Characteristics and Classification of Alkali Soils on Siwalik Hills of Satluj-Yamuna Divide, North-West India

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Abstract : *Alkali soils have been found to occur on the steeply sloping Siwalik hills of Satluj-Yamuna divide in north-west India with lithological discontinuities. They have udic moisture regime; silt loam texture and are calcareous. Electrical conductivity is low and pH varies from 8.8 to 9.7. Soils have low hydraulic conductivity. ESP varies from 14 to 45. Na^+ and Cl^- are the dominant ions in the saturation extract. Fertility status of these soils is low. They are deficient in DTPA extractable Fe, Mn and Zn. Taxonomically they have been classified as Typic Udorthents.* (**Key words** : *Siwalik hills, udic soil moisture regime, alkali soils)*

In the Indian sub-continent a major portion of alkali soils occur in the Indo-Gangetic plains of north India. Estimates of reported area of alkali soils vary from 2.8 m ha (Abrol & Bhumbla 1977) to 3.6 m ha (Szabolcs 1989). Alkali soils have been reported to generally occur in association with the so called normal cultivated soils (Vinayak *et al.* 1981). There is general agreement that these soils occur in 20-30 cm micro-depressions in the alluvial plains having ustic to aridic soil moisture regimes only (Aggarwal & Yadav 1954; Bhumbla *et al.* 1973; Bhargava & Bhattacharjee 1982; Mehta 1983; Sharma 1989; Szabolcs 1989; and Acharya & Abrol 1991). Recently, Grewal and Juneja (1991), and Kumar (1992) observed the occurence of alkali soils in the hilly forested catchment of Siwalik hills. Accordingly, present investigation is an initial attempt to understand the occurence, geomorphology, macromorphology, physico-chemical characteristics, nutrient status and taxonomy of these soils in the Siwalik hills of the Satluj-Yamuna divide in north-west India.

MATERIAL AND METHODS

Area under study is located at the boundaries of Punjab and Haryana state in the Siwalik hills (Fig.1) with elevation ranging from 380 m to 480 m and rainfall varying from 1100 to 1125 mm (Table 1). Both the sites are excessively drained and there are no evidences of water stagnation even in the near past. Temperature and moisture regimes of these soils are Thermic and Udic respectively (Sehgal *et al.* 1987)

Particle size fractionation was carried out by using the procedure of Jackson (1975). Soil texture was estimated with the help of USDA soil textural diagram. Hydraulic conductivity of disturbed soil sample was estimated by adopting the method described by Richards (1954). Moisture retention was determined with Richard's pressure plate apparatus (Richards & Fireman 1943). Bulk density of the undisturbed clods was calculated from their mass and volume determined by immersing the wax coated clods in specially disigned apparatus for this purpose.

pH and EC soil samples was measured in 1:2 soil water suspension. The organic carbon, was determined by following the standard procedures (Soil Conservation Service 1972).

Saturation paste was prepared as per the procedure outlined by Rhoades (1982). Water soluble

