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Characterization and classification of soils on sand dune toposequences of Haryana

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Abstract

Three representative sand dunal sites of Haryana were studied with regard to their soil characteristics, pedogenic development and Soil Taxonomy. On the basis of topography, two sand dunal sites were separated into sand dune top, slope, base and plain and third site was differentiated into hummocks and inter-dunal depression. Ten pedons, representing each of the topographic position, were studied for their morphological, physical and chemical characteristics and classified as per Soil Taxonomy. The soils of the sand dune top, slope, hummocks and inter-dunal depression were sandy, loose, single grained or weekly developed subangular blocky, non-saline, moderately alkaline, non-calcareous to slightly calcareous and low in organic carbon, clay content and cation exchange capacity. These soils were classified as Typic Torripsamments / Aridic Ustipsamments. The soils of the sand dune base were sand to loamy sand and sandy loam in texture at lower depths, weak subangular blocky moderately calcareous and more fertile than those of the above mentioned toposequence. Taxonomically, these soils were placed under coarse loamy, calcareous, Typic Camborthids. The soils of the plain are loamy sand to sandy loam, nonsaline, moderately alkaline and relatively higher in clay content, CEC, organic carbon and calcium carbonate. Taxonomically these soils were classified as coarse loamy / fine loamy, Typic Camborthids or Aridic Ustochrept. The soils of the plain areas were pedogenically more developed as evidenced from the illuviation and calcification processes whereas soils on other topographic positions were either lacking or weak in pedogenic activity.

Additional key words : sand dunal topography, soil characteristics and classification

Introduction

The sand dunal areas, covering an area of 18.7 per cent, occurring mainly, with western zone of Haryana with an isohyet of less than 500 mm (Ahuja *et al*, 1979) face several problems. Topography is one of the important soil forming factors causing the differences in soils characteristics and classification. This factor has played a vital role in differentiating the soils of alluvial as well as aeolian region of Haryana. The sand dunes with respect to their intensity, wind erosion, height and soil properties varies with the toposequences and isohyet of the region. The study of soil properties in the field and in the laboratory and their placement in the soil taxonomic system is imperative to understand the nature, origin, genesis and problem of the soils for land evaluation and management.

Attempts have been made in the past to study the soil characteristics and classification of the sand dunal areas of Haryana (Ahuja *et al,* 1979; Khanna *et al,* 1974 and Sangwan, 1978). But not much emphasis have been given on the studies in relation to dunal toposequences, which is important and essential for the management of these areas. Keeping in view its importance the present study was conducted.

Materials and methods

Three representative sand dunal sites in different locations of Haryana i.e. Balawas, Balsamand and Bilawal were selected (Fig. 1). Each sand dune was subdivided into different topo-positions. Ten pedons were exposed on these topopositions and were

studied morphologically (FAO 1966) in the field. Soil samples were collected horizon-wise (Soil Survey Staff, 1975) and processed for laboratory investigations. Physico-chemical properties were estimated according to the standard procedures (Piper 1966; Chopra and Kanwar 1976). Deep auger hole samples upto 5 meter depth were also studied to know the nature and genesis of the sediments. Based on these properties each pedon was classified according to Soil Taxonomy (Soil Survey Staff 1975).

