# PEDOGENESIS OF SOILS FROM VARIOUS LAND FORMS IN THE CENTRAL PUNJAB

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Four dominant soils representing different physiographic units were investigated for their pedogenesis. The Samana Soils (from sand dune complexes) permitting easy percolation of water are well drained, Dhoda and Jagjitpur soils (developed in flat plains) showing the presence of Fe-Mn concretions or mottles below surface horizon are imperfectly drained and Jatwan soils (developed in Channels), showing characteristics associated with wetness (reduced colour accompanied by mottles and Fe-Mn concretions below 32 cm) are poorly drained. Samana soils show the leaching of carbonates from the column and other soils show the variable amount of free carbonates in the control section. In Jagjitpur and Jatwan soils, the carbonates have also been precipitated in the form of lime nodules but none of these soils show the development of calcic horizon. Texturally the Samana soils are sandy loam, Dhoda and Jagjitpur soils are loam to clay loam and Jatwan soils are silty clay in control section. The irregular distribution of soil separates as also of sand/silt ratios suggest lithologic discontinuities in all the pedons, indicating stratified parent material. The Jagjitpur salt affected soils have exchangeable sodium around 80 per cent in the A horizon with a tendency to decrease with depth in the B horizon suggesting that the process of alkalization started from the surface and proceeded downward due to high water table accompanied by flooding. Jatwan soils developed in channels are slightly sodic (ESP = 15–19) and Dhoda and Samana soils are normal with ESP = 15. The differences among the soils developed on different physiographic positions are primarily due to topography and to some extent to age. According to soil taxonomy, soils from sand dune complexes, normal and salt affected plains and channels have been classified as Udic Ustochrepts, Aquic-alfic Ustochrepts, Natraquic Camborthids and Aeric Halaquepts respectively.

## INTRODUCTION

THE soils developed on alluvium cover major portion of Punjab (India). The alluvial plain between Beas and Sutlej Rivers in the central Punjab is popularly known as 'Bist Doab' which exhibits interesting land forms viz., flat plains; terraces; sand dune complexes; channels; flood plains and piedmont areas. The localized areas within the flat plains are salt affected. The parent material of these soils is derived from the Himalayan mountains by river of Indus system during Pliestocene and recent times (Wadia, 1966). The soils exhibit varying degrees of pedogenesis ranging from undifferentiated sediments (Entisols) in the flood-plains and sand-dunes to the soil showing argillic/Natric/Cambic horizons in plain areas away from the rivers (Sehgal, 1974; Sidhu *et al.*, 1976*a,b,c*; and Anand *et al.*, 1977). The role of different soil forming factors in the pedogenesis of the widely distributed and potentially very productive soils of

Indo-Gangetic plain have been evaluated by various workers. Shankaranarayana and Hirekerur (1972) attributed the formation of these soils to rainfall only. Sharma *et al.* (1974) and Sehgal (1974) ascribed the formation of north Indian plain soils to the influence of climate followed by topography. Recently, Sidhu *et al.* (1976) and Anand *et al.* (1977) reported that the differential degree of pedogenic development between the flood-plain, channels and upper terrace soils is due to topography and time, however, the differences within the upper terrace soils are probably due to rainfall. From the reports, it appears that very limited information is available on the pedogenesis of the systematically mapped soils of the central Punjab. The present paper is aimed at the evaluation of the contribution of different soil forming factors to the development of soils from various land forms in the central Punjab and their classification according to the U.S. comprehensive system of classification.

## Experimental

The soil survey of the area (30,551 ha) situated in the NE of Punjab and between North latitude of 31°7′ to 31°22′ and the east longitudes of 75°40′ to 75°55′ was carried out through systematic aerial photo-interpretation technique (Goosen, 1967 as modified by Shamacharya & Srinivasan, 1972).

The major land forms (Sand dune complexes, flat plains and channels) and their sub-division based on tone, texture, slope and land use were studied for corresponding soils and relation between them was established. Based on the field and laboratory data, a map showing the association of soil series (Fig. 1) was prepared. In the present study, four pedons representing four widely distributed soil series viz., Samana from sand-dune complexes, Dhoda and Jagjitpur developed in flat plains and Jatwan developed in channels were exposed up to a depth of 1.5–2.0 m and described following *Soil Survey Manual,* 1951 and its supplement, 1961. The soil samples collected horizonwise were dried, crushed and passed through 2 mm sieve and analysed for physical and chemical properties following the standard techniques (Soil Cons. Service, 1972) except for calcium carbonate which was determined by rapid titration procedure (Puri, 1930).

## Results and Discussion

*Morphology* — The morphological properties (Summarized in Table I) indicate that the poorly drained Jatwan soils (developed in channels) have the characteristics associated with wetness (reduced colours alongwith mottles and Fe-Mn concretions) below the plough layer which may be the result of prevailing reduced conditions due to occasional flooding and high water table within 1 metre. The Dhoda and Jagjitpur soils (developed in flat plains) show the presence of Fe-Mn concretions or mottles below the surface horizons of these soils are imperfectly drained. The mottles of higher chroma in Jagjitpur, Dhoda and Jatwan soils indicate that these soils might have been subjected to occasional wetting and drying conditions.

The above three soils show the development of weak to moderate subangular blocky structure in the control section indicating alteration of original sediments by the pedogenic factors. The distribution of clay with depth also corroborates the above assertion.