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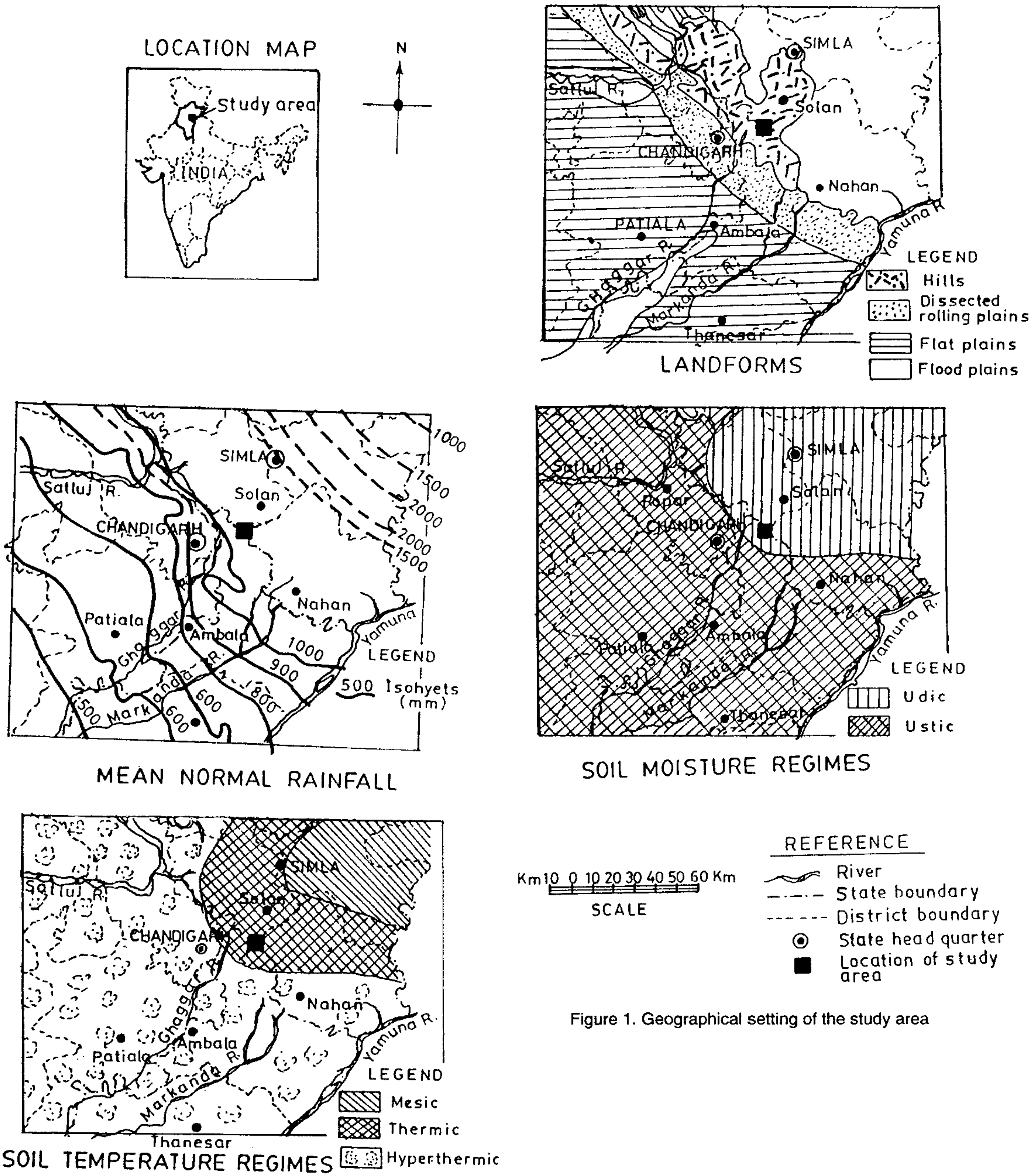

Figure 1. Geographical setting of the study area

TABLE 1. Geographical setting of the area.

Geographical setting	Ramgarh pedon	Panchkula pedon
Location	30°38'11"N, 76°52'53"E Panchkula to Yamunanagar road	30°44'47"N, 76°54'54"E Ghaggar river bank on Panchkula to Morni hills road
Physiography	Siwalik hills	Siwalik hills
Topography	Hill crest (30% slope)	Escarpment, (25-30 % slope)
Drainage	Excessively drained	Excessively drained
Land Use	Scrubby forest	Scrubby vegetation
Elevation (m)	380	480
Mean annual Rainfall (mm)	1100	1125
Soil Temperature regime	Thermic	Thermic
Soil moisture regime	Udic	Udic

ions were estimated as per the various procedures outlined by Jackson (1958). pH and EC of saturation extract were also measured.

RESULTS AND DISCUSSION

Morphology : Colour of the soils under moist condition varies from reddish brown to yellowish brown (Table 2). Silt loam is the dominant texture. Consistency of these soils is dominantly sticky and plastic. Upper hirozons have few fine roots. Many concretions of calcareous nature are present in the lower horizon of Ramgarh and upper horizons of Panchkula pedon. Both the soils are calcareous in nature. They have clear irregular to gradual irregular horizon boundaries.

Physical characteristics : Silt is the dominant fraction in these soils (31.6 to 62.9%). Coarse fragment, mostly of calcareous nature varies from 10 to 36 per cent (Table 3). Available moisture content of Ramgarh soil varies from 8.3 to 13.6 per cent and that of Panchkula soils varies from 11.8 to 15.5 per cent. Available moisture content is minimum in 10-46 cm layer of Ramgarh. This is due to the presence of very high amount of silt (43.2%) and clay (50.7%). Bulk density of these soils varies from 1.65 to 1.69 m^{-3}. However, it is high (1.83 Mg m^{-3}) in 0-50 cm layer of Panchkula due to the presence of coarse fragments in the clods (Table 3). Hydraulic conductivity of these soils is very low varying from <0.001 cm hr^{-1} to 0.636 cm hr^{-1}.