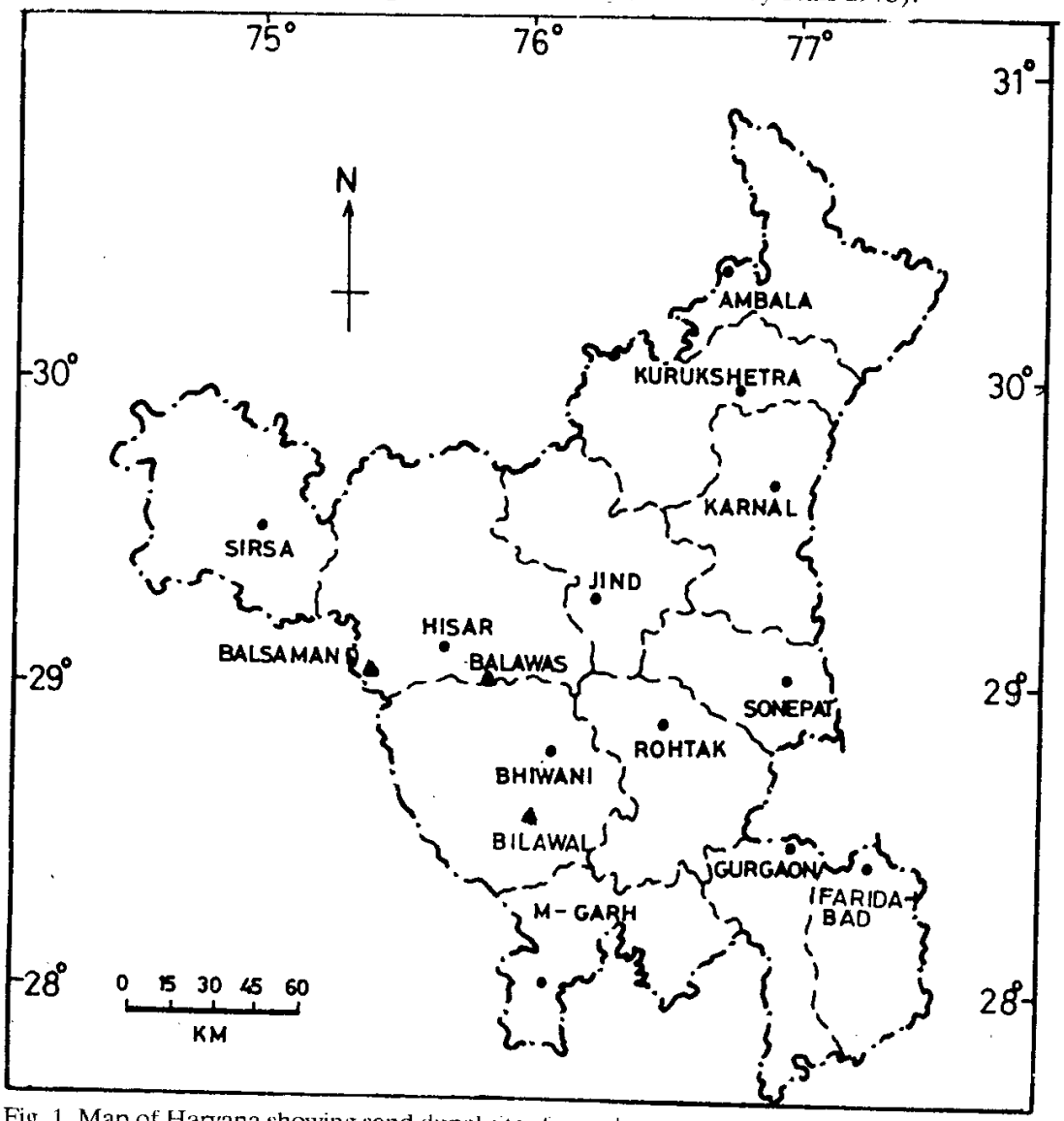

Fig. 1. Map of Haryana showing sand dunal sites for pedons.

Results and discussion

Visual interpretation of satellite data and aerial photographs indicated the presence of three major landforms like aeolian, fluvial, fluvio-aeolian in the districts of the western zone of Hayrana (Ahuja and Singh 1983 and Ahuja *et al.* 1992).

The present study was conducted mainly in the aeolian landform which is further differentiated into sand dunes, sand dunal hummocks and interdunal depressions. On the basis of topography, vegetation, cultivation, stabilization and erosion the sand dunes

(Balawas and Balsamand) were further separated into sand dune top, slope, base and plain areas. The toposequence of sand dunes of Balawas and Balsamand are described as under :

Sand dune top : These are active dunal areas, higher in position, unstabilized and barren in nature.

Sand dune slope : These are partially cultivated dunal areas partially stabilized and medium in position with respect to height.

Sand dune base : These are aeolian covered, very gently sloping, low intensity of erosion and lower in position with respect to height and are stabilized in nature.

Plain : These are nearly level to very gently sloping plain areas with aeolian cover over fluvial plain.

The sand dunes of Bilawal were differentiated into hummocks and interdunal depression. The hummocks are low height sand dunes occurring in scattered patches. The interdunal depression occupy low lying positions between sand dunes.

