*Agropedology 2013, 23 (2), 65-76*

# Influence of landscape on soil properties in upper Gangetic plain of Uttar Pradesh

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**Abstract:** Twelve typical pedons representing four major landforms (Old alluvial plain, recent alluvial plain, ravinous land and active flood plain) developed in alluvium of Yamuna river were studied for their morphological, physical and chemical properties using IRS-1B LISS III geo-coded satellite data and survey of India toposheets (1:50,000 scale) in Bhagyanagar and Auraiya blocks of Auraiya district, Uttar Pradesh. The soils support different land uses and are very deep, neutral to very strongly alkaline in reaction, sandy to silty clay loam in texture, low in organic carbon (<4 g $kg^{-1}$) and low to medium in CEC (2.0 to 20.9 cmol (p+) $kg^{-1}$). In the old alluvial plains soils are relatively stabilized, and are grouped as Typic Haplustepts (dominant), Typic Haplustalfs and Sodic Haplustepts. In recent alluvial plains soils are in the initial stage of development (cambic sub-surface horizons) and classified as Typic Haplustepts. Ravinous lands suffering from moderate to severe erosion have calcic sub-surface diagnostic horizon (Typic Calciustepts). The active flood plains soils are prone to seasonal flooding and hence these soils are classified as Typic Ustipsamments (dominant) and Calcic Haplustepts. A statistical analysis of horizon thickness showed a wide range of variability within different landscape as indicated by high standard deviations and coefficient of variations. Significant variation amongst sand, silt, clay, organic carbon, pH and electrical conductivity was also noticed.

**Additional key words**: *Geo-coded satellite data, alluvial plain, soil morphology, soil classification, argillic horizon, soil variability*

## Introduction

The Gangetic plain is one of the most productive region and it is bowl of food grain production, but now facing severe challenge of erosion, salinity, sodicity and water-logging which affects the productivity of crops. These soils are heterogeneous in nature due to different activities like mass movement, irregular seepage and non-uniform deposition of sediments as a result of periodic flooding, streams and multiple source of parent material. However, the soil health needs knowledge on morphological, physical and chemical characteristics and classification of soils. These properties of soils are highly governed by the landforms on which they have developed (Sawhney *et al.* 1992; Sharma *et al*. 1999; Verma *et al.* 2012). Identification of such geomorphic domains, possible processes and climatic conditions are of utmost importance which leads to evolution of different soils. Any change in geomorphic processes also influences the pedogenic processes (Hall 1983). This has led to assumption that soil formed in a single landscape unit may have almost similar pedogenic properties. The present study was, therefore carried out to study the characteristics,

genesis and influence of landscape positions on soil properties to protect the finite soil resource and to achieve sustainable crop production in alluvial plain of Bhagyanagar and Auraiya blocks of Auraiya district of Uttar Pradesh.

## Materials and Methods

*Location and climate*

The study area (26°21' to 27°01' N; 78°45' to 79°45' E) is located in the middle of Gangetic plain comprising more or less plain area. It covers the parts of Bhagyanagar and Auraiya blocks of district Auraiya, Uttar Pradesh. The area forms a parts of Northern plain (Agro-ecological Sub-region No.4.3) formed by fluvial action of rivers in Pleistocene and Holocene periods. The mean annual rainfall of the area is 792 mm and with mean annual soil temperature of more than 22°C. Thus, area qualifies for *ustic* moisture and *hyperthermic* moisture regimes. The length of growing period is 120-150 days. The *rabi* season crops are wheat, mustard, gram, barley, pea and potato. Maize, paddy, pearl-millet, maize, pigeon pea and sorghum are grown in *kharif* season.

*Methodology*

A semi reconnaissance soil survey of 2.05 lakh ha area was conducted in Auraiya district as per procedure outlined by AIS&LUS (1970) on 1:50,000 scale. The visual interpretation of IRS 1B LISS III geo-coded data on of 1:50,000 scale in conjunction with survey of India Toposheets and later on ground truth indicated 4 dominant landforms, *i.e.* old alluvial plain, recent alluvial plain, ravinous land and active flood plain**. S**everal minipits, auger bore and pedons were studied for their morphological properties (Soil Survey Division Staff 2000). After soil correlation 12 typical pedons representing 12 soil series were identified *i.e.* five series in old alluvial plain, three in recent alluvial plain, one in ravinous land and three in actives flood plain. Soils of old alluvial plains (Gopalpur-P1, Makhanpur-P2, Nagla Chand-P3, Rahtauli-P4 and Shekhupur-P5); recent alluvial plains (Ajlapur-P5, Chamkani-P6 and Raja ka bagh-P7); active flood plains (Bijhalpur-P10, Biraundhi-P11 and Keontra-P12) falls under cultivated lands, whereas, soils of ravinous land (Paighamberpur-P9) support forest and at places under cultivation. The soil samples of each horizon of the typical pedons were characterized for relevant physical and chemical properties (Black 1965 and Jackson 1973). Soils were classified as per Keys to Soil Taxonomy (Soil Survey Staff 2006). For comparing dispersion among different soil properties, coefficient of variation (CV) was determined and defined relative to standard deviation (SD) and mean (X) as: CV= (SD/X) * 100.

## Results and Discussion

*Soil morphology*

The pedons had their colours in hue 10YR and 2.5Y to 5 Y, value 4 to 6 and chroma 3 to 6 (Table 1). These soils were imperfectly to excessively drained. The soil occurring on very gently to moderately steep sloping land (3-15%) had yellowish brown to dark yellowish brown (10YR 5/4 to 4/4M) in recent, ravinous and active flood plain and that of nearly level slopes (0-1%) had light yellowish brown to olive brown (10YR5/4 to 5Y 5/4M) colour with fine to common medium distinct to prominent light yellowish brown mottles (10YR 5/6) mostly in old alluvial plain. The soil colour appears to be the function of chemical and mineralogical composition as well as textural make-up of the soils as conditioned by topographic positions and moisture regime (Walia and Rao 1997). The soils of the area showed a wide textural variation (sandy to silty clay) might be due to variation in topography, depositional cycle and translocation of clay. The structure of the soil is sub-angular blocky to single grain. Pedon (P2) showed thin and continuous clay cutans and also had an argillic (Bt) sub-surface diagnostic horizons whereas, other pedons (P1, P5, P6, P7, P8, P9, P11, P12) had cambic sub-surface diagnostic horizons. Pedon (P3) showed cambic as well as natric sub-surface horizons and pedon (P10) lacks any diagnostic sub-surface horizons.