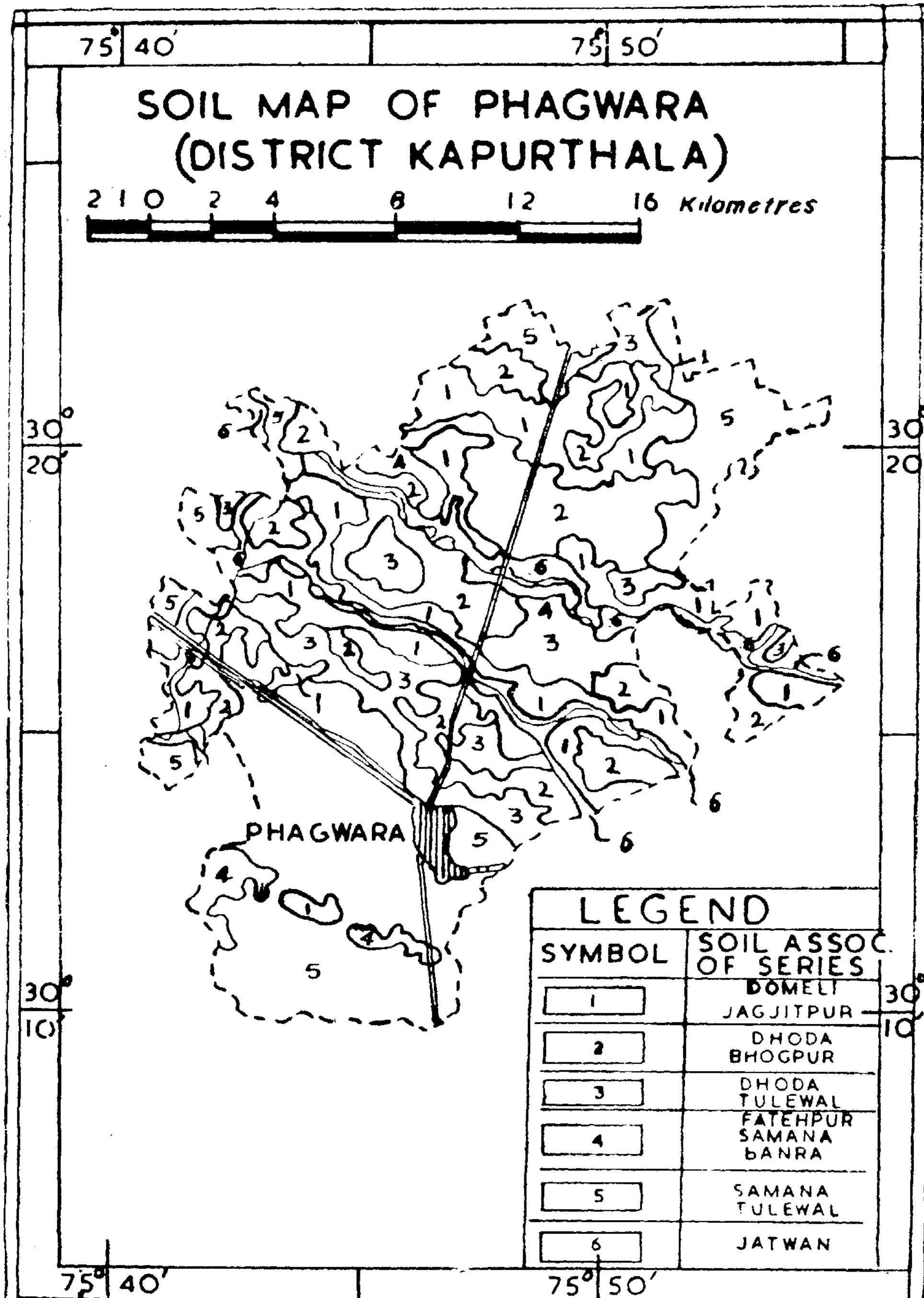
SOIL MAP OF PHAGWARA
(DISTRICT KAPURTHALA)
2 1 0 2 4 8 12 16 Kilometres
75° 40′
75° 50′
30° 20′
30° 10′
PHAGWARA
LEGEND
SYMBOL
SOIL ASSOC. OF SERIES
1 DOMELI JAGJITPUR
2 DHODA BHOGPUR
3 DHODA TULEWAL
4 FATEHPUR SAMANA BANRA
5 SAMANA TULEWAL
6 JATWAN