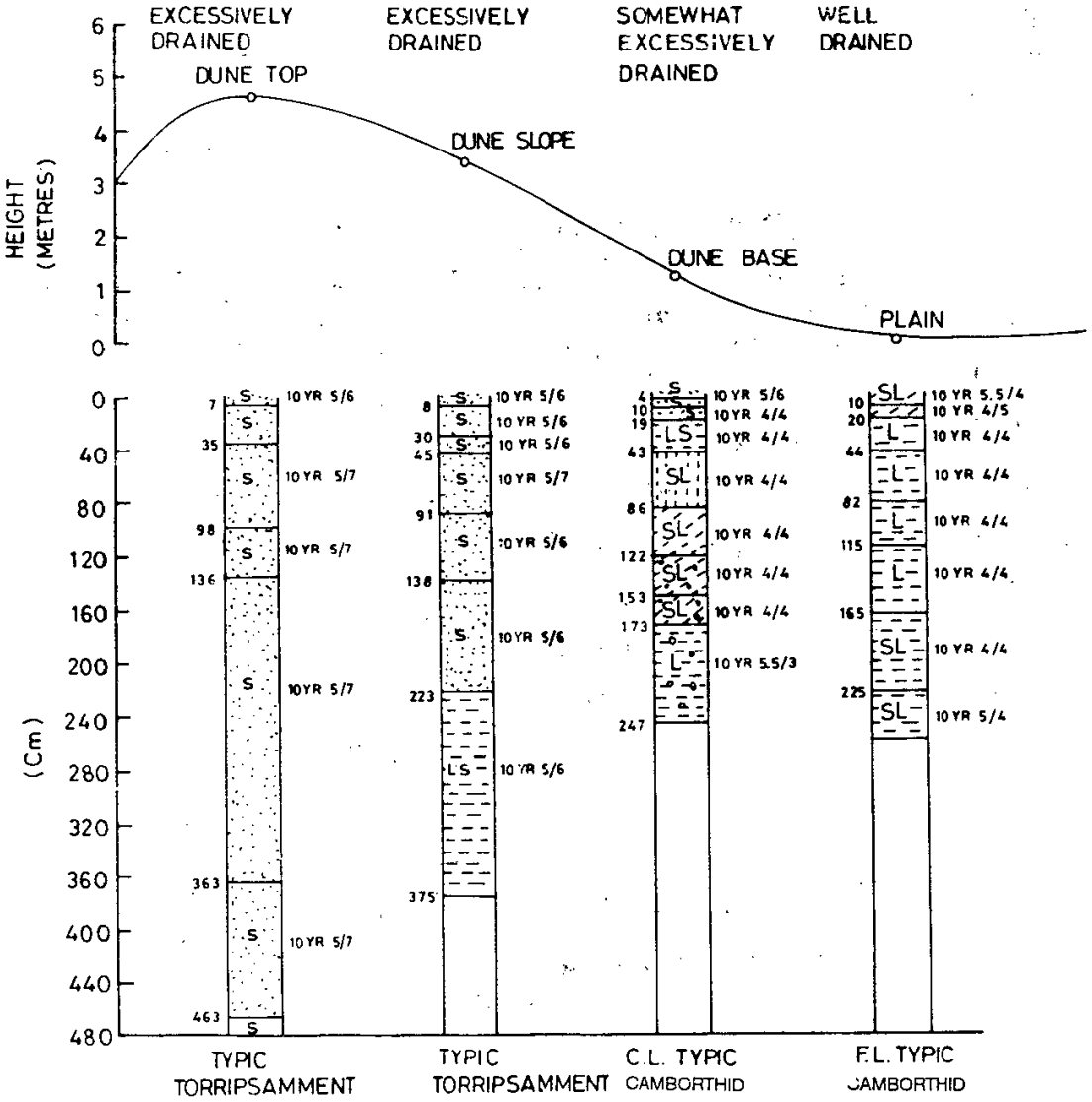

Fig. 2. Schematic cross-section of Balawas sand dune showing topography-soil relationship.

The soil characteristics, profile development and taxonomy of these topopostions were described and are discussed in the following chapters.

Morphological characteristics

The soil colour of the area is yellowish brown in all the pedons except subsurface horizons of dunal base and plain which had a colour of light brownish grey and light grey