Chemical characterisitcs : Both the soils have low organic carbon (0.05 to 0.30%) and are calcareous in nature. $CaCO_3$ ranges from 0.5 to 9.2 per cent (Table 4). The pH varies from 8.8 to 9.7, EC varies from 0.20 to 1.36 dSm^{-1}.

In case of Ramgarh pedon, ESP and CEC of different horizons varied from 14 to 24, and 18.5 to 23.6 C mol kg^{-1} respectively. In the Panchkula pedon, ESP and CEC of various horizons varied from 9 to 45 and 9.3 to 12.2 C mol kg^{-1} respectively. Thus, both these soils are alkali in nature.

Saturation extract analysis : Saturation percentage of these soils vary from 43 to 48 per cent (Table 5). The pH of saturation paste (pHs) ranges between 8.4 and 8.9. The CEe ranges between 0.69

TABLE 2. Morphology of pedons

Depth (cm)	Horizon	Boundary	Colour (moist)	Texture* (USDA)	Consistence	Roots	C.fragments	Reaction
Ramgarh								
0-10	A	ci	5YR 4/3	sil	ws,wsp	f,f	-	ev
10-46	2C1	ci	7.5YR 6/4	sic	ws,wp	-	conca,m	es
46-100	3C2		10YR 5/4	sil	ws,wp	-	conca,m	es
Panchkula								
0-50	A	gi	7.5YR 4/4	sl	wss,wsp	f,f	conca,m	es
50-200+	2C		7.5YR 4/4	sil	ws,wp	-		e

* sil = silt loam; sic = silty clay; sl = sandy loam

TABLE 3. Physical characteristics.

Depth (cm)	Horizon	Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	C.fragments	Moisture (%) 33 kPa	Moisture (%) 1500 kPa	Moisture (%) Available	B.D. $Mg\ m^{-3}cm$	*Hyd. cond. $cm\ hr^{-1}$
		<--	--	(%) --	-->					
Ramgarh										
0-10	A	14.5	59.2	26.3	-	22.9	9.3	13.6	1.67	0.047
10-46	2C1	6.1	43.2	50.7	10	24.5	16.2	8.3	1.65	0.123
46-100	3C2	16.0	62.9	21.1	33	21.2	12.2	9.0	1.68	0.038
Panchkula										
0-50	A	55.6	31.6	12.8	36	16.6	4.8	11.8	1.89	0.636
50-200	2C	23.8	55.4	20.8	-	25.0	9.5	15.5	1.69	<0.001

* Hydraulic conductivity

and 3.49 dSm^{-1}. Highest value being in the 2C horizon of Panchkula with lithological discontinuity. Sodium followed by magnesium and chloride followed by bicarbonates dominated among the cations and anions in the saturation extract. Subsurface horizon of Panchkula soils has as high as 26.7 me/l of Na and almost equal amounts of chloride in the saturation extract indicating NaCl to be dominant salt in the soil solution.

Available nutrient status : Ramgarh soils are low in available nitrogen and phosphorus and medium in available potassium (Table 6). These soils are deficient in DTPA extractable Fe, Mn and Zn. However, available Cu is sufficient. Panchkula pedon (0-50 cm) is medium in available nitrogen and potassium but low in available phosphorus. However, the subsurface layer is low in all the available macronutrients. Micronutrient status of these soils is similar to one discussed for the Ramgarh pedon.

Soil classification : Ramgarh and Panchkula soils have ochric epipedon, Udic soil moisture regime and Thermic termperature regime. These pedons have one (Panchkula) or two (Ramgarh) lithological discontinuities. As per Soil Taxonomy (Soil Survey Staff 1975), these soils have been classified as mixed, hyperthermic family of Typic Udorthents. Textural family of Ramgarh and Panchkula soils is fine silty and coarse loamy respectively. However, such classification does not indicate the alkali characteristics of these soils which is an important aspect for land use management.

TABLE 4. Chemical characteristics.

Depth (cm)	Horizon	O.C. (%)	$CaCO_3$ (%)	pH	EC dSm^{-1}	Exch. cations Na	Mg	Ca	K	CEC	ESP (%)
						<---	C mol kg^{-1}			--->	
Ramgarh											
0-10	A	0.11	0.7	9.7	0.44	4.5	3.2	11.0	0.21	18.9	24
10-46	2C1	0.05	1.3	9.5	0.48	3.3	4.8	15.2	0.35	23.6	14
46-100	3C2	0.05	1.9	9.5	0.51	3.8	2.8	11.2	0.25	18.5	20
Panchkula											
0-50	A	0.30	9.2	8.8	0.20	0.8	0.8	7.6	0.14	9.3	9
50-200+	2C	0.09	0.5	9.8	1.36	5.5	1.2	5.4	0.12	12.2	45