FIG. 1

TABLE I

*Brief morphology of the pedons*

| Horizon (depth in cm) | Colours (moist) | Mottles/Fe + Mn concretion | Texture[2] | Structure[3] | Consistency[4] | Reaction with HCl |
|---|---|---|---|---|---|---|
| Pedon 1 (Severely salt affected and located 75° 46′ 34″E and 31° 16′ 40″ N, about 600 meter SE of the village of Bhogpur in Phagwara tehsil of Kapurthala distt.) | | | | | | |
| $A_1$ (0–10) | 10 YR 4/2 | Nil | Sl | WK, I, Sbk | Fr | es |
| II $A_3$ (10–28) | 10 YR 4/3 | Fw, 1, ft. | 1 | WK, 1, Sbk | Fr | es |
| III $B_1$ (28–48) | Same as II $A_3$ except for heavion texture (clay loam) and relatively low *p*H (10.3) | | | | | |
| III $B_{21}$ (48–72) | 10 YR 4/4 | Fw, 1, dt (10 YR 5/6) | Cl | WK, 1, abk | Fr | es |
| IV $B_{22}$ (72–95) | Same as III $B_{21}$ except for lower *p*H (10.0) | | | | | |
| V $B_{23}$ (95–115) | Same as above except for massive nature and clear smooth boundry | | | | | |
| V $C_1$ (115–135) | 10 YR 4/4 | Fw, 1, d(10 YR 5/6) | Cl | m | Fr | es |
| V $C_2$Ca (135–180) | Same as above except for slightly lower *p*H (9.6) | | | | | |
| Pedon 2 (developed on plains/normal and located 75° 48′ 50″ E and 31° 18′ 10″ N about 125 metre west of the village of Jagjitpur in Phagwara tehsil of Kapurthala district) | | | | | | |
| Ap (0–14) | 10 YR 4/4 | Nil | Sl | Wk, I, Sbk | Fr | eo |
| II $A_3$ (14–27) | 10 YR 4/3 | Nil | 1 | Wk, I, Sbk | Fr | eo |
| II $B_1$ (27–42) | 10 YR 4/3 | Co, 2, dt (10 YR 5/6) | 1 | Wk, I, Sbk | Fr | eo |
| II $B_{21}$ (42–52) | 10 YR 3/3 | FW, I, dt (10 YR 5/6) | 1 | Wk, I, Sbk | Fr | eo |
| III $B_{22}$ (52–60) | Same as above except for common mottles and clay loam texture. | | | | | |
| III $B_{23}$ (60–83) | 10 YR 4/2 | Fw, 1, dt (10 YR 5/6) | Cl | Mod, 2, abk | Fm | eo |
| III $B_{24}$ (83–98) | Same as above except for relatively more Fe-Mn concretions | | | | | |
| IV $B_{25}$ (98–120) | 10 YR 3/3 | Co, 2, dt. (10 YR 5/6) | Cl | Wk, 2, abk | Fm | eo |
| V $B_{31}$ (120–139) | 10 YR 4/4 | Fw, I, dt (7.5 YR 5/6) | l/Scl | Wk, 2, 3, abk | Fm | eo |
| $V_1$ $B_{32}$ (139 +) | Same as above except sandy clay loam | | | | | |
| Pedon 3 (developed on filled up channels and located 75° 45′ 45″ E & 31° 19′ 40″ N about 250 metre north of the village of Rawalpindi about 15 meter south of white Bein in Phagwara tehsil of Kapurthala district). | | | | | | |
| Ap (0–17) | 10 YR 4/4 | Nil | Sil | Wk, J, pt | Fr | es |
| $B_1$ (17–32) | 10 YR 3/2 | Nil | Sic | Mod, 2, Sbk | Fr | es |
| $B_{21}$ (32–45) | 10 YR 4/2 | Co, 2, dt. (7.5 4/4) | Sic | Mod, 2, Sbk | Fr | es |
| $B_{22}$ (45–71) | 10 YR 3/2 | Fw, I, ft. (10 YR 5/6) | Sic | Mod, 2, Sbk | Fr | ev |
| $B_{23}$ (71–92) | 10 YR 5/2 | Fw, I, ft. (10 YR 5/6) | Sic | Mod, 2, Sbk | Fr | es |
| $B_{24}$ (92–127) | 10 YR 5/2 | Fw, I, ft. (10 YR 5/6) | Sic | Wk, H, Sbk | Fm | es |
| II $B_3$ (127 + ) | 2.5 Y 5/2 | Nil | Cl | m | Fm | es |
| Pedon 4 (Sand dune complex and located 75° 42′ E and 31° 12′ 50″ N about 1.75 km North of village Darwespind in Phagwara tehsil of Kapurthala district). | | | | | | |
| $Ap_1$ (0–11) | 10 YR 4/3 | Nil | Sl | m | Fm | e |
| II $Ap_2$ (11–28) | 10 YR 4/3 | Nil | Sl | Mod, 2, Sbk | Fm | e |
| III $B_1$ (28–45) | 10 YR 3/4 | Nil | Sl | Mod, 2, Sbk | Fm | e |
| III $B_{21}$ (45–72) | Same as above except for friable consistency and slightly low *p*H (8.3) | | | | | |
| IV $B_{22}$ (72–102) | 10 YR 3/4 | Nil | S1 | Mod, 1 to 2, Sbk, | Fr | e |
| V $B_{23}$ (102-122) | 7.5 4/4 | Nil | S1 | Wk, 1 to 2, Sbk | Fr | e |
| V $B_{24}$ (122–146) | 7.5 4/4 | Nil | S1 | Wk, 1 to 2, Sbk | Fr | e |
| V $B_3$ (146–165) | 10 YR 4/4 | Nil | S1 | Wk, 1 to 2, Sbk | Fr | e |