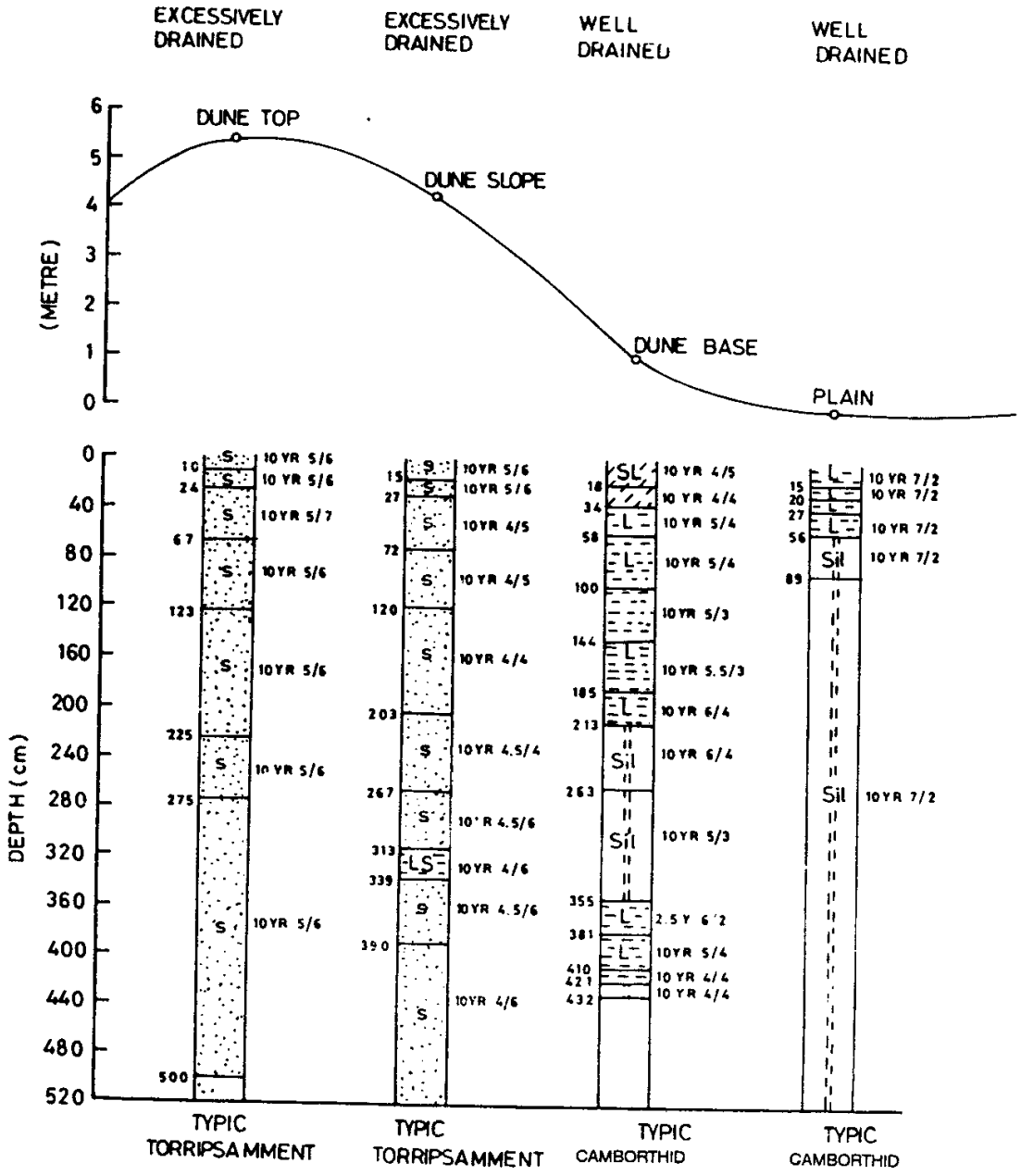

Fig.3 . Schematic cross-section of Balsamand sand dune showing topography-soil relationship

(Figs. 2,3 & 4). The light colour of these soils is mainly due to low organic matter content and aridic moisture regime.

The soil texture varied from sand to loamy sand in sand dune top, slope, inter-dunal depression and hummocks areas, whereas it was sandy loam to silt loam in plain areas (Figs. 2, 3 & 4). Lower horizons of the dunal base comprise silt loam texture (Fig. 2). The increase in fineness of texture from loamy sand to sandy loam / silt loam / loam in plain areas is due to aeolian and fluvial process. Dasgupta and Dassarma (1983) observed a sequence of four aeolian and three fluvial morphostratigraphic units in the Quaternary sequence near Jaipur.

