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# Pedological Development of Soils of Saraswati River Palaeochannels across Haryana through Field Morphology Rating System

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***Abstract*:** To evaluate the pedological development of soils in Saraswati river palaeochannels in Haryana, a study was carried out. Twelve Soil pedons were dug and exposed to study the level of soil development according to field morphology rating system. Six soil profiles were studied in Yamunanagar district, one soil profile in Kurukshetra district, two from Kaithal district, one from Fatehabad district and two from Sirsa district. The slope of the soils from Yamunanagar district was 1-3% (nearly level to gently sloping land). Rest of the soil profiles were in 0-1% sloping lands. The structure of pedons varied from single grain, granular, angular blocky to sub-angular blocky in type, structureless to strong in grade and fine to medium in class. Soils of pedons 1(P-1 Ranipur, Yamunanagar), 2 (P-2 Mugalwali, Yamunanagar), 3 (P-3 Bansewala, Yamunanagar), 5 (Painsal-NB Yamunanagar), 6 (P-6 Mustafabad, Yamunanagar), 7(P-7 Ishargarh, Kurukshetra), 10 (P-10 Birdhana, Fatehabad) and 12 (P-12 Farwai-2, Sirsa) and surface horizon of pedon 11 (P-11 Farwai-1, Sirsa) exhibited sub-angular blocky structure due to low clay and low organic carbon content. The textural analysis of soil particles indicated that pedon 1, 2, 3, 4, 5 and 12 were light, pedon 7 was light to medium and pedon 6, 8, 9, 10 and 11 were heavy in texture. The calcium carbonate concretions were present in pedon 10, 11 and 12 due to calcium containing parent rock which released calcium upon weathering and soil formation. The soils of pedon 2, 3, and 9 have a relative horizon distinctness (total) value of 20 each, pedon 7, 5, 6 and 10 have values 19, 17, 16 and 16 respectively and pedon 12 & 8 14 each. The relative profile development (total) value of the pedons varied from 16 to 33 being minimum in pedon 8 and maximum in pedon 11 and 5. . The horizon boundary, differences in moist colour, texture, structure, consistency, pH, and EC all had a role in the rating variation.

***Keywords*:** Relative horizons distinctness, Relative profile development, Saraswati river, Pedon

Soil morphology offers vital insights into pedogenic processes by revealing variations in horizonation, structure, texture, and colour that reflect the intensity and duration of soil development. In alluvial and paleochannel environments, these morphological patterns not only become more critical but also more complex due to depositional layering and parent-material heterogeneity, which often obscure the signs of true soil development (Lalitha et al., 2023). Field morphology rating system enables quantitative assessments of soil development. These approaches compare profile differentiation and horizon distinctness across geomorphic surfaces, facilitating more rigorous evaluation of paedogenic variations. Despite their ecological significance, the soils within the palaeochannel of the Saraswati River in Haryana remain insufficiently studied. While geophysical investigations have detailed subsurface characteristics of these palaeochannels (Kumar et al., 2024), interpretations of surface morphology and pedogenesis are still lacking. The current study applies a morphological rating system to quantify soil development and assess pedological variation in these paleochannel landscapes of Haryana. The aim of study is to enhance understanding of soil genesis in these unique geomorphic environments and inform regionally tailored land management strategies.

## MATERIAL AND METHODS

Twelve representative pedons from palaeochannels of Saraswati River were investigated from Haryana (Table 1).

**Table 1.** Sites location

| Pedon | Location | Latitude | Longitude |
|---|---|---|---|
| P1 | Ranipur, Yamunanagar | 30°24'47"N | 77°19'54"E |
| P2 | Mugalwali, Yamunanagar | 30°23'56"N | 77°19'33"E |
| P3 | Bansewala, Yamunanagar | 30°22'42"N | 77°16'58"E |
| P4 | Painsal-1 Yamunanagar | 30°18'57"N | 77°12'52"E |
| P5 | Painsal-NB Yamunanagar | 30°18'57"N | 77°12'52"E |
| P6 | Mustafabad, Yamunanagar | 30°13'43"N | 76°10'6"E |
| P7 | Ishargarh, Kurukshetra | 30°0'49"N | 76°54'9"E |
| P8 | Mangna, Kurukshetra | 29°57'35"N | 76°29'43"E |
| P9 | Kaekor, Kaithal | 29°57'14"N | 76°25'50"E |
| P10 | Birdhana, Fatehabad | 29°33'16"N | 75°31'45"E |
| P11 | Farwai-1, Sirsa | 29°36'40"N | 75°6'12"E |
| P12 | Farwai-2, Sirsa | 29°36'40"N | 75°6'12"E |