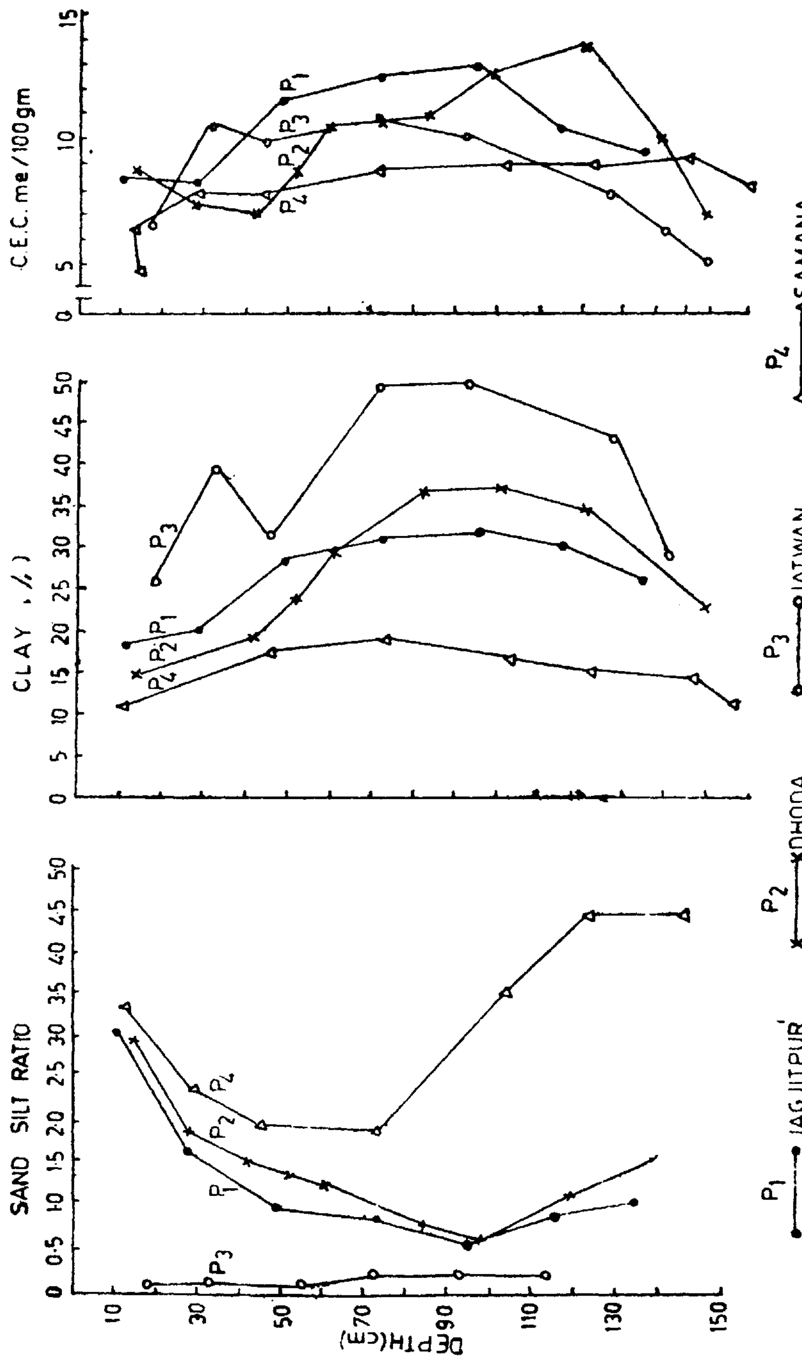


FIG. 2. Depth distribution of sand silt ratios, clay and cation exchange capacity in different series

## Physico-Chemical Properties

The data pertaining to particle size distribution show that total sand is more in flat plain soils as compared to soils developed on filled up channels, as the channel soils are believed to have formed as a result of frequent shifting and abandoning of old water course and filling with finer sediments later. In flat plain soils, the high content of sand at the surface, which decreases with depth in the sub-surface horizons may be due to translocation of finer fractions from the upper to the sub-surface horizons especially during the monsoon period when the soils get dispersed due to beating action of rain drops (Sehgal, 1970; and Sidhu *et al.*, 1976*a*, *b*, *c*). Another possible source of sandy nature of the surface horizons could be wind borne material from the surrounding sandy belts formed by brading action of Beas river and fanning of seasonal 'chos' originating in the Shivalik hills and subside before reaching the flat plains and their subsequent reworking.

In general, the clay content increases with depth within the series control section in all the soils and then it shows a decreasing trend. Sidhu *et al.* (1976) proposed that for diagnosing the lithological discontinuities in the alluvial soils of central Punjab, a limit of 0.2 in the sand/silt ratio of the two adjacent horizons may be optimum. Following the above consideration, one may observe such breaks in Jagjitpur, Dhoda and Samana soils within the control section indicating stratified parent material. The absence of such breaks in Jatwan profile indicates the presence of uniform material within the control section. The distribution of clay with depth (Fig. 2) clearly indicates the fertilization for a minimal (Samana soils) medial (Jagjitpur and Jatwan soils) and maximal (Dhoda soils) separation of these alluvial soils on the basis of their stage of profile development.

The presence of appreciable amounts of Ca + Mg carbonates (Table II) throughout the depth in the salt affected soils (Jagjitpur series) and soils developed in filled up channels (Jatwan series) might be due to low infiltration rate and rise of underground water containing sodium, especially during rainy season. The excessive sodium displaces calcium and magnesium during alkalization process which subsequently get precipitated as carbonates and bicarbonates at a depth where an equilibrium is established between the capillary rise and leaching from the surfaces. This evidence is supported by the observations of Bandyopadhya (1973). Sehgal and Stoops (1972) from various lines of evidences concluded that the lime nodules in Punjab soils are formed, pedogenetically and not inherited from the alluvium. In the normal cultivated soils, permitting easy percolation, the carbonates are either absent or present in minute amounts (Dhoda series) in the control section, suggesting that they have been leached to the deeper layers.