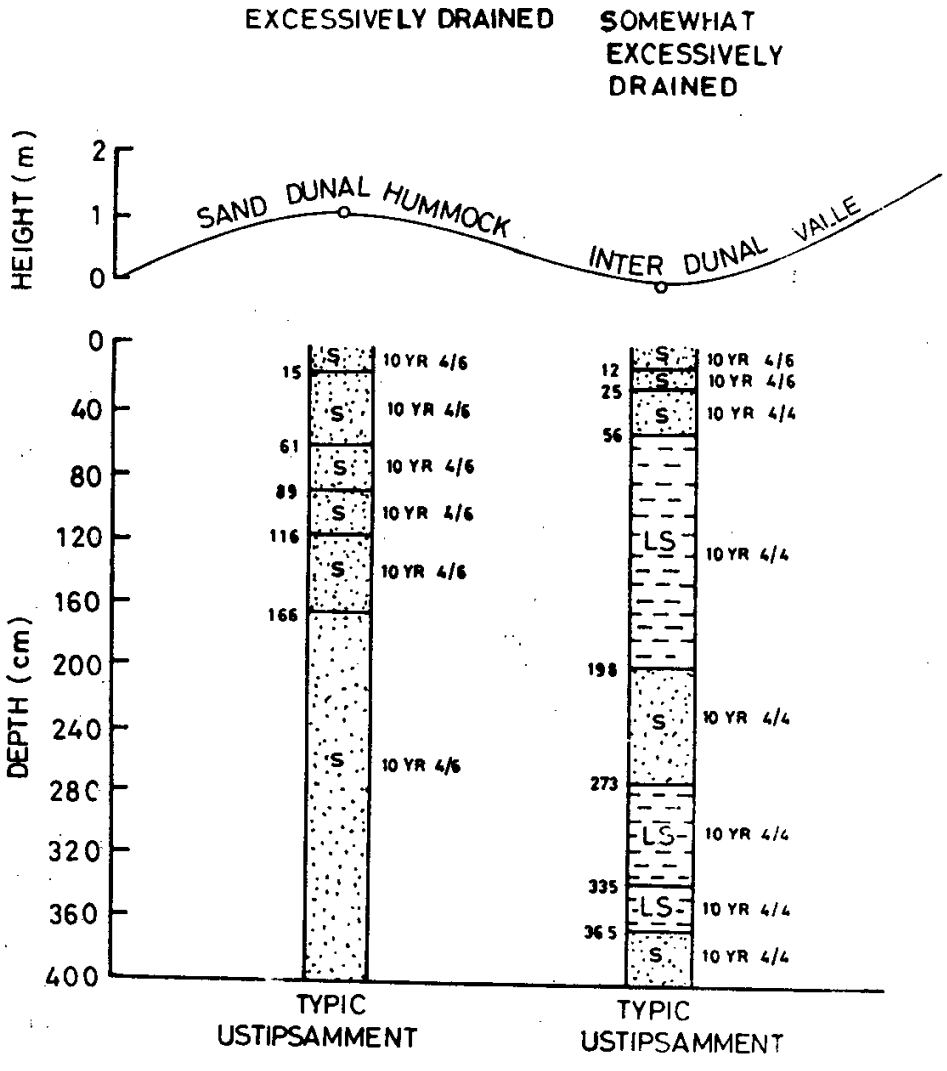

Fig. 4 Schematic cross-section of Bilawal sand dune showing topography-soil relationship

The soil structure was mainly loose single grained to weaky developed subangular blocky in all the topopositions except plain having a moderately developed subangular blocky. These results indicate that these soils have not undergone any pedogenic activity due to low rainfall and limited irrigation and cultivation practices. Similar findings were also reported by Choudhary (1992).

The consistence of the soils of the topographic positions was loose, soft or slightly hard under dry condition and loose, friable under moist condition and non sticky nonplastic under wet condition. The subsurface horizons of dunal base and plain areas were sticky and plastic. The poor consistence was due to light texture of the soil. Hard calcium carbonate concretions were present in dunal base and the very gently sloping plain areas. These *kankars* are primary in origin (Manchanda *et al*. 1984); Ahuja and Khanna 1984) but also reported as secondary in nature (Sehgal and Stoops, 1972; Dhir 1995).

Physical characteristics

The results are presented in table 1. The analysis of the various soil separates indicated that very coarse and coarse sand fractions were absent in all the pedons. The fine sand (2.44 to 21.55 per cent) was low in dune top, dune slope, hummocks and inter-dunal depression, whereas subsurface horizons of dunal base and plain areas had higher content of fine sand fraction (36.7 per cent). Medium sand fraction was higher in all the topo-positions and varied from 21.6 to 90.9 per cent. The silt fraction varied from 1.0 to 4.0 per cent in dune top, dune slope, hummocks and interdunal depression, whereas dunal base and plain areas had shown its higher content varying from 1.0 to 31.2 per cent. The low content of silt in these positions in comparison to sand fractions was due to aeolian activity on account of their location near to desert areas of Rajasthan. The clay content was quite low in sand dune top, sand dune slope, hummocks and interdunal depression ranging from 4.1 to 7.3 per cent whereas in dunal base and plain areas, it varied from 4.8 to 22.0 per cent. The clay content of dunal base and plain areas increased with depth thereby indicating the process of illuviation and other pedogenic activity resulting relatively into better development of horizons in these topopositions than that of other positions which were weakly developed or undeveloped pedogenetically. The clay content in all the topographic positions was higher than silt except subsurface of plain areas.

Chemical Characteristics

The results are presented in table 1. The analysis of the soil samples for pH indicated that the soils were moderately alkaline in nature having a pH range of 8.0 to 8.8 in the surface and subsurface horizons of sand dunal top, slope and hummocks. The subsurface horizons of dunal base, interdunal depression and plain areas had shown the higher pH values (upto 9.8). It might be due to sodic nature of fluvial parent material (Raj Kumar 1992). The electrical conductivity of all the topographic positions indicated that the soils were non- saline in nature. It is due to sandy nature and non-irrigating agricultural practices. Similar results were also reported by Sehgal *et al.* (1986).

Organic Carbon : The soils were poor in organic carbon. The organic carbon of soils of all the topographic positions varied from 0.01 to 0.45 per cent. The subsurface horizons of plain and inter-dunal depressions had relatively higher organic carbon content than soils of other topographic positions. Dhir (1977) had also reported lower amount of