Indian Space Research Organization' BHUVAN platform was used for identification of Saraswati River palaeochannels. Additionally, False Colour Composite from Sentinel-2 imagery with 5×5m resolution was used for palaeochannel identification and study of tone and texture of

soil of the area. Field traversing was also done before the initiation of the study. Two indices of soil development viz. morphological properties such as soil colour, texture, structure, consistency, pedon reaction and concretions were observed in each pedon in the field (USDA' Soil Survey Manual 2017). Soil pH was determined using pH meter consists the glass electrode in 1:2 soil: water suspension at room temperature (Jackson, 1973). Electrical conductivity was determined using a conductivity meter in 1: 2: soil: water suspension at room temperature 25°C (Jackson, 1973). Relative horizon distinctness (RHD) and relative profile development (RPD) were calculated from the soil morphological data as defined by Bilzi and Ciolkosz (1977). RHD was determined by comparing the morphological features of two adjacent horizons and RPD by comparing of the morphological feature of each horizon with the C horizon within each pedon. Soil pedons were classified in accordance with Key to Soil Taxonomy (Soil Survey Staff 2022). The soils were evaluated and points assigned as described below:

**Boundaries:** Points are assigned according to the distinctness of the lower or shared horizon as follows: diffuse-0, gradual-1, clear-2, abrupt-3 and very abrupt-4.

**Colour (dry and moist):** One point is assigned for any class change in hue and for any unit change in value or chroma. For example, a change from 10 YR 4/6 to 5 YR 3/8 would have a value of 5 for the twofold class change, the one – unit change in value, and two – unit change in chroma. Where two colours are observed (other than mottles), each one is compared, and the average difference is used.

**Texture:** One point is assigned for each class change on the textural triangle. In addition, a change from non-gravelly to gravelly or very gravelly is assigned one or two points, respectively.

**Structure:** One point is assigned for any change in type of aggregated structure, for each unit change in grade (1, 2, 3), and for each class change in size (vf, f, m, c, vc), irrespective of the aggregate type. For example, a change from weak, very fine subangular blocky (lvfsbk) to moderate, medium angular blocky (2m abk) is assigned a value 4. When the change is from no aggregated-to-aggregated structure (or vice versa), however, only the grade of the aggregate type is evaluated, in addition to the one point assigned for the type change. For example, a change from massive to weak, fine subangular blocky (1f sbk) is assigned a value of 2.

**Consistence:** One point is assigned for any class change in wet (so, ss, s, vs, po, ps, p, vp) consistence.

**Cutans:** One point is assigned for each class change in frequency or thickness at any single location.

**Coarse fragments/Stoniness (>7.5 cm diameter):** Points are assigned according to the volume of coarse fragments (>7.5 cm diameter) present in the matrix of the soil (1 for 80%).

**Chemical rating system:** This was evaluated and points assigned (Salem et al., 1997).

**Soluble salts (dS/m):** One point is assigned for each class change in quantity (non, very slightly, moderately, highly, extremely saline).

**pH value of soil paste:** One point is assigned for each class change in quantity (ultra-acid, extremely acid, very strongly acid, strongly acid, moderately acid, slightly acid, neutral, slightly alkaline, moderately alkaline, strongly alkaline and very strongly alkaline).

## RESULTS AND DISCUSSION

The morphological and chemical properties of twelve pedons each covering soils of Saraswati River palaeochannels across Haryana from Yamunanagar to Sirsa district are represented in Table 2. The data were evaluated and prospective points were assigned as described by Bilzi and Ciolkosz (1997), Meixner and singer (1981) and Salem et al. (1997), and the soil rating scales are applied.