**Table 1.** Morphological characteristics of the soils*

| Horizon | Depth (cm) | Boundary | Colour (moist) | Mottles | Texture | Structure | Cutans | Concretions | Consistence |
|---|---|---|---|---|---|---|---|---|---|
| Gopalpur(P1): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | | | | | |
| Ap | 0-15 | cs | 10YR5/4 | - | sl | m1sbk | - | - | h,fi,ssps |
| AB | 15-29 | cs | 10YR4/4 | - | sl | m1sbk | - | - | fi,sp |
| $Bw_1$ | 29-44 | gs | 10YR4/4 | - | l | m2sbk | - | - | fi,sp |
| Bw2 | 44-66 | cs | 10YR4/4 | - | l | c3sbk | - | - | fi,sp |
| Bw3 | 66-87 | gs | 10YR4/4 | - | sil | c2sbk | - | - | fi,vsp |
| Bw4 | 87-120 | gs | 10YR4/4 | - | l | c2sbk | - | - | fi,vsp |
| BC | 120-150 | - | 10YR4/4 | - | l | m2sbk | - | - | fi,vsp |
| Makhanpur (P2) : Fine-silty over fine, mixed, hyperthermic Typic Haplustalf | | | | | | | | | |
| Ap | 0-18 | cs | 10YR5/4 | - | sil | m1sbk | - | - | sh,fr,sp |
| EB | 18-41 | cs | 10YR4/4 | - | sicl | m2sbk | - | - | fi,sp |
| Bw | 41-76 | cs | 10YR4/3 | - | sicl | m2sbk | T tn c | - | fi,vsvp |
| Bt1 | 76-101 | gs | 10YR4/4 | 10YR5/6 (f I f) | sic | m2sbk | T tn c | - | fi,vsvp |
| Bt2 | 101-130 | gs | 10YR4/4 | f1 d | Sic | m2sbk | T tn c | f f Fe/Mn | fi,vsvp |
| BCk | 130-155 | - | 10YR5/4 | f2 f | Sic | m2sbk | - | f f Fe/Mn | fi,vsvp |
| Nagla Chand (P3): Coarse-loamy over fine, mixed, (calcareous) hyperthermic Sodic Haplustept** | | | | | | | | | |
| Ap | 0-18 | aw | 2.5Y6/2 | - | sl | f1abk | - | - | Soft,vfr,sspo |
| AB | 18-40 | cs | 2.5Y5/4 | - | sil | m1abk | - | - | fi,sp |
| 2Bw1 | 40-72 | cs | 2.5Y5/4 | - | sicl | m2sbk | - | - | fi,sp |
| 2Bw2 | 72-105 | aw | 2.5Y4/4 | 10YR5/6 F1d | sicl | m2sbk | - | - | fi,vsvp |
| 2Bw3 | 105-134 | gs | 5Y5/3 | 10YR5/6 c1d | sicl | m2sbk | - | f f Fe/Mn/ m c lime | fi,vsp |
| 2BCk | 134-160 | - | 5Y5/4 | 10YR5/6 C2d | sicl | m2sbk | - | f f Fe/Mn/ m c lime | fi,vsp |
| Rahtauli (P4) : Fine-loamy over fine silty, mixed (calcareous) hyperthermic Typic Calciustept | | | | | | | | | |
| Ap | 0-17 | cs | 10YR5/4 | - | l | massive | - | - | sh,fr,sp |
| AB | 17-32 | gs | 10YR4/4 | - | l | m1sbk | - | - | h,fi,ssp |
| Bw1 | 32-56 | gs | 10YR4/4 | - | l | m2sbk | - | m c lime | fi,sp |
| Bw2 | 56-70 | gs | 10YR4/4 | - | l | m1sbk | - | m c lime | fi,sp |
| Bk1 | 70-91 | gs | 10YR4/4 | - | l | m2sbk | - | m m lime | fi,sp |
| Bk2 | 91-110 | gs | 10YR4/4 | - | l | m2sbk | - | m m lime | fi,sp |
| Ck | 110-150 | - | 10YR4/4 | - | l | massive | - | m c lime | fi,sp |
| Shekhupur (P5): Fine-loamy, mixed, hyperthermic Typic Haplustept | | | | | | | | | |
| Ap | 0-15 | cs | 10YR5/4 | - | sl | m1sbk | - | - | sh,fr,ssps |
| Bw1 | 15-38 | gs | 10YR4/4 | - | sl | m2sbk | - | - | fi,sp |
| Bw2 | 38-60 | gs | 10YR4/4 | - | sl | m2sbk | - | - | fi,sp |
| Bw3 | 60-84 | gs | 10YR4/4 | - | scl | m2sbk | - | - | fi,sp |
| Bw4 | 84-116 | gs | 10YR4/4 | - | scl | m2sbk | - | f c Fe/Mn | fi,sp |
| BC | 140-160 | - | 10YR4/4 | - | scl | m3sbk | - | f c Fe/Mn | fr,ss |
| Ajlapur (P6): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | | | | | |
| Ap | 0-18 | cs | 10YR5/4 | - | sl | m 1 sbk | - | - | soft,fr,ssps |
| Bw1 | 18-42 | cs | 10YR5/4 | - | cl | m 1 sbk | - | - | fi,sp |
| Bw2 | 42-80 | gs | 10YR4/4 | - | cl | m 1 sbk | - | f f Fe,Mn | fi,vsp |
| Bw3 | 80-110 | cs | 10YR4/4 | 7.5YR 5/6 (f 1 p) | cl | m 2 sbk | - | f c Fe,Mn | fi,vsvp |
| Bw4 | 110-150 | - | 10YR4/4 | c 2 p | cl | c 3 sbk | - | m c Fe,Mn | fi,vsvp |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Chamkani (P7): Coarse-loamy, mixed, hyperthermic Typic Haplustept | | | | | | | | | |
| Ap | 0-11 | cs | 10YR5/3 | - | ls | massive | - | - | soft,vfr,so |
| BA | 11-30 | gs | 10YR5/4 | - | ls | f 1 sbk | - | - | soft,vfr,sopo |
| Bw1 | 30-62 | gs | 10YR4/4 | - | sl | m 1 sbk | - | - | fr,sssp |
| Bw2 | 62-81 | gs | 10YR4/4 | - | sl | m 1 sbk | - | - | fr,sssp |
| Bw3 | 81-113 | gs | 10YR4/4 | - | sl | m 1 sbk | - | - | fr,sssp |
| Bw4 | 113-133 | gs | 10YR4/4 | - | sl | m 1 sbk | - | - | fr,sssp |
| BC | 133-155 | - | 10YR4/4 | - | sl | m 1 sbk | - | - | fr,sssp |
| Raja ka bagh (P8): Coarse-loamy, mixed (calcareous) hyperthermic Typic Haslustept | | | | | | | | | |
| Ap | 0-13 | cs | 10YR5/4 | - | ls | massive | - | - | soft,fr,sopo |
| Bw1 | 13-34 | gs | 10YR5/4 | - | sl | m 1 sbk | - | - | sh,fr,ssps |
| Bw2 | 34-60 | gs | 10YR4/4 | - | sl | m 2 sbk | - | - | fr,ssps |
| Bw3 | 60-84 | gs | 10YR4/4 | - | sl | m 2 sbk | - | - | fi,sp |
| Bw4 | 84-121 | gs | 10YR4/4 | - | l | m 2 sbk | - | - | fi,sp |
| BC | 121-150 | - | 10YR4/4 | - | l | m 1 sbk | - | - | fi,ssps |
| Paigamberpur (P9) : Course-silty over fine-loamy, mixed (calcareous) hyperthermic Typic Calciustept | | | | | | | | | |
| A | 0-17 | cs | 10YR5/4 | - | sl | m1sbk | - | m f lime | sh,fr,ss |
| AB | 17-34- | gs | 10YR4/4 | - | sl | m1sbk | - | m c lime | sh,fr,ss |
| Bk1 | 34-50 | gs | 10YR4/4 | - | sl | m1sbk | - | m c lime | fi,sssp |
| Bk2 | 50-74 | gs | 10YR4/4 | - | sl | m1sbk | - | m c lime | fi,sssp |
| Bk3 | 74-102 | gs | 10YR4/4 | - | sl | m1sbk | - | m c lime | fi,sssp |
| Bk4 | 102-125 | gs | 10YR4/4 | - | sl | m2sbk | - | m c lime | fi,sp |
| Bk5 | 125-150 | - | 10YR4/4 | - | sl | m1sbk | - | m f lime | fr,sssp |
| Bijhalpur (P10) : Calcareous, mixed, hyperthermic Typic Ustipsamment | | | | | | | | | |
| Ap | 0-15 | cs | 10YR5/4 | - | s | Sg | - | - | loose, so |
| AC | 15-25 | cs | 10YR5/4 | - | s | Sg | - | - | loose, so |
| C1 | 25-65 | gs | 10YR5/6 | - | s | Sg | - | - | loose, so |
| C2 | 65-112 | gs | 10YR5/6 | - | s | Sg | - | - | loose, so |
| C3 | 112-160 | - | 10YR5/6 | - | s | Sg | - | - | loose, so |
| Biraundhi (P11): Coarse-loamy over sandy, mixed (calcareous) hyperthermic Calcic Haplustept | | | | | | | | | |
| Ap | 0-17 | cs | 10YR5/4 | - | sl | Massive | - | f c lime | sh,fr,ssps |
| Bw | 17-45 | gs | 10YR5/4 | - | sl | f 1 sbk | - | m c lime | sh,fr,ssps |
| Bk | 45-64 | cs | 10YR4/6 | - | sl | f 1 sbk | - | f f lime | fr,ssps |
| 2C1 | 64-100 | gs | 10YR4/6 | - | ls | sg. | - | f f lime | loose, sopo |
| 2C2 | 100-150 | - | 10YR4/6 | - | ls | sg. | - | c f lime | loose, sopo |
| Keontra (P12): Fine, mixed (calcareous) hyperthermic Oxyaquic Haplustept | | | | | | | | | |
| Ap | 0-17 | cs | 10YR4/3 | - | sicl | Massive | - | f f krotovinas | vh,fi,vsvp |
| BW1 | 17-43 | gs | 10YR4/3 | - | sic | m2sbk | - | f f krotovinas | vh,fi,vsvp |
| BW2 | 43-70 | gs | 10YR4/3 | - | sic | m2sbk | - | - | fi,vsvp |
| BW3 | 70-90 | cs | 10YR4/3 | - | sicl | m2sbk | - | - | fi,vsvp |
| BW4 | 90-108 | cs | 10YR4/3 | - | sicl | m2sbk | - | - | fi,sp |
| Bw5 | 108-135 | gs | 10YR4/3 | - | sic | m2sbk | - | - | fi,vsvp |
| BC | 135-160 | - | 10YR4/3 | - | Sic | m2sbk | - | - | fi,vsvp |