Table 1 ; Physical and chemical characteristics of soils

Depth (cm)	Horizon	Particle size (mm) Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Texture	pH (1:2)	ECe (dSm^{-1})	$CaCO_3$ (%)	0.C. (%)	Exchangeable cation and CEC Ca	Mg	Na	K	CEC
												(cmol(+) kg^{-1})		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pedon-1		*Balawas, sand dune top - Typic Torripsamment*												
0-7	Ap	93.3	1.3	5.3	sand	8.0	0.19	0.2	0.03	1.29	0.67	0.37	0.39	4.79
7-35	C1	93.6	1.3	5.0	sand	8.2	0.18	0.2	0.03	1.31	0.74	0.29	0.22	4.95
35-98	C2	93.8	1.1	5.0	sand	8.2	0.20	0.5	0.01	1.29	0.67	0.29	0.37	4.79
98-136	C3	93.9	1.1	4.9	sand	8.2	0.18	0.3	0.04	1.24	0.75	0.27	0.30	4.75
136-163	C4	94.2	1.2	4.6	sand	8.2	0.14	0.5	0.04	1.20	0.76	0.25	0.19	4.40
163-363	C5	93.3	1.0	5.1	sand	8.1	0.14	0.6	0.06	1.19	0.76	0.25	0.19	4.40
363-463	C6	93.6	1.3	5.0	sand	8.3	0.15	0.5	0.03	1.28	0.80	0.29	0.27	4.95
Pedon-2		*Balawas, sanddune slope - Typic Torripsamment*												
0-8	Ap	93.9	1.1	5.0	sand	8.2	0.19	0.5	0.07	1.28	0.79	0.27	0.50	4.80
8-30	C1	93.8	1.0	5.2	sand	8.2	0.19	0.5	0.06	1.20	0.80	0.25	0.26	4.58
30-45	C2	93.8	1.1	5.2	sand	8.1	0.18	0.6	0.06	1.28	0.80	0.27	0.29	4.80
45-91	C3	94.7	1.1	4.4	sand	8.3	0.14	0.5	0.04	1.19	0.68	0.27	0.36	4.79
91-138	C4	93.4	1.8	4.7	sand	8.2	0.18	0.6	0.04	1.19	0.68	0.27	0.31	4.60
138-223	C5	94.2	1.6	4.1	sand	8.3	0.14	0.7	0.04	1.19	0.73	0.26	0.28	4.66
223-373	C6	90.2	3.2	6.7	sand	8.3	0.14	0.7	0.09	1.19	0.71	0.29	0.27	4.82

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pedon-3		*Balawas, sand dune base : Coarse loamy, calcareous Typic Camborthid*												
0-4	Ap1	94.0	1.0	4.9	sand	8.4	0.30	0.5	0.16	1.23	0.68	0.31	0.29	4.58
4-10	Ap2	92.8	1.8	5.4	sand	8.4	0.28	0.5	0.11	1.30	0.75	0.27	0.26	4.70
10-19	AB	90-5	1.8	7.6	sand	8.5	0.28	0.5	0.12	1.02	1.03	0.29	0.30	4.80
19-43	B1	82.4	3.8	13.9	loamy sand	8.1	0.78	0.5	0.13	1.64	0.75	0.36	0.30	5.80
43-86	B2	82.8	4.0	13.1	loamy sand	8.1	0.14	1.0	0.13	1.64	0.75	0.36	0.35	5.80
86-122	B2	79.2	6.2	14.6	loamy sand	8.8	0.26	2.5	0.12	1.64	0.80	0.39	0.26	6.00
122-173	Ck1	85.6	3.8	10.6	loamy sand	8.9	0.30	2.5	0.09	1.78	1.40	0.49	0.25	7.10
173-297	Ck2	74.2	13.0	12.8	loamy sand	8.9	0.24	2.7	0.07	1.80	1.36	0.62	0.18	7.40
Pedon-4		*Balawas, level to very gently sloping plain : Fine loamy, calcareous Typic Camborthid*												
0-10	Ap	85.5	3.8	10.7	loamy sand	8.4	0.75	1.0	0.30	2.03	0.58	0.22	0.20	5.8
10-20	AB	83.9	4.0	12.0	loamy sand	8.3	0.46	1.2	0.27	2.03	0.60	0.20	0.20	5.8
20-44	B1	70.6	9.4	20.0	sandy loam	8.0	0.32	1.0	0.30	1.34	1.25	0.30	0.27	6.1
44-82	B2	65.7	13.0	21.3	sandy clay loam	7.9	0.24	1.0	0.14	1.73	1.18	0.60	0.20	7.1
82-115	B3	61.9	19.2	18.9	sandy loam	8.0	0.23	1.2	0.18	1.84	1.35	0.61	0.18	7.5
115-225	Ck1	74.2	13.1	12.8	loamy sand	8.8	0.26	2.5	0.09	1.40	0.73	0.17	0.19	5.1
225+	Ck2	70.3	19.7	10.0	loamy sand	8.8	0.26	2.5	0.09	1.40	0.73	0.17	0.19	5.1
Pdeon-5		*Balsamand, sand dune top : Typic Torrisamment*												
0-10	Ap	93.7	1.0	5.3	sand	8.7	0.16	0.2	0.02	1.28	0.65	0.28	0.36	4.60
10-24	AC	93.5	1.4	5.0	sand	8.6	0.15	0.3	0.03	1.30	0.70	0.37	0.30	4.67
24-67	C1	93.3	1.5	5.2	sand	8.5	0.12	0.5	0.01	1.40	0.73	0.17	0.19	5.04
67-123	C2	93.0	1.5	5.4	sand	8.5	0.12	0.3	0.06	1.05	0.88	0.20	0.17	4.04
123-225	C3	92.4	1.9	5.5	sand	8.5	0.18	0.0	0.01	1.03	0.83	0.2	0.14	4.10
225-275	C4	91.4	1.4	7.2	sand	8.7	0.18	0.5	0.09	1.12	0.83	0.26	0.15	4.42
275-500	C5	92.3	2.0	5.7	sand	8.7	0.18	0.5	0.07	1.18	0.83	0.27	0.15	4.52