TABLE 5. Saturation extract analysis

Depth (cm)	Horizon	Saturation (%)	pHs	ECe dSm^{-1}	Saturation analysis (me/l) Na	Mg	Ca	K	CO_3	HCO_3	Cl	SO_4
Ramgarh												
0-10	A	43	8.6	1.08	6.0	4.5	1.0	0.05	1.4	4.5	5.5	1.4
10-46	2C1	46	8.4	1.12	7.1	4.5	1.3	0.12	1.4	3.1	4.5	2.7
46-100	3C2	46	8.5	1.43	8.5	6.8	0.8	0.06	1.4	3.1	7.0	1.3
Panchkula												
0-50	A	44	8.4	0.69	1.4	3.5	2.5	0.08	-	4.2	3.0	0.66
50-200	2C	48	8.9	3.49	26.7	4.0	3.3	0.04	-	5.4	26.0	1.16

The data (Table 4 & 5)indicated that the soils with alkali character occur in highly sloping Siwalik hills having high rainfall and udic soil moisture regime (Fig. 1). Occurrence of similar alkali soils has also been reported by Grewal and Juneja (1991) in Nurpur Bedi (Dist. Hoshiarpur); catchment of Sukhana lake, Sukhomajri, Nada and Bunga in the union territory of Chandigarh; Panchkula in Haryana; and in Nahan, Nalagarh, Bilaspur areas of Himachal Pradesh. Thus soils with alkali character occur extensively in the Siwalik hills.

Though, the occurrence of these alkali soils is absolutely a natural phenomenon, yet it raises many questions about the machanisms of formation of alkali soils as reported by earlier workers. Almost the entire Indian work on the occurrence and genesis of alkali soils reports their formation to release of sodium by weathering of aluminosilicate minerals and subsequent carbonation resulting in formation of sodium carbonate. The micro-depressions in the plains facilitated periodic accretion through accumulation of surface wash also served as evaporating pans resulting in the evolution of sodic soils (Bhargava & Bhattacharjee 1982).

Though this mechanism seems sound, yet it fails to explain the presence of alkali soils in hilly

TABLE 6. Available nutrient status

Pedon	Available (kg ha^{-1})			DTPA extractable (ppm)			
	N	P	K	Fe	Mn	Cu	Zn
Ramgarh							
0-10	212	4.48	183	2.8	1.6	0.34	0.32
10-46	97	5.60	305	2.7	1.8	0.30	0.22
46-100	92	4.48	218	2.8	2.0	0.38	0.22
Panchkula							
0-50	295	3.36	122	2.2	2.8	0.40	0.18
50-200	174	7.84	104	2.1	2.6	0.24	0.20

areas with high rainfall, udic moisture regime and steep slopes. Recently, Szabolcs (1989) reported that salt affected soils (alkaline) in mountainous regions at high and medium heights, are more frequent than was previously realised. These alkali soils also have lithological discontinuities. Such morphological features do not find support from the earlier proposed mechanism of development of sodicity from weathering of feldspars in these Entisols with alkali character. Earlier, Gupta and Gupta (1989) reported that alkali feldspars are less stable in the high pH soils and thus, albites may be acting as diffused source of sodium in these alkali soils. On the contrary, research based on thermo-dynamic principles on weathering of soil minerals by Kittrick (1971), Lindsay (1979) and Kumar (1992) strongly indicate that feldspars including albites become highly stable in high pH soil environment. Further, the alumino-silicate weathering as the source of salts can not explain the presence of appreciable amount of chlorides in these soils. Thus, near dominance of sodium and chloride ions in the saturation extract of these alkali soils in hilly areas of Siwaliks should provide sufficient reason to the research workers for a fresh thinking on the genesis of alkali soils of north-west India.

Presence of 300 km long salt range in western Himalayas, Mandi rock salt area (Himachal Pradesh) and salt rich marine or salt water lagoongeological formation like Shali (saline series); Subathu, Jutugh, Tal and Karil series in the sub-Himalayas has been reported earlier by Pascoe (1965) and Wadia (1979). In fact the soils and site of present investigation belong to Subathu formation (Gansser, 1964). Deposition of these salt and smectite rich formations (Kumar *et al.* 1993, 1994) occurred in the marine environment of Tethyan sea during Miocene to Eocene periods (25-40 million yr.). After many geological upheavals these materials were later transported by ancient river system in alte Pleistocent to Recent period (1 million yr.) and deposited to form the present day alluvial plains.

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