*abbreviations are as per Soil Survey Manual (Soil Survey Division Staff 2000)
***Proposed by Verma et al. (2007)*

**Table 2.** Physical properties of the soils

| Horizon | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Clay/silt+clay |
|---|---|---|---|---|---|
| Gopalpur(P1): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | |
| Ap | 0-15 | 74.50 | 14.25 | 11.25 | 0.42 |
| AB | 15-29 | 64.50 | 16.75 | 18.75 | 0.53 |
| $Bw_1$ | 29-44 | 43.03 | 37.75 | 19.28 | 0.34 |
| Bw2 | 44-66 | 34.00 | 46.50 | 19.50 | 0.32 |
| Bw3 | 66-87 | 23.00 | 52.75 | 24.25 | 0.32 |
| Bw4 | 87-120 | 26.50 | 48.25 | 25.25 | 0.35 |
| BC | 120-150 | 28.00 | 46.50 | 25.50 | 0..35 |
| Makhanpur (P2) : Fine-silty over fine, mixed, hyperthermic Typic Haplustalf | | | | | |
| Ap | 0-18 | 33.25 | 48.50 | 18.25 | 0.27 |
| EB | 18-41 | 19.25 | 53.50 | 27.25 | 0.34 |
| Bw | 41-76 | 18.00 | 50.25 | 31.25 | 0.38 |
| Bt1 | 76-101 | 15.75 | 42.75 | 41.50 | 0.49 |
| Bt2 | 101-130 | 17.75 | 39.00 | 43.25 | 0.53 |
| BCk | 130-155 | 17.00 | 37.50 | 45.50 | 0.55 |
| Nagla Chand (P3): Coarse-loamy over fine, mixed (calcareous) hyperthermic Sodic Haplustept | | | | | |
| Ap | 0-18 | 71.50 | 17.00 | 11.50 | 0.40 |
| AB | 18-40 | 38.25 | 47.25 | 14.50 | 0.23 |
| 2Bw1 | 40-72 | 18.50 | 45.75 | 35.75 | 0.44 |
| 2Bw2 | 72-105 | 19.25 | 46.25 | 34.50 | 0.43 |
| 2Bw3 | 105-134 | 18.75 | 47.00 | 34.25 | 0.42 |
| 2BCk | 134-160 | 18.00 | 46.50 | 35.50 | 0.43 |
| Rahtauli (P4): Fine-loamy over fine-silty, mixed (calcareous) hyperthermic Typic Calciustept | | | | | |
| Ap | 0-17 | 37.69 | 50.56 | 11.75 | 0.19 |
| AB | 17-32 | 36.20 | 45.80 | 18.00 | 0.28 |
| Bw1 | 232-56 | 33.24 | 42.26 | 24.50 | 0.37 |
| Bw2 | 56-70 | 31.26 | 41.99 | 26.75 | 0.40 |
| Bk1 | 70-91 | 28.33 | 45.17 | 26.50 | 0.37 |
| Bk2 | 91-110 | 30.10 | 44.40 | 25.50 | 0.37 |
| Ck | 110-150 | 31.75 | 43.25 | 25.00 | 0.37 |
| Shekhupur (P5) : Fine-loamy, mixed, hyperthermic Typic Haplustept | | | | | |
| Ap | 15-38 | 67.25 | 15.00 | 17.25 | 0.53 |
| Bw1 | 15-38 | 51.00 | 20.00 | 29.00 | 0.59 |
| Bw2 | 38-60 | 53.00 | 17.00 | 29.50 | 0.63 |
| Bw3 | 60-84 | 56.25 | 17.00 | 26.75 | 0.61 |
| Bw4 | 84-116 | 55.25 | 19.00 | 32.90 | 0.64 |
| Bw5 | 116-140 | 59.25 | 14.00 | 18.90 | 0.58 |
| BC | 140-160 | 69.75 | 12.50 | 17.75 | 0.59 |
| Ajlapur (P6): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | |
| Ap | 0-18 | 61.00 | 28.50 | 10.50 | 0.27 |
| Bw1 | 18-42 | 43.00 | 31.00 | 26.00 | 0.46 |
| Bw2 | 42-80 | 37.00 | 32.00 | 31.00 | 0.49 |
| Bw3 | 80-110 | 37.75 | 27.50 | 34.75 | 0.56 |
| Bw4 | 110-150 | 38.50 | 24.75 | 36.75 | 0.60 |