**Morphological characteristics:** The colour of the pedons varied from brown (10YR 5/3) to very pale brown (10YR 7/4) with dominant hue of 10YR. The values ranged from 5 to 7, whereas chromas were 2 to 6. The pale brown soil colour at the surface horizon of the pedons 6, 8, 9 and 11 could be attributed to the relatively higher accumulation and decomposition of OM content of the study site. Teshome et al. (2016) reported that the surface horizons have darker color than the subsurface horizons because of relatively higher soil OM contents. Agbugba (2018) also found similar results. The variation in colour of different pedons is due to different texture, topography, mineralogy and chemical composition of soils (Leelavathi et al., 2009, Sekhar et al., 2019). Horizon boundaries of the pedon 1, 2, 3, 4, 7, 8, 9 & 11 varied from clear and smooth to gradual and smooth, clear and smooth to gradual and wavy to gradual and smooth in pedon 5 & 12, clear and smooth to clear and wavy to gradual and smooth in pedon 6 and abrupt and smooth to gradual and smooth in pedon 10. These differences in surface-subsurface soil layer boundary characteristics may be due to the occurrence of unique morphological features with pedon depth, which would therefore suggest that the study area is still in the early phases of soil development (Ukut et al., 2014).

The textural analysis of soil particles indicated that pedon 1, 2, 3, 4, 5 and 12 were light, pedon 7 was light to medium and pedon 6, 8, 9, 10 and 11 were heavy in texture. Textural variations are due to different parent material and differential degree of weathering. Translocation of finer particles from

**Table 2.** Morphological and physico-chemical properties of the studied pedons

| Soil profile | Horizon | Depth (cm) | Horizon boundary | Colour (Dry) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction | pH | EC (dSm-1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 (Ranipur) | Ap1 | 0-25 | c-s | 10YR 5/4 | sl | sbk 2 m | SSNP | - | | stmf | - | 6.53 | 0.17 |
| | Ap2 | 25-38 | c-s | 10YR 5/4 | sl | sbk 2 m | SSNP | - | - | - | - | 6.41 | 0.06 |
| | AC1 | 38-71 | g-s | 10YR 5/6 | sl | sbk 2 m | SSNP | - | - | - | - | 6.32 | 0.16 |
| | AC2 | 71-86 | g-s | 10YR 5/6 | sl | sbk 2 m | SSNP | - | - | - | - | 6.43 | 0.15 |
| | C1 | 86-114 | g-s | 10YR 5/6 | sl | sbk 2 m | NSNP | | - | - | - | 6.52 | 0.14 |
| | C2 | 114-135+ | | 10YR 5/4 | sl | sbk 2 m | NSNP | | | | | 6.40 | 0.15 |
| P2 (Mugalwali) | Ap1 | 0-32 | c-s | 10YR 5/4 | l | sbk 2 m | SSSP | - | mf | - | - | 6.42 | 0.24 |
| | Ap2 | 32-57 | c-s | 10YR 6/6 | sl | sbk 2 m | SSNP | - | ff | - | - | 6.63 | 0.17 |
| | AC | 57-79 | g-s | 10YR 6/6 | sl | sbk 2 m | SSNP | - | ff | - | - | 6.65 | 0.17 |
| | C1 | 79-105 | g-s | 10YR 6/6 | sl | sbk 2 m | SSNP | - | ff | - | - | 6.35 | 0.12 |
| | C2 | 105-150+ | | 10YR 6/4 | ls | sbk 1 m | NSNP | | - | - | - | 6.81 | 0.10 |
| P3 (Bansewala) | Ap | 0-18 | c-s | 10YR 6/4 | l | sbk 2 m | MSSP | - | | - | - | 6.81 | 0.24 |
| | B1 | 18-38 | g-s | 10YR 7/4 | sl | sbk 2 m | SSNP | - | - | - | - | 6.84 | 0.29 |
| | B2 | 38-56 | g-s | 10YR 6/5 | sl | sbk 1 fn | SSNP | - