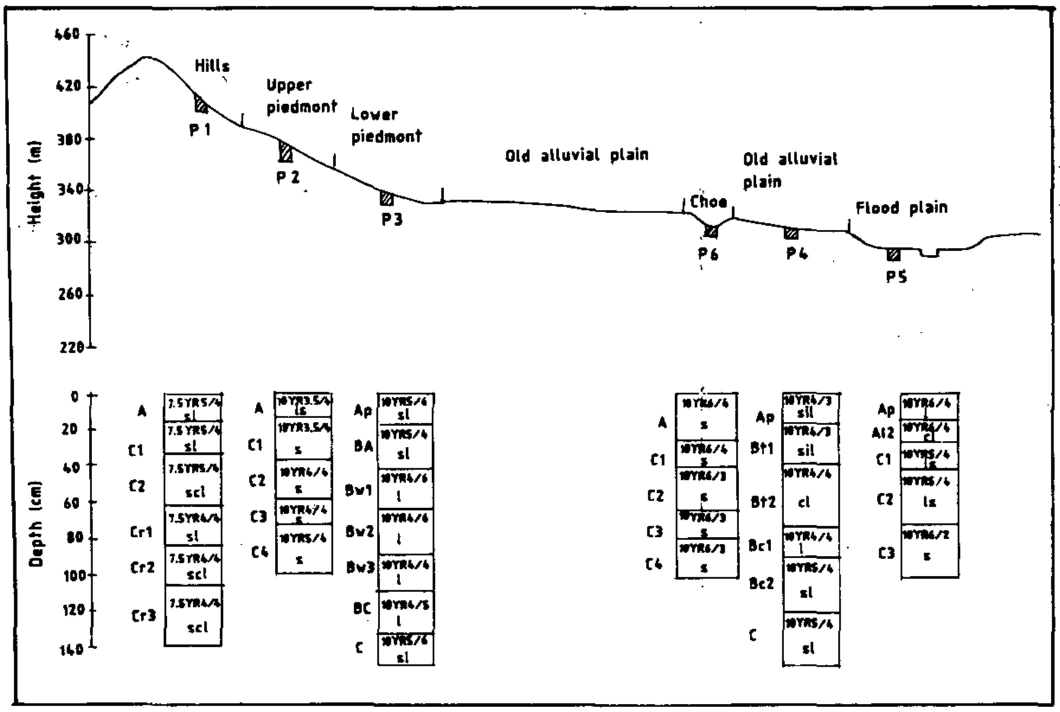

Fig. 2. Transect showing soil-physiographic relationship.

Soil classification : The soils were classified according to the criteria outlined in Key to Soil Taxonomy (Soil Survey Staff 1998). The soils on Siwaliks (P1), upper piedmont plains (P2), recent flood plains (P5) and 'Choe' beds (P6) were young, stratified and lack any diagnostic horizon and as such were classified as Entisols. The coarse texture (loamy sand/ sand) of upper piedmont plain (P2) and 'Choe' bed (P6) soils were grouped as Psamments at suborder level. These soils were classified as Typic Ustipsamments because of ustic moisture regime and unique characteristic at subgroup level. The stratified soils on recent flood plain (P5) were classified as Fluvents at suborder level, as these soils show irregular decrease in organic carbon content and have highly variable texture (Suri 1976) with depth. These soils were qualified for Aquic Ustifluvents because of the reducing conditions that prevail for one month or more during the year. The Entisols developed on hills (P1) were classified as Typic Ustorthents. The soils from lower piedmont and old plains have cambic and argillic subsurface diagnostic horizons, respectively and thus classified as Typic Haplustepts and Typic Haplustalfs.

Conclusions

The soils and physiographic study of the southeastern part of the submontane tract of Punjab carried out using remote sensing and conventional techniques demonstrated a well marked soil-physiographic relationship in the submontane tract of Punjab. The soils from Siwalik hills, upper piedmont plains, flood plains and 'Choe' beds showed A-C profile, the soils from lower piedmont plains showed A-Bw-C profile and that the soils from old alluvial plains had A-Bt-C profile. The soil variation in the submontane tract has been ascribed primarily due to topography and parent material. The soils from stable landscape which showed some pedogenic development, however, suggest additional role of time factor besides topography and parent material.