| | | | | | |
|---|---|---|---|---|---|
| Chamkani (P7) : Coarse-loamy, mixed, hyperthermic Typic Haplustept | | | | | |
| Ap | 0-11 | 79.00 | 15.25 | 5.75 | 0.28 |
| BA | 11-30 | 74.75 | 14.75 | 10.50 | 0.42 |
| Bw1 | 30-62 | 70.25 | 17.25 | 12.50 | 0.42 |
| Bw2 | 62-81 | 67.25 | 15.50 | 17.25 | 0.53 |
| Bw3 | 81-113 | 65.00 | 16.25 | 18.75 | 0.54 |
| Bw4 | 113-133 | 70.00 | 14.00 | 16.00 | 0.53 |
| BC | 133-155 | 72.25 | 13.00 | 14.75 | 0.53 |
| Raja ka bagh (P8): Coarse-loamy, mixed (calcareous) hyperthermic Typic Haslustept | | | | | |
| Ap | 0-13 | 79.50 | 13.75 | 6.75 | 0.33 |
| Bw1 | 13-34 | 62.00 | 26.50 | 11.50 | 0.30 |
| Bw2 | 34-60 | 53.25 | 32.00 | 14.75 | 0.32 |
| Bw3 | 60-89 | 52.00 | 30.00 | 18.00 | 0.38 |
| Bw4 | 89-121 | 45.50 | 36.75 | 17.75 | 0.33 |
| BC | 121-150 | 46.00 | 39.50 | 16.50 | 0.30 |
| Paigamberpur (P9) : Coarse-silty over fine-loamy, mixed (calcareous) hyperthermic Typic Calciustept | | | | | |
| A | 0-17 | 62.75 | 25.75 | 11.50 | 0.31 |
| AB | 17-34 | 61.50 | 26.00 | 12.50 | 0.33 |
| Bk1 | 34-50 | 59.50 | 24.00 | 16.50 | 0.41 |
| Bk2 | 50-74 | 59.00 | 24.00 | 17.00 | 0.55 |
| Bk3 | 74-102 | 58.50 | 23.75 | 17.75 | 0.43 |
| Bk4 | 102-125 | 53.50 | 25.75 | 20.75 | 0.45 |
| Bk5 | 125-150 | 52.75 | 29.00 | 18.25 | 0.49 |
| Bijhalpur (P10) : Calcareous, mixed, hyperthermic Typic Ustipsamment | | | | | |
| Ap | 0-15 | 95.46 | 2.04 | 2.50 | 0.55 |
| AC | 15-25 | 88.83 | 6.67 | 4.50 | 0.40 |
| C1 | 25-65 | 95.58 | 2.42 | 2.00 | 0.45 |
| C2 | 65-112 | 89.17 | 6.63 | 4.20 | 0.40 |
| C3 | 112-160 | 91.81 | 4.39 | 3.80 | 0.46 |
| Biraundhi (P11): Coarse-loamy over sandy, mixed (calcareous) hyperthermic Calcic Haplustept | | | | | |
| Ap | 017 | 72.00 | 20.75 | 7.25 | 0.26 |
| Bw | 17-45 | 70.00 | 21.00 | 9.00 | 0.30 |
| Bk | 45-64 | 69.00 | 24.00 | 7.00 | 0.23 |
| 2C1 | 64-100 | 91.00 | 5.25 | 3.75 | 0.42 |
| 2C2 | 100-150 | 93.50 | 2.75 | 3.75 | 0.60 |
| Keontra (P12): Fine, mixed (calcareous) hyperthermic Oxyaquic Haplustept | | | | | |
| Ap | 0-17 | 3.75 | 55.75 | 40.50 | 0.42 |
| BW1 | 17-43 | 4.19 | 52.51 | 43.30 | 0.45 |
| BW2 | 43-70 | 9.50 | 49.80 | 40.70 | 0.45 |
| BW3 | 70-90 | 11.70 | 50.50 | 37.80 | 0.43 |
| BW4 | 90-108 | 7.40 | 51.70 | 40.90 | 0.44 |
| Bw5 | 108-135 | 4.50 | 55.30 | 40.20 | 0.42 |
| BC | 135-160 | 3.80 | 55.20 | 41.00 | 0.43 |

*Physical characteristics*

The relevant physical characteristics of soils are presented in table 2. The data indicated that sand and silt constitute major portion in mechanical composition and clay varied from 2.50 to 45.5%. The increase in sand with depth in pedon (P10) could be due to sandy parent material and the presence of higher sand in surface soils of other pedons might have been caused by translocation or removal of finer soil fractions by illuviation (Singh *et al.* 1991). Silt and sand irregularly distributed with depth might be due to lithological discontinuities in the profiles. The increase in clay content in pedon (P2) could be attributed to vertical migration or translocation of clay. The increase in clay content in Bw horizons of pedons (P1, P3, P4, P5, P6, P7, P8, P9, P12) was primarily due to *in-situ* weathering of parent material. The ratio of clay to clay plus silt showed slight increase with depth in most of the pedons.