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pedon-6		*Balsamand, sand dune slope : Typic Torripsamment*												
0-15	Ap	93.8	1.0	5.2	sand	8.6	0.16	0.2	0.01	1.28	0.65	0.28	0.36	4.60
15-27	C1	93.8	1.1	5.1	sand	8.6	0.16	0.5	0.60	1.40	0.73	0.17	0.19	4.70
27-72	C2	93.9	1.8	5.2	sand	8.5	0.15	0.6	0.03	1.05	0.88	0.21	0.19	4.90
72-120	C3	93.1	1.7	5.2	sand	8.5	0.12	0.5	0.04	1.34	0.95	0.15	0.29	5.04
120-203	C4	92.9	1.0	6.0	sand	8.6	0.12	0.5	0.09	1.40	0.73	0.17	0.19	5.03
203-267	C5	91.4	1.3	7.2	sand	8.7	0.12	0.6	0.07	1.40	0.78	0.20	0.17	5.09
267-313	C6	93.1	1.1	5.7	sand	8.7	0.14	0.6	0.04	1.38	0.88	0.28	0.15	5.11
313-339	C7	88.9	3.5	7.5	sand	8.7	0.12	0.6	0.06	1.38	0.90	0.29	0.14	5.03
339-390	C8	91.0	2.2	6.7	sand	8.7	0.12	0.7	0.07	1.13	0.66	0.29	0.36	4.49
390	C9	91.6	2.2	6.1	sand	8.8	0.18	1.0	0.07	1.27	0.70	0.25	0.28	4.77
Pedon-7		*Balsamand sand dune base : Coarse loamy, calcareous Typic Camborthid*												
0-18	Ap	80.7	7.4	11.9	loamy sand	8.8	0.34	1.0	0.27	1.14	0.80	0.26	0.15	4.40
18-34	AB	75.7	9.3	14.9	loamy sand	8.7	0.41	2.5	0.28	2.10	0.55	0.22	0.20	5.70
34-58	B1	65.9	18.6	15.5	sandy loam	8.7	0.34	2.8	0.25	2.10	0.55	0.21	0.20	5.70
58-100	B2	62.5	21.9	15.6	sandy loam	8.8	0.36	4.0	0.42	1.25	1.00	0.25	0.28	5.20
100-144	B3	60.8	23.6	15.5	sandy loam	8.7	0.30	8.0	0.15	1.73	1.20	0.65	0.28	7.40
144-185	Ck1	59.5	24.4	16.1	sandy loam	8.7	0.34	7.5	0.15	1.40	1.30	0.34	0.27	6.10
185-213	Ck2	64.8	22.5	12.7	sandy loam	8.8	0.44	3.0	0.13	1.36	1.33	0.37	0.23	6.10
213-263	Ck3	55.0	28.6	18.3	sandy loam	9.3	0.63	13.8	0.15	1.70	0.90	0.46	0.34	6.20
263-355	Ck4	38.5	36.0	25.5	loam	9.4	1.10	14.0	0.15	1.71	1.16	0.62	0.18	7.10

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pedon-8		*Balsamand : Plain level to gently slopping : Coarse loamy calcareous Typic Camborthid*												
0-15	Ap	69.9	44.2	15.8	sandy loam	8.8	0.41	5.6	0.39	2.11	0.51	0.23	0.25	5.7
15-26	ABk	63.2	22.1	14.7	sandy loam	8.5	0.41	5.6	0.45	1.48	1.30	0.35	0.18	6.1
26-37	Bk1	60.8	24.0	15.2	sandy loam	8.7	0.34	7.5	0.43	1.48	1.36	0.40	0.23	6.4
37-57	Bk2	64.1	20.9	15.0	sandy loam	8.9	0.44	10.0	0.42	1.49	1.41	0.47	0.21	6.5
56-89	Bk3	55.0	26.9	17.9	sandy loam	8.7	0.62	15.0	0.33	1.45	1.43	0.41	0.18	6.7
89++	BCk	39.4	35.6	25.4	loam	9.0	1.10	11.3	0.24	1.40	1.02	0.41	0.14	6.1
Pedon-9		*Bilawal, Sand dunal hummocks : Typic Ustipsamment*												
0-15	Ap	90.8	3.5	5.7	sand	8.6	0.20	-	0.19	1.40	0.68	0.19	0.19	4.9
15-61	C1	91.3	3.0	5.7	sand	8.6	0.20		0.11	1.10	0.83	0.27	0.17	4.9
61-89	C2	91.3	3.1	5.5	sand	8.6	0.22	-	0.11	1.05	0.81	0.27	0.15	4.2
89-116	C3	90.8	3.0	6.1	sand	8.6	0.27	-	0.19	1.28	0.68	0.39	0.14	4.6
116-166	C4	91.4	3.1	5.6	sand	8.6	0.38	-	0.21	1.25	0.70	0.40	0.13	4.4
166+	C5	91.3	3.1	5.6	sand	8.7	0.28	-	0.12	1.25	0.70	0.41	0.12	4.4
Pedon-10	*Bilawals Interdunal depression - Typic Ustipsamment*													
0-12	Ap	91.7	2.1	6.1	sand	8.6	0.21	0.5	0.28	1.08	0.75	0.45	0.15	4.2
12-25	A1	91.5	3.4	5.1	sand	8.4	0.25	0.4	0.16	1.06	0.87	0.20	0.17	4.8
25-53	C1	90.8	4.1	5.0	sand	8.5	0.25	0.5	0.21	1.06	0.80	0.21	0.17	4.8
53-198	Ck1	89.6	3.9	6.4	sand	8.7	0.29	0.5	0.24	1.30	0.63	0.28	0.36	4.6
198-273	Ck2	91.3	2.9	5.7	sand	8.9	0.27	0.5	0.22	1.25	0.65	0.39	0.25	4.5