A perusal of the data in (Table II) reveals that the cation exchange capacity of different horizons range from 6.5 to 14.0 me/100 g of soil. Because of low organic carbon ($< 0.58$) in these soils the cation exchange capacity is mainly controlled by clay content which follow almost the same trend (Fig. 2). In the normal soils Ca + Mg are the dominant cations on the exchange complex and are followed by sodium. On the other hand in the salt affected soils (Jagjitpur series) exchange complex is dominated by sodium. The exchangeable sodium percentage values of these soils are high (80 to 83) in the surface horizons which decrease (50–60) with depth in B-horizon, showing that the process of alkalization might have started from the upper

TABLE II

*Physico-chemical characterisation*

| Horizon | Depth (cm) | Particle size analysis (%) Sand (50 u-2mm) | Silt (2-50 u) | Clay (<2 u) | Textural class (USDA) | Sand/Silt ratio | $CaCO_3$ (%) (<2 mm) | (>72 mm) | O.C. (%) | *p*H | ECe (mmhos/cm) | CEC (me/100 gm) | Exchangeable cations me/100 g Ca+Mg | Na | K | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| | | | | | Pedon 1 Jagjitpur Sandy loam (Severely salt affected) | | | | | | | | | | | |
| $A_1$ | 0–10 | 62.0 | 19.8 | 18.2 | Sl | 3.10 | Nil | Nil | 0.36 | 9.9 | 7.2 | 8.5 | 1.9 | 6.8 | 0.2 | 80.0 |
| II $A_3$ | 10–28 | 48.4 | 30.1 | 21.5 | 1 | 1.60 | 0.2 | Nil | 0.20 | 10.2 | 6.1 | 8.2 | 1.4 | 6.8 | 0.2 | 83.0 |
| III $B_1$ | 28–48 | 35.9 | 35.6 | 28.5 | Cl | 1.00 | 0.5 | Nil | 0.20 | 10.0 | 5.9 | 11.4 | 4.8 | 6.5 | 0.3 | 57.0 |
| III $B_{21}$ | 48–72 | 32.0 | 37.0 | 31.0 | Cl | 0.86 | 0.6 | 1.2 | 0.20 | 10.0 | 5.2 | 12.5 | 4.8 | 7.4 | 0.5 | 59.2 |
| IV $B_{22}$ | 72–95 | 25.4 | 42.5 | 32.1 | Cl | 0.57 | 0.7 | 2.5 | 0.10 | 9.8 | 4.6 | 12.8 | 6.0 | 6.5 | 0.4 | 50.0 |
| V $B_{23}$ | 95–115 | 33.2 | 36.8 | 30.0 | Cl | 0.92 | 0.8 | 2.5 | 0.10 | 9.7 | 2.6 | 10.5 | 4.1 | 5.8 | 0.4 | 55.2 |
| V $C_1$ | 115–135 | 38.9 | 34.8 | 26.3 | 1 | 1.10 | 1.5 | 5.8 | 0.10 | 9.5 | 1.8 | 9.8 | 3.9 | 5.3 | 0.3 | 54.1 |
| V $C_2Ca$ | 135–180 | 40.4 | 35.6 | 24.0 | 1 | 1.10 | 0.9 | Nil | 0.06 | 9.2 | 1.6 | 9.8 | 4.6 | 4.8 | 0.3 | 49.0 |
| | | | | | Pedon 2 Dhoda Sandy loam (developed on plains/normal) | | | | | | | | | | | |
| Ap | 0–14 | 64.8 | 21.4 | 14.8 | Sl | 3.02 | 0.5 | Nil | 0.56 | 8.0 | 1.4 | 8.8 | 7.7 | 0.8 | 0.2 | 9.1 |
| II $A_3$ | 14–27 | 50.7 | 28.5 | 20.8 | 1 | 1.77 | 0.3 | Nil | 0.37 | 8.0 | 1.5 | 7.5 | 6.5 | 0.8 | 0.2 | 10.6 |
| II $B_1$ | 27–42 | 50.0 | 31.5 | 18.5 | 1 | 1.58 | 0.2 | Nil | 0.24 | 7.9 | 1.3 | 7.0 | 6.1 | 0.6 | 0.3 | 8.6 |
| II $B_{21}$ | 42–52 | 44.0 | 32.0 | 24.0 | 1 | 1.37 | 0.6 | Nil | 0.26 | 7.9 | 1.0 | 9.8 | 8.7 | 0.6 | 0.4 | 6.1 |
| II $B_{22}$ | 52–60 | 39.7 | 31.8 | 28.5 | Cl | 1.24 | 0.4 | Nil | 0.18 | 7.8 | 1.0 | 10.5 | 9.5 | 0.6 | 0.4 | 5.2 |
| III $B_{23}$ | 60–83 | 28.8 | 36.0 | 35.2 | Cl | 0.80 | 0.5 | Nil | 0.18 | 8.0 | 0.6 | 11.0 | 10.1 | 0.5 | 0.4 | 4.5 |
| III $B_{24}$ | 83–98 | 23.7 | 38.5 | 37.8 | Cl | 0.61 | 0.3 | Nil | 0.16 | 7.8 | 0.7 | 12.8 | 12.1 | 0.5 | 0.2 | 3.8 |
| IV $B_{25}$ | 98–120 | 35.0 | 29.8 | 35.2 | Cl | 1.20 | 0.2 | Nil | 0.14 | 7.9 | 0.5 | 14.0 | 13.1 | 0.4 | 0.4 | 3.0 |
| V $B_{31}$ | 120–139 | 47.4 | 28.0 | 24.6 | 1/SCl | 1.68 | 0.2 | Nil | 0.14 | 7.9 | 0.5 | 10.2 | 9.7 | 0.4 | 0.3 | 3.7 |
| VI $B_{32}$ | 139+ | 54.9 | 21.5 | 23.6 | SCl | 2.55 | 0.3 | Nil | 0.12 | 7.8 | 0.4 | 7.1 | 6.5 | 0.4 | 0.2 | 4.9 |