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References

Abd El-Hady, A.M., Rognon, P., Escadafal, R., and Pouget, M. (1991). Contribution of Landsat data (MSS) to soil survey : application to the soil of southwestern Sinai (Egypt). *International Journal of Remote Sensing* **12**, 1053-1062.

Ahuja, R.L., Manchanda, M.L., Sangwan, B.S., Goyal, V.P., and Agrawal, R.P. (1992). Utilization of remotely sensed data for soil resource mapping and its interpretation for landuse planning of Bhiwani district, Haryana. *Journal of the Indian Society of Remote Sensing* **20,** 105-120.

Anand, R.R., Sehgal, J.L., and Sharma, P.K. (1977). Study of relationship between physiography and soil by using aerial photographs as a base map in a part of the Malwa alluvial plain (Punjab). *Fertilizer Technology* **14**, 70-75.

Chakraborty, D.N., Sehgal, J.L., and Dev, G. (1979). Sand mineralogy of the alluvium derived soils of southern bank of the river Brahmaputra in Assam. *Journal of Indian Society of Soil Science* **27**, 417-426.

Gastellu-Rtchegorry, J.P., Van Der Meer Mohr, H., Handaya, A., and Surjanto, W.J. (1990). An evaluation of SPOT capacity for mapping the geology and soils of Central Java. *International Journal of Remote Sensing* **11**, 685-702.

Holmes, D.A., and Western, S. (1969). Soil texture patterns in the alluvium of the lower Indus Plains. *Journal of Soil Science* **20**, 23-37.

Ibrahimi, J.M., Sehgal, J.L., and Sharma, P.K. (1986). Two dominant stages of pedogenic development in the soils of Bist Doab alluvial plain in Punjab. *Journal of Indian Society of Soil Science* **34**, 334-342.

Jassal, H.S., and Sidhu, P.S. (1991). 14 A^0 minerals in soils of sub-mountain region of Punjab. *Clay Research* **10**, 48-51.

Klute, A. (1994). 'Methods of Soil Analysis'. (American Society of Agronomy and Soil Science Society of America : Wisconsin, USA).

Sawhney, J.S., Verma, V.K., Sharma, B.D., and Sharma, P.K. (1992). Pedogenesis in relation to physiography in semi-arid and arid tracts of Punjab, India. *Arid Soil Research and Rehabilitation* **6,** 93-103.

Sehgal, J.L., Sharma, P.K., and Karale, R.L. (1988). Soil resource inventory of Punjab using remote sensing technique. *Journal of the Indian Society of Remote Sensing* **16**, 39-47.

Sharma, P.K., Sehgal, J.L., Saggar, S., and Chandi, K.S. (1986). Soils of the Kandi area in Punjab and their suitability for landuse planning. *Journal of Indian Society of Soil Science* **34**, 133-141.

Sidhu, P.S. (1992). Soil resources of Punjab. In Souvenir, Published on International Symposium on 'Nutrient Management for Sustained Productivity' (Punjab Agri cultural University : Ludhiana).

Singh, C. (1979). Characterization of soils of the operational project for dryland agriculture in Malewal group of villages in Hoshiarpur district (Punjab), M.Sc. Thesis, Punjab Agricultural University, Ludhiana.

Soil Survey Staff (1951). 'Soil Survey Manual', Agric. Handbook 18 (USDA : Washington, DC).

Soil Survey Staff (1998). 'Key to Soil Taxonomy' Eighth Edition (USDA, Natural Resources Conservation Service : Washington, D.C.).

Suri, B.L. (1976). Pedogenesis of salt-affected soils and their associated cultivated soil of the Kapurthala district. M.Sc. Thesis. Punjab Agricultural University, Ludhiana.

Verma, V.K., Chopra, R., Sharma, P.K. and Singh, C. (1998). Integrated resource study for conservation and management of Ropar wetland ecosystem, Punjab. *Journal of Indian Society of Remote Sensing* **26**, 185-195.

Wadia, D.N. (1976). 'Geology of India'. (Tata McGraw Hill Publishing Co. : New Delhi).

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