*Chemical characteristics*

Chemical characteristics of the soils are presented in table 3. The pH of pedon (P1, P6) were slightly acidic to neutral, slightly alkaline (pH 7.6-7.5) for P5 and P12; slightly to moderately alkaline (7.8-8.5) for P2, P4, P7 and P9 and slightly to strongly alkaline (7.8 to 8.9) for P10 and P11 owing to presence of lime rich parent material whereas, in P3 pH is high due to salinity/sodicity. The pedons showed low to medium electrical conductivity (0.07 to 1.60 $dSm^{-1}$), thereby indicating non-saline nature barring P3. The organic carbon content of these soils was found to be low (0.6 to 6.6 $gkg^{-1}$ of soil) and decreased with depth in all the pedons (Verma *et al.* 2012) owing to addition of plant residues and farm yard manures to the surface soils. The CEC of P2, P3, P5, P6 and P12 ranged from 11.3–20.9 cmol ($p^+$) $kg^{-1}$ and other soil had low CEC varying from 1.39 to 8.90 cmol ($p^+$) $kg^1$. These soils are calcareous except P2, P5, P6 and P7. The calcium carbonate content ranged from 4.7 to 250 g $kg^{-1}$ soil and the higher $CaCO_3$ content was noticed in the pedons P3, P4, P9, P11 and P12. However, in P4, P9 and P10 it increased with depth might be due to downward movement of calcium and its subsequent precipitation as carbonate and/or decomposition of calcium carbonate. Pedons P3, P8, P11 and P12 showed an irregular distribution of $CaCO_3$ with depth, which either may be due to variable nature of geological material that contributed to these soils or rapid leaching of carbonates (Singh and Agarwal 2005). Exchangeable bases in all the pedons were in the order of $Ca^{+2}>Mg^{+2}>Na^{+1}>K^{+1}$. The base saturation of these soils varied from 53 to 99.9%.

*Magnitude of soil variability*

A statistical analysis (Table 4) of horizon thickness showed a wide range of variability within different landscape positions as indicated by high standard deviations and coefficient of variations. The soils developed on recent (P6) and active flood plain (P11 and P12) had thicker horoizon as compared to old alluvial plain due to frequent deposition of sediments. The pedon (P3) of old alluvial had more thick horizons (mean value 26.7 cm) due to concave slope which might have favoured deposition of materials from other areas. The soil developed on active flood plain showed high amount of sand (mean value 92.17% and 79.1%) followed by ravinous land (mean value 58.21%) and recent alluvial plain (mean value 43.45%) with narrow range of variability amongst the horizons. The mean value of silt and clay content in pedons were higher in P2, P3 (old alluvial plain) and P6 (recent alluvial plain) with wide range of variability while narrow range of variability was observed in P12 (active flood plain). However, coefficient of variation did not show any definite trend due to heterogeneity of parent material. The geomorphological processes governing the deposition of sediments are also responsible for the variation and irregular distribution of silt in these soils. The increase of clay content in deeper horizons of the soils may be due to translocation by the percolating water. Statistics of pH and electrical conductivity values showed significant differences in mean values having standard deviations (0.35) which indicated that the dispersion about their mean values is not large. In general, pH values increased with depth may be attributed to downward leaching of soluble salts with percolating water, crop removal and root exudation. Narrow range of variations (low SD) were recorded in the mean electrical conduc-

tivity of all the pedons, however, the soils showed greater dispersion (CV) about their means. The range of mean value as well as greater dispersion of EC of pedon (P3) attributed to finer texture and impeded drainage that create saline-sodic environment. Considering the coefficient of variation in entire profiles, EC of all the soils from different landscapes positions showed wide variations in their means (CV). The organic carbon was low in coarse-textured soils as compared to fine-textured soils. The fine-textured soils (P2, P3) of old alluvial plain, recent (P6) and active flood plain (P12) had relatively flat topography and low run-off and hence support better growth of vegetation and *in-turn* higher organic carbon.