(*Contd.*)

**TABLE II** (*Contd.*)

*Physico-chemical characterisation*

| Horizon | Depth (cm) | Particle size analysis (%) | | | Textural class (USDA) | Sand/ Salt ratio | $CaCO_3$ (%) | | O.C. (%) | *p*H | ECe (mmhos/ cm) | CEC (me/ 100gm) | Exchangeable cations me/100 g | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand (50 u- 2mm) | Silt (2-50 u) | Clay (<2u) | | | (<2 mm) | (>72 mm) | | | | | Ca+ Mg | Na | C | ESP |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| | | | | | Pedon 3 Jatwan silt loam (filled up channels) | | | | | | | | | | | |
| Ap | 0–17 | 6.4 | 67.4 | 26.2 | Sil | 0.09 | 1.9 | Nil | 0.30 | 8.2 | 0.82 | 6.7 | 5.2 | 1.2 | 0.2 | 17.9 |
| $B_2$ | 17–32 | 6.9 | 53.5 | 39.7 | SiCl | 0.13 | 0.7 | Nil | 0.11 | 8.5 | 0.95 | 10.6 | 8.4 | 2.0 | 0.1 | 18.8 |
| $B_{21}$ | 32–45 | 5.2 | 53.8 | 41.0 | Sic | 0.08 | 1.1 | 12.6 | 0.09 | 8.5 | 1.30 | 9.9 | 7.8 | 1.8 | 0.3 | 18.1 |
| $B_{22}$ | 45–71 | 9.9 | 42.1 | 48.0 | Sic | 0.23 | 5.7 | 3.8 | 0.09 | 8.7 | 0.95 | 10.8 | 8.5 | 1.9 | 0.3 | 17.1 |
| $B_{23}$ | 71–92 | 10.2 | 40.4 | 49.4 | Sic | 0.22 | 5.2 | 1.2 | 0.08 | 8.9 | 0.70 | 10.3 | 8.2 | 1.8 | 0.3 | 17.4 |
| $B_{24}$ | 92–127 | 11.3 | 45.1 | 43.6 | Sic | 0.22 | 2.8 | Nil | 0.07 | 9.0 | 0.70 | 8.9 | 7.1 | 1.5 | 0.2 | 16.6 |
| II $B_3$ | 127+ | 24.3 | 45.9 | 29.8 | Cl | 0.53 | 7.6 | Nil | 0.08 | 8.9 | 0.50 | 6.4 | 5.1 | 1.0 | 0.2 | 15.6 |
| | | | | | Pedon 4 Samana Sandy loam (Sand dune complex) | | | | | | | | | | | |
| $Ap_1$ | 0–11 | 68.8 | 20.0 | 11.2 | Sl | 3.44 | Nil | Nil | 0.58 | 8.1 | 1.35 | 6.2 | 5.3 | 0.5 | 0.3 | 8.1 |
| II $AP_2$ | 11–28 | 59.8 | 26.0 | 14.2 | Sl | 2.30 | Nil | Nil | 0.31 | 8.1 | 1.20 | 7.9 | 6.9 | 0.5 | 0.4 | 6.1 |
| III $B_2$ | 28–45 | 34.8 | 28.2 | 17.0 | Sl' | 1.94 | Nil | Nil | 0.29 | 8.1 | 0.80 | 8.0 | 7.1 | 0.6 | 0.3 | 7.5 |
| III $B_{21}$ | 45–72 | 54.0 | 27.4 | 18.6 | Sl | 1.96 | Nil | Nil | 0.23 | 8.0 | 0.95 | 8.8 | 7.8 | 0.7 | 0.3 | 7.9 |
| IV $B_{22}$ | 72–102 | 65.0 | 18.0 | 17.0 | Sl | 3.61 | Nil | Nil | 0.19 | 7.8 | 0.85 | 9.1 | 8.2 | 0.6 | 0.3 | 6.5 |
| V $B_{23}$ | 102–122 | 68.8 | 15.2 | 16.0 | Sl | 4.52 | Nil | Nil | 0.17 | 7.6 | 0.93 | 9.2 | 8.3 | 0.5 | 0.3 | 5.4 |
| V $B_{24}$ | 122–146 | 69.7 | 15.5 | 14.8 | Sl | 4.49 | Nil | Nil | 0.16 | 7.5 | 1.20 | 9.5 | 8.6 | 0.5 | 0.3 | 5.2 |
| V $B_3$ | 146–165 | 71.4 | 16.4 | 13.2 | Sl | 4.35 | Nil | Nil | 0.19 | 7.5 | 1.00 | 7.5 | 6.9 | 0.4 | 0.3 | 5.3 |

layers and continued downward. The source of salts in these soils may be the flood waters of the East Bein (which contain residual sodium carbonate of 2 me or more), seepage waters from the sorrounding high areas and poor quality underground waters which saturate the control section during monsoon season. The addition of about 1000 kg/ha of sodium rich wind borne material (Sidhu *et al.*, 1976) might also be responsible for higher amounts of exchangeable and soluble sodium in the surface horizons.