organic carbon in soils of sand dunal areas. The low organic carbon content in these areas was due to the difference in the degree of colonization by vegetation, aridic moisture regime, low rainfall, high termperature and poor vegetation. Jenny and Raychaudhary (1960) during their study had brought out the effect of climate, cultivation and role of texture on the organic carbon and nitrogen status of the soils. Ahuja *et al.* (1979) also reported the low content of organic carbon in dunal soils.

Calcium carbonate : The data indicated that these soils were non- calcareous to slightly carcareous except subsurface horizons of dunal base and plain areas. The absence of calcium carbonate in sand dunal soils indicated that non-calcareous sediments have been transported and deposited in these areas. The presence of higher amount of $CaCO_3$ at lower depths was due to the calcareous sediments which were transported and deposited by fluvial activity. The possibility of *in situ* formation of $CaCO_3$ due to calcification process and aridic climatic conditions in these soils cannot be ignored. Evidences in support of such activities were also reported by Dhir (1977).

Exchangeable cations : The results of exchangeable cations indicated that the order of dominance of these cations was Ca > Mg > Na > K. No definite pattern of these ions with depth was observed in any of these topographic positions. The higher content of Ca^{++} and Mg^{++} in all these topographic positions suggested that the parent material, whether aeolian or fluvial are rich in these cations. The higher content of Na^{+} in dunal base and plain areas in comparison to other positions was due to sodic nature of the parent material. Cation exchange capacity of all the pedons was very low, which could be ascribed to sandy nature of the soil and their low clay and organic carbon content.

Soluble cations and anions : The results of saturation extract indicated that the order of dominance of soluble cations were $Mg^{++} > Ca^{++} > Na^{+} > K^{+}$. The amount of soluble Ca^{++} and Mg^{++} was higher in dunal base and plain areas in comparison to other areas. The higher content of soluble Na^{+} in dunal base (0.13 to 2.88 m.e. L^{-1}) and plain areas (0.23 to 1.17 m.e. L^{-1}) was due to their lower topographical postion, finer texture and higher salt content in comparison to other positions. This amount of Na^{+} is not harmful to the crops as it is well below the critical limit of SAR (1.0). The order of dominance for soluble anions was : HCO_3^{-} (0.38 - 6.28 m.e. L^{-1}) > Cl^{-} (0.35 - 6.0 m.e. L^{-1}) > SO_4^{--} (0.3 - 3.78 m.e. L^{-1}) > CO_3^{--} (0.6 - 0.8 m.e. L^{-1}).

Available nutrients : The results of the available nutrients indicated that the soils of all the topographic positions were low in nitrogen except subsurface horizons of dunal base and plain areas which were medium in status. Available phosphorus was low to medium in surface horizons and medium to high in all the pedons. Available potassium of sand dunal top and inter-dunal depression was comparatively lower than the dunal base, hummocks and plain.

Soil Classification : The soils of the different topographic positions have been classified taxonomically and topography - soil relationship has been established (Figs 2,3, & 4). Taxonomically the soils at the sand dune top, slope, hummocks and inter-dunal depression were placed under the order Entisol and dunal base and plain under Aridisol. The Entisol order was due to lack of pedogenic activity and absence of diagnostic horizons in pedons of these areas, whereas the Aridisol order was due to presence of cambic subsurface horizons and aridic soil moisture regime. Entisols of dune tops and slopes of Balawas and Balsamand were placed under great group of Torripsamments

due to presence of sand to loamy sand texture and aridic moisture regime of the area. Entisols of the interdunal depression and hummocks of Bilawal were placed under the great group of Ustipsamments due to presence of ustic soil moisture regime in these area. Aridisols were placed under great group of Camborthid due to cambic horizons. At the family level the soils of sand dune base and plain area were placed under coarse loamy and fine loamy respectively. The landform - Soil Taxonomy relationship has also been reported by Ahuia *et al.* (1996) for desert soils of Haryana.

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