**Table 3.** Chemical characteristics of the soils

| Horizon | Depth (cm) | pH (1:2.5) | E.C. (1:2.5) $dsm^{-1}$ | O.C. (g $kg^{-1}$) | $CaCO_3$ (g $kg^{-1}$) | CEC (cmol(p+) $kg^{-1}$) | Exchangeable Cations (cmol(p+)$kg^{-1}$) | | | | Base Saturation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | |
| Gopalpur(P1): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | | | | | | | |
| Ap | 0-15 | 6.20 | 0.07 | 5.1 | - | 7.17 | 3.58 | 0.93 | 0.52 | 0.10 | 71.6 |
| AB | 15-29 | 6.43 | 0.04 | 2.1 | - | 9.22 | 4.41 | 0.91 | 0.43 | 0.10 | 68.4 |
| $Bw_1$ | 29-44 | 6.58 | 0.06 | 1.9 | - | 9.80 | 4.75 | 0.81 | 0.48 | 0.13 | 73.7 |
| Bw3 | 66-87 | 6.70 | 0.05 | 1.7 | - | 11.51 | 5.95 | 1.17 | 0.61 | 0.15 | 90.3 |
| Bw2 | 44-66 | 6.70 | 0.09 | 1.8 | - | 10.10 | 5.22 | 1.01 | 0.65 | 0.18 | 86.6 |
| Bw4 | 87-120 | 6.69 | 0.06 | 1.5 | - | 11.90 | 6.09 | 1.35 | 0.61 | 0.13 | 90.7 |
| BC | 120-150 | 6.73 | 0.06 | 1.0 | - | 11.29 | 5.94 | 1.33 | 0.56 | 0.15 | 91.6 |
| Makhanpur (P2) : Fine-silty over fine, mixed, hyperthermic Typic Haplustalf | | | | | | | | | | | |
| Ap | 0-18 | 7.80 | 0.15 | 3.1 | - | 10.46 | 3.36 | 2.18 | 0.56 | 1.28 | 70.6 |
| EB | 18-41 | 7.89 | 0.15 | 1.5 | - | 15.35 | 6.81 | 2.95 | 0.57 | 1.28 | 75.6 |
| Bw | 41-76 | 8.05 | 0.14 | 1.2 | - | 15.45 | 7.76 | 2.83 | 0.69 | 1.15 | 80.5 |
| Bt1 | 76-101 | 8.15 | 0.18 | 1.0 | - | 18.91 | 8.03 | 4.14 | 0.77 | 1.92 | 78.6 |
| Bt2 | 101-130 | 8.20 | 0.25 | 0.6 | 3.6 | 19.78 | 8.43 | 4.19 | 0.91 | 1.86 | 77.8 |
| BCk | 130-155 | 8.17 | 0.25 | 0.2 | 81.0 | 19.56 | 7.88 | 4.14 | 0.93 | 1.86 | 75.7 |
| Nagla Chand (P3): Coarse-loamy over fine, mixed, (calcareous) hyperthermic Sodic Haplustepts | | | | | | | | | | | |
| Ap | 0-18 | 9.88 | 0.64 | 3.2 | 8.5 | 7.15 | 4.20 | 1.05 | 1.15 | 0.56 | 97.3 |
| AB | 18-40 | 9.75 | 0.16 | 1.8 | 4.7 | 8.23 | 4.12 | 1.25 | 1.98 | 0.62 | 96.8 |
| 2Bw1 | 40-72 | 9.33 | 0.39 | 1.2 | 8.5 | 16.85 | 7.05 | 4.19 | 2.18 | 1.35 | 87.7 |
| 2W2 | 72-105 | 9.31 | 0.49 | 1.0 | 12.5 | 16.25 | 6.89 | 4.20 | 2.50 | 1.15 | 90.7 |
| 2Bw3 | 105-134 | 9.09 | 0.29 | 0.8 | 109.2 | 16.24 | 7.00 | 4.15 | 2.38 | 1.24 | 91.0 |
| 2BCk | 134-160 | 9.31 | 0.30 | 0.6 | 249.8 | 16.46 | 7.15 | 4.30 | 2.40 | 1.16 | 91.2 |
| Rahtauli (P4): Fine-loamy over fine-silty, mixed (calcareous) hyperthermic Typic Calciustept | | | | | | | | | | | |
| Ap | 0-17 | 7.77 | 0.16 | 4.0 | 13.5 | 6.69 | 4.88 | 0.83 | 0.61 | 0.28 | 98.7 |
| AB | 17-32 | 8.10 | 0.11 | 2.8 | 19.8 | 8.91 | 7.52 | 0.79 | 0.43 | 0.10 | 99.2 |
| Bw1 | 232-56 | 8.46 | 0.11 | 2.8 | 39.6 | 11.87 | 8.55 | 0.76 | 1.00 | 0.08 | 87.5 |
| Bw2 | 56-70 | 8.42 | 0.12 | 2.5 | 124.2 | 12.61 | 9.35 | 0.50 | 0.91 | 0.08 | 86.0 |
| Bk1 | 70-91 | 8.50 | 0.13 | 2.3 | 202.5 | 11.52 | 9.09 | 0.50 | 0.96 | 0.06 | 92.1 |
| Bk2 | 91-110 | 8.43 | 0.15 | 2.1 | 207.0 | 11.30 | 9.78 | 0.51 | 0.78 | 0.05 | 98.4 |
| Ck | 110-150 | 8.23 | 0.15 | 0.8 | 252.0 | 11.83 | 9.11 | 0.86 | 0.65 | 0.05 | 90.2 |
| Shekhupur (P5) : Fine-loamy, mixed, hyperthermic Typic Haplustept | | | | | | | | | | | |
| Ap | 0-15 | 7.53 | 0.12 | 4.2 | - | 9.81 | 4.68 | 2.17 | 0.35 | 0.29 | 76.4 |
| Bw1 | 15-38 | 7.52 | 0.15 | 1.9 | - | 14.55 | 6.36 | 3.16 | 0.45 | 0.48 | 71.8 |
| Bw2 | 38-60 | 7.60 | 0.10 | 1.8 | - | 14.20 | 6.63 | 3.59 | 0.54 | 0.36 | 78.3 |
| Bw3 | 60-84 | 7.60 | 0.10 | 1.5 | - | 13.45 | 5.94 | 3.01 | 0.52 | 0.42 | 73.5 |
| Bw4 | 84-116 | 7.62 | 0.10 | 0.8 | - | 12.70 | 5.34 | 2.97 | 0.50 | 0.36 | 72.2 |
| Bw5 | 116-140 | 7.60 | 0.12 | 0.7 | - | 13.35 | 5.50 | 3.01 | 0.48 | 0.36 | 70.0 |
| BC | 140-160 | 7.62 | 0.10 | 0.6 | - | 9.80 | 5.61 | 2.10 | 0.52 | 0.18 | 85.8 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ajlapur (P6): Fine-silty, mixed, hyperthermic Typic Haplustept | | | | | | | | | | | |
| Ap | 0-18 | 7.30 | 0.10 | 5.0 | - | 6.90 | 2.75 | 1.84 | 0.55 | 0.48 | 81.5 |
| Bw1 | 18-42 | 7.26 | 0.14 | 2.9 | - | 13.00 | 6.18 | 3.05 | 0.60 | 0.49 | 79.4 |
| Bw2 | 42-80 | 7.25 | 0.13 | 1.9 | - | 15.15 | 6.50 | 4.26 | 0.65 | 0.48 | 78.5 |