The soils are generally low in organic carbon which may be due to scanty vegetation and prevailing hyperthermic temperature regime (MAT 24 °C) which results in its fast decomposition. The high amounts of calcium carbonates in Jagjitpur and Jatwan soils may be responsible for coagulating $Ca^{++}$ ions with humus (Jenny, 1941; and Gupta, 1967). The normal cultivated soils have relatively high organic carbon content possibly due to continuous cropping and regular addition of organic manures to their surfaces. In all the soils, the organic carbon is highest at the surface which decreases with depth.

In normal soils, the *p*H of the saturated soil is around 8.0 which decreases with depth to 7.8 in Dhoda soils and to 7.5 in Samana soils. The slightly high *p*H in the upper horizons may be due to the addition of highly calcareous aeolian materials rich in bases during summer. The widespread observations on dust blankets during summer (May-June) at the presenting alkaline earth carbonates in relatively higher amounts in the crusts support that the crusts are calcareous and may not be of local origin (Sidhu *et al.*, 1976). The dust may, therefore, have an important role in the recharging of the surfaces with calcareous materials rich in bases and in turn retard the translocation of clay.

In the salt-affected soils *p*H is high (10.0–10.2) below the surface horizon, which decreases with depth. Slightly low *p*H at the surface may be due to leaching of soluble salts to the lower horizon. In Jatwan soils, the *p*H is lowest at the surface that gradually increases with depth to a maximum value of 9.0. The electrical conductivity of saturation extract in Jagjitpur salt affected soils is 7.2 mmhos/cm at the surface which decreases with depth to 1.6 mmhos/cm below 135 cm. In all other soils, the ECe values are less than 1.5 mmhos/cm and decreases with depth except in Jatwan soils where these are irregularly distributed indicating the recharging of profile from the surface by flooding and capillary rise of underground water rich in salts.

## Classification

Based on field morphology and laboratory data, the soils have been classified according to the US Comprehensive system of soil classification (*Soil Taxonomy*, 1973).

Since the soil moisture regime plays an important role in classifying soils, its evaluation at this stage may be necessary. A perusal of the water balance data, according to the Thornthwaite Scheme (1948) revised by Vernamenun (1969) (Fig. 3), suggests that the water need for most of the year is more than the water supply and soils remain dry for 6–9 months in a year. From July to September, the water supply occasionally exceeds the water need and may break the long dry spells. This renders the soils moist for 3 months or more and dry for 6–9 months in a year hence the area qualifies for an ustic soil moisture regimes. The Jagjitpur salt affected soils have

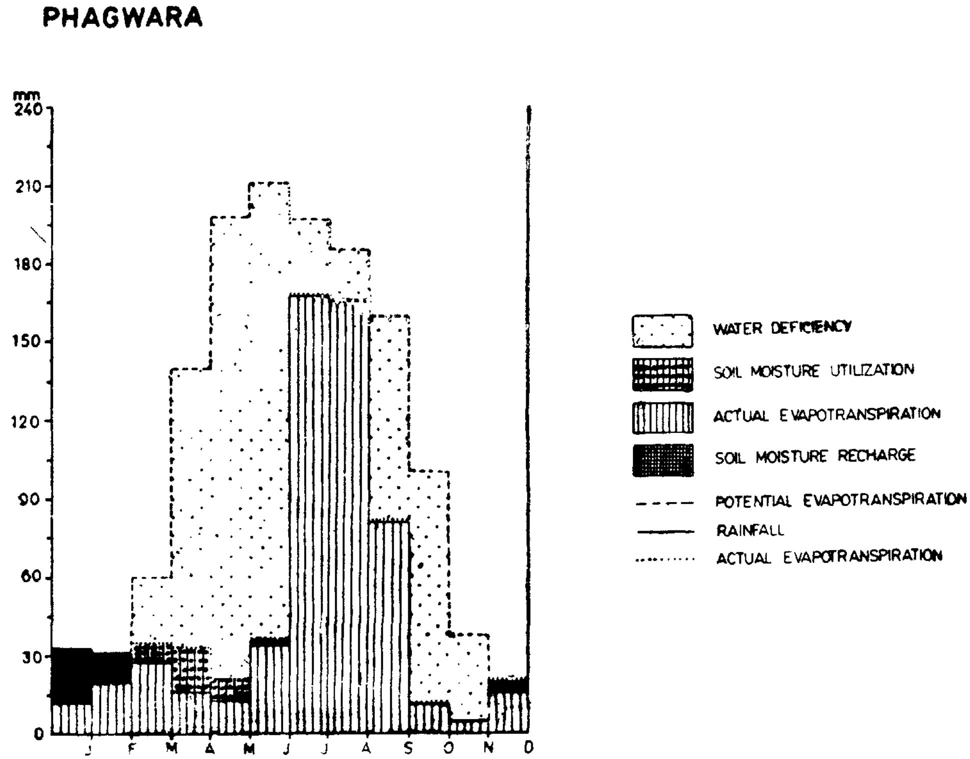


FIG. 3. Water balance diagram

electrical conductivity of the saturation extract more than 2 mmhos/cm in series control section and as such, qualify for an order Aridisols. In addition, these soils have an ochric epipedon underlain by a cambic (altered-B) horizon. In view of these characteristics, these soils have been classified under the sub-order orthids and great soil group camborthids. Further, these soils have characteristics associated with wetness within 75 cm of the surface and high (40%) sodium on exchange complex bringing them to sub-group Natraquic Camborthids. Soils of the filled up channels have an ochric epipedon underlain by altered-B (Cambic) horizon and greyish colours accompanied by mottles just below Ap horizon and qualify for the order, Inceptisols and sub-order-Aquepts. The sodium saturation is more than 15 per cent in the upper 50 cm which decrease with depth below 50 cm bring them to great group Halaquept and mean annual temperature of 22 °C brings them to the sub-group Aeric Halaquept.