| Bw3 | 80-110 | 7.28 | 0.12 | 1.7 | - | 17.30 | 6.79 | 4.45 | 0.68 | 0.66 | 72.7 |
| Bw4 | 110-150 | 7.30 | 0.10 | 1.5 | - | 18.70 | 7.35 | 5.24 | 0.85 | 0.78 | 76.0 |
| Chamkani (P7): Coarse-loamy, mixed, hyperthermic Typic Haplustept | | | | | | | | | | | |
| Ap | 0-11 | 8.12 | 0.36 | 3.0 | - | 3.50 | 1.07 | 1.15 | 0.45 | 0.42 | 88.3 |
| BA | 11-30 | 8.15 | 0.21 | 1.7 | - | 5.60 | 1.72 | 1.66 | 0.46 | 0.24 | 72.9 |
| Bw1 | 30-62 | 8.42 | 0.14 | 1.1 | - | 6.50 | 1.92 | 1.26 | 0.50 | 0.36 | 62.2 |
| Bw2 | 62-81 | 8.35 | 0.14 | 1.0 | - | 9.00 | 2.59 | 1.49 | 0.50 | 0.24 | 53.6 |
| Bw3 | 81-113 | 8.50 | 0.07 | 0.9 | - | 9.50 | 2.64 | 1.57 | 0.61 | 0.30 | 53.9 |
| Bw4 | 113-133 | 8.45 | 0.06 | 0.8 | - | 8.20 | 2.18 | 1.43 | 0.59 | 0.24 | 54.2 |
| BC | 133-155 | 8.35 | 0.10 | 0.7 | - | 7.40 | 2.02 | 1.78 | 0.82 | 0.24 | 65.7 |
| Raja ka bagh (P8): Coarse-loamy, mixed (calcareous) hyperthermic Typic Haslustept | | | | | | | | | | | |
| Ap | 0.13 | 8.16 | 0.14 | 3.6 | 9.0 | 3.82 | 1.24 | 0.61 | 0.60 | 0.57 | 79.1 |
| Bw1 | 13-34 | 8.40 | 0.30 | 3.0 | 24.3 | 6.52 | 2.63 | 0.51 | 0.62 | 0.64 | 67.5 |
| Bw2 | 34-60 | 8.73 | 0.60 | 2.8 | 27.0 | 8.04 | 3.20 | 1.31 | 0.68 | 0.51 | 70.9 |
| Bw3 | 60-89 | 8.72 | 1.50 | 2.6 | 27.0 | 9.04 | 3.68 | 1.52 | 0.82 | 0.70 | 74.3 |
| Bw4 | 89-121 | 8.95 | 1.50 | 1.4 | 19.8 | 8.80 | 3.49 | 1.46 | 1.02 | 0.64 | 75.1 |
| BC | 121-150 | 9.12 | 1.50 | 1.2 | 20.7 | 8.50 | 3.40 | 1.53 | 1.12 | 0.70 | 79.4 |
| Paigamberpur (P9) : Course-silty over fine-loamy, mixed (calcareous) hyperthermic Typic Calciustept | | | | | | | | | | | |
| A | 0-17 | 7.93 | 0.17 | 3.9 | 106.2 | 6.83 | 3.31 | 1.51 | 0.51 | 0.64 | 87.4 |
| AB | 17-34 | 7.94 | 0.14 | 2.1 | 139.5 | 6.53 | 3.03 | 1.48 | 0.52 | 0.70 | 87.7 |
| Bk1 | 34-50 | 7.94 | 0.13 | 1.9 | 153.7 | 8.76 | 3.39 | 1.56 | 0.52 | 0.70 | 70.4 |
| Bk2 | 50-74 | 7.92 | 0.15 | 1.8 | 177.3 | 8.90 | 3.61 | 1.67 | 0.54 | 0.77 | 74.1 |
| Bk3 | 74-102 | 7.92 | 0.15 | 1.7 | 190.8 | 9.39 | 4.04 | 1.86 | 0.54 | 0.83 | 77.4 |
| Bk4 | 102-125 | 8.05 | 0.19 | 1.5 | 208.8 | 10.50 | 5.46 | 2.44 | 0.56 | 0.77 | 85.3 |
| Bk5 | 125-150 | 8.07 | 0.25 | 1.1 | 217.8 | 9.24 | 5.73 | 2.22 | 0.58 | 0.77 | 100+ |
| Bijhalpur (P10) : Calcareous, mixed, hyperthermic Typic Ustipsamment | | | | | | | | | | | |
| Ap | 0-15 | 8.10 | 0.08 | 0.9 | 74.7 | 1.74 | 0.89 | 0.27 | 0.39 | 0.05 | 92.0 |
| AC | 15-25 | 8.04 | 0.10 | 0.6 | 73.8 | 2.00 | 0.81 | 0.53 | 0.48 | 0.06 | 94.0 |
| C1 | 25-65 | 8.00 | 0.10 | 0.4 | 96.3 | 1.39 | 0.70 | 0.20 | 0.37 | 0.04 | 94.2 |
| C2 | 65-112 | 8.01 | 0.08 | 0.4 | 103.5 | 2.04 | 1.04 | 0.69 | 0.41 | 0.06 | 99.1 |
| C3 | 112-160 | 7.95 | 0.08 | 0.4 | 105.3 | 2.22 | 1.03 | 0.58 | 0.43 | 0.15 | 98.7 |
| Biraundhi (P11): Coarse-loamy over sandy, mixed (calcareous) hyperthermic Calcic Haplustept | | | | | | | | | | | |
| 0-17 | Ap | 8.89 | 0.11 | 2.7 | 121.5 | 5.43 | 2.17 | 1.32 | 1.08 | 0.45 | 92.5 |
| 17-45 | Bw | 8.51 | 0.06 | 2.3 | 140.4 | 4.46 | 1.82 | 1.07 | 0.86 | 0.38 | 92.6 |
| 45-64 | Bk | 8.49 | 0.03 | 1.3 | 193.5 | 4.32 | 2.26 | 1.19 | 1.08 | 0.38 | 97.2 |
| 64-100 | 2C1 | 8.64 | 0.06 | 1.1 | 90.0 | 2.39 | 0.86 | 0.59 | 0.54 | 0.26 | 94.1 |
| 100-150 | 2C2 | 8.62 | 0.06 | 0.8 | 96.5 | 2.17 | 0.93 | 0.48 | 0.43 | 0.20 | 94.0 |
| Keontra (P12): Fine, mixed (calcareous) hyperthermic Oxyaquic Haplustept | | | | | | | | | | | |
| Ap | 0-17 | 7.50 | 0.06 | 6.6 | 18.00 | 20.90 | 8.19 | 4.93 | 0.71 | 1.21 | 72.0 |
| Bw1 | 17-43 | 7.50 | 0.20 | 4.2 | 18.00 | 20.43 | 8.10 | 4.55 | 0.68 | 1.41 | 72.2 |
| Bw2 | 43-70 | 7.60 | 0.20 | 4.0 | 17.10 | 19.78 | 7.68 | 4.15 | 0.79 | 1.28 | 70.3 |
| Bw3 | 70-90 | 7.63 | 0.20 | 4.0 | 21.60 | 18.39 | 7.55 | 4.03 | 0.71 | 1.28 | 73.8 |
| Bw4 | 90-108 | 7.65 | 0.18 | 4.0 | 20.70 | 20.13 | 8.49 | 4.88 | 0.77 | 1.79 | 79.1 |
| Bw5 | 108-135 | 7.65 | 0.20 | 3.8 | 18.50 | 19.82 | 8.19 | 4.48 | 0.76 | 2.04 | 78.1 |
| BC | 135-160 | 7.58 | 0.28 | 3.6 | 19.35 | 20.18 | 8.31 | 4.94 | 0.93 | 1.60 | 78.2 |

**Table 4.** Mean values (M), Standard deviation (SD) and coefficient of variation (CV) of the selected properties of soils

| Soils | Statistics | Horizon thickness (cm) | Sand (%) | Silt (%) | Clay (%) | pH (1:2.5) | EC (1:2.5) $dSm^{-1}$ | O.C. ($g\ kg^{-1}$) | CEC ($cmol(p+)\ kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Old alluvial Plain | | | | | |
| P1 | Mean | 21.42 | 41.93 | 37.54 | 20.54 | 6.58 | 0.06 | 2.16 | 10.14 |
| | SD | 13.23 | 20.10 | 15.71 | 5.05 | 0.20 | 0.02 | 1.34 | 1.64 |
| | CV | 61.76 | 47.94 | 41.85 | 24.59 | 3.04 | 33.33 | 62.04 | 16.17 |
| P2 | Mean | 25.83 | 20.17 | 45.25 | 34.5 | 8.04 | 0.19 | 1.27 | 16.58 |
| | SD | 5.24 | 6.51 | 6.46 | 10.71 | 0.15 | 0.05 | 1.34 | 3.60 |
| | CV | 20.29 | 32.23 | 14.28 | 31.04 | 1.87 | 26.32 | 62.04 | 21.71 |
| P3 | Mean | 26.67 | 30.71 | 41.63 | 27.67 | 9.45 | 0.38 | 1.43 | 13.53 |
| | SD | 5.34 | 21.47 | 12.08 | 11.41 | 0.30 | 0.17 | 0.96 | 4.54 |
| | CV | 20.03 | 63.82 | 29.02 | 41.24 | 3.18 | 44.74 | 67.13 | 33.56 |
| P4 | Mean | 21.43 | 32.65 | 44.78 | 22.57 | 8.27 | 0.13 | 2.47 | 10.68 |
| | SD | 8.89 | 3.32 | 2.92 | 5.61 | 0.26 | 0.02 | 0.99 | 2.11 |
| | CV | 41.48 | 10.17 | 6.52 | 24.86 | 3.14 | 15.38 | 40.01 | 19.76 |
| P5 | Mean | 22.86 | 58.82 | 16.36 | 24.57 | 7.58 | 0.11 | 1.64 | 12.55 |
| | SD | 5.11 | 7.13 | 2.69 | 6.46 | 0.04 | 0.02 | 1.25 | 1.97 |
| | CV | 22.35 | 12.12 | 16.64 | 26.29 | 0.53 | 18.18 | 76.22 | 15.70 |
| | | | | Recent alluvial plain | | | | | |
| P6 | Mean | 30.00 | 43.45 | 28.75 | 27.80 | 7.28 | 0.12 | 2.60 | 14.21 |
| | SD | 9.27 | 10.08 | 2.88 | 10.50 | 0.02 | 0.02 | 1.45 | 4.62 |
| | CV | 30.90 | 23.20 | 10.02 | 37.77 | 0.28 | 0.17 | 55.77 | 32.51 |
| P7 | Mean | 22.14 | 71.21 | 15.14 | 13.64 | 8.33 | 0.15 | 1.31 | 7.10 |
| | SD | 7.56 | 4.67 | 1.41 | 4.46 | 0.15 | 0.10 | 0.81 | 2.09 |
| | CV | 34.15 | 6.56 | 9.31 | 32.70 | 1.80 | 66.67 | 61.83 | 29.44 |
| P8 | Mean | 25.00 | 56.38 | 29.75 | 14.21 | 8.68 | 0.92 | 2.43 | 7.45 |
| | SD | 6.96 | 12.82 | 9.12 | 4.37 | 0.35 | 0.65 | 0.94 | 1.99 |
| | CV | 27.84 | 22.74 | 30.66 | 30.75 | 4.03 | 70.65 | 38.68 | 26.71 |
| | | | | Ravinous land | | | | | |
| P9 | Mean | 21.43 | 58.21 | 25.46 | 16.32 | 7.97 | 0.17 | 2.00 | 8.59 |
| | SD | 4.72 | 3.78 | 1.83 | 3.26 | 0.06 | 0.04 | 0.90 | 1.42 |
| | CV | 22.03 | 6.49 | 7.19 | 19.98 | 0.80 | 23.53 | 45.00 | 16.53 |
| | | | | Active flood plain | | | | | |
| P10 | Mean | 32.00 | 92.17 | 4.43 | 3.40 | 8.02 | 0.09 | 0.54 | 1.88 |
| | SD | 18.15 | 3.27 | 2.21 | 1.09 | 0.05 | 0.01 | 0.22 | 0.32 |
| | CV | 56.72 | 3.55 | 49.89 | 32.06 | 0.62 | 11.11 | 40.74 | 17.02 |
| P11 | Mean | 30.00 | 79.10 | 14.75 | 6.15 | 8.63 | 0.06 | 1.64 | 3.75 |
| | SD | 13.51 | 12.09 | 9.94 | 2.32 | 0.16 | 0.03 | 0.82 | 1.41 |
| | CV | 45.03 | 1.53 | 67.39 | 37.72 | 1.85 | 50.00 | 50.00 | 37.60 |
| P12 | Mean | 22.86 | 6.41 | 52.97 | 40.63 | 7.59 | 0.19 | 4.31 | 19.95 |
| | SD | 4.38 | 3.19 | 2.45 | 1.61 | 0.06 | 0.06 | 1.03 | 0.79 |
| | CV | 19.16 | 49.77 | 4.63 | 3.96 | 79.05 | 31.58 | 23.90 | 3.96 |

A fairly constant and significant increase in mean values of CEC was observed in fine textured soils (P1 to P5, P6, P12) than coarse-textured soils (P10, P11, P9, P7, P8). The increase/decrease in CEC of soils occurring on different landscapes showed positive relationship with clay. The wide variation in CEC among soils may be ascribed to differences in clay content and stratified and young nature of the parent materials.

*Influence of soil forming factors*

The morphological, physical and chemical characteristics of soils from different geomorphic surfaces indicated three different stages of pedogenic development characterized by A-C, A-(Bw)-C, A-(Bt)-C profiles. The young and stratified soils (P10) of unstable geomorphic surfaces (active flood plain) showed little alteration of original deposits. Topography of land and nature of parent material seemed to have played a vital role in the genesis of these soils. These areas receive coarser sediments from the peripheral land because of its gradients towards the Yamuna and its tributaries. The soils from active flood plain and active ravinous land have their genesis over deposits of coarser sediments from peripheral land to rivers, as these soils get frequently flooded during the rainy season and hence little time for consolidation of sediments into aggregates.

Relatively low slope gradient and enhanced percolation of water through the solum resulted in the formation of distinct altered cambic sub-surface horizon (Bw) in P1, P3 to P9 and P11, P12 and argillic sub-surface horizon (Bt) in P2 owing to eluviations and illuviations. The transformation of minerals and organic substances indicated that colour and structure get transformed in sub-soil leading to the development of cambic horizon in P1, P3 to P9 and P11, P12. The wide variation in textures of soils developed on different geomorphic surfaces might be due to the heterogeneity of parent material (Verma *et al.* 1998) and to differences in geomorphological processes governing the deposition of sediments (Holmes and Western 1969).

**Conclusions**

The standard deviations and co-variance are good tools to evaluate the solum and horizon thickness which showed a wide range of variability within different landscape positions. The soils developed on recent and active flood plain had comparatively thicker horoizon as compared to old alluvial plain due to frequent deposition of sediments. The soils formed on different geomorphic positions show different stages of pedogenic development. The young and stratified soils from the unstable geomorphic surfaces (active flood plain) without any diagnostic horizon showed little alteration of original deposits. But soils on stable landscape (old alluvial plain) due to low slope gradient and low erosion enhanced the percolation of water throughout the solum and that resulted in the formation of distinct altered cambic (Bw) and argillic (Bt) sub-surface horizons. So, climate, vegetation, topography of land along with the time factor and nature of parent material seemed to have played a vital role in the genesis and development of these soils.

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*Received : May 2013; Accepted : November 2013*