Normal cultivated soils (Samana & Dhoda) having an ochric epipedon underlain by altered-B (Cambic) horizon and ustic moisture regime have been classified under the order Incepisols sub-order-Ochrept and great group-Ustochrept. Dhoda soils showing the characteristics associated with wetness within 75 cm of surface qualify for Aquic sub-group. These intergrade soils have a better developed clay-enriched B-horizon and have been classified by introducing a new sub-group alfic as Aquic-alfic Ustochrepts at the sub-group level. The soils of the sand dune complexes are free of carbonates within a depth of 70 cm of the surface and qualify for Udic Ustochrepts at sub-group level.

## GENESIS CONSIDERATIONS

Simunson (1959) proposed that soil genesis be considered as two overlapping steps: viz., the accumulation of parent materials and the differentiation of horizon in the profile. Horizon differentiation is ascribed to additions, removals, transfers and transformations in the soil system. The addition of organic matter, removal of soluble salts and carbonates, transfer of humus, clay and sesquioxides and transformation of primary minerals into secondary minerals are the important changes that contribute to the development of horizons.

The physico-chemical data indicate the migration of clay from the A to the B horizons in all these soils; however, the amount is variable (Table II) in Jagjitpur soils and the increase is 14.0%, in Dhoda and Jatwan soils 23.2% and in Samana soils 7.5%. The low increase in Samana soils may be due to inherent low clay percentage in the parent material. The differential movement of clay in Dhoda and Jagjitpur soils developed on similar landscape position is due to restricted clay transfer, in case of Jagjitpur soils as a result of dispersion of these soils due to alkalinization. The distribution of carbonates in the different soils indicate their translocation to some horizon (Jagjitpur and Jatwan soils) in the control section or out of the control section (Dhod and Samana soils). Sidhu *et al.* (1977) have reported illite, chlorite and Kaolinite minerals in the clay fractions of salt affected and normal soils of Punjab. In addition, they reported the presence of quartz, muscovite, plagioclase and alkali feldspar, amphibole, biotite and chlorite in sand and silt fractions. They suggested that most of the minerals are directly inherited from the parent rocks with chemical alteration of illite *in situ* to variable extent. This shows that weathering has not brought about much alteration in the mineral suits of soils developed on different physiographic units.

The specific difference between the soils developed on different geomorphic zones is explained in the light of different soil forming factors prevailing in the area. In a small region with comparable parent material (alluvium), climate and vegetation; topography and time may influence the soil development.

The use of climate and soil data has been advocated for calculating the age of soil (Arklay, 1963). These calculations may not be possible because of the erratic distribution of rainfall over the year. In this area, mean annual rainfall varies between 500 mm to 680 mm, a major portion (70 per cent) of which is received as summer monsoon (July to September) and that too is received mostly as brisk showers during comparatively small number of hours of a few days in a month. The monthly water balance data (Sehgal, 1970) suggest no surplus available water for leaching, but actual observations suggest that the soils are subjected to leaching during the rainy season. Therefore, to make more meaningful observations concerning the mobility of mobile soil constituents and ultimately profile development, the detailed meteorological observations on the distribution, duration or intensity of rain in a year or in a month or in a single day are necessary.

Topography plays important role in the genesis of the studied soils. The soils in the channels (Jatwan series) are gently sloping and poorly drained as indicated by characteristics associated with wetness due to their development under occasional flooding and high and fluctuating water table (within one metre in the rainy season). The Dhoda soils developed in the normal and partly salt affected plains are imperfectly drained as indicated by presence of mottles/Fe-Mn concretions below 35 cm and low intake rate (0.18 cm/hr). The micro topography have played considerable role in the pedogenesis of Jagjitpur soils. The accumulation of rain water in relatively low lying positions results in the accumulation of salts. Flooding high water table and seepage of water from the adjoining areas to the 'East Bein' may have collectively resulted in the development of salt affected (Jagjitpur soils) within the plains around 'East Bein' and its tributaries. The Samana soils permitting easy percolation of water due to coarse textures are devoid of carbonates as a result of their leaching to deeper layers.

Since the original topography has been greatly modified over the past centuries and no record on the past topography is available, the evaluation of the exact role of topography in the genesis of these soils may be difficult. Similarly, because of the lack of adequate records on the natural vegetation, it is very difficult to quantify the role of vegetation on the genesis of these soils.

On the basis of an arbitrary difference of 0.2 or more in the sand/silt ratios as an index of lithological discontinuity (Sidhu *et al.,* 1976). Such breaks are observed in Jagjitpur, Dhoda and Samana soils due to their alluvial origin. The Jatwan soils do not show such breaks, this might be due to the gradual filling of the channels with finer sediments received alongwith flood waters during rainy season. In these circumstances, the identification of the true parent material of the solum is difficult and hence the calculations of soil genesis are subject to serious errors (Barshad, 1964; Brewer, 1964; and Sidhu *et al.*, 1976). From the available information on the geology it is known that the material on the uplands represents the older alluvium (Bhangar) and that in channels represent the newer alluvium (Khadar). The radioisotopes dating of the buried organic material should however, yield more reliable data that can help to determine the impact of age on these soils. From the field and laboratory data, we may conclude that differences in profile development in these soils are primarily due to topography and to some extent to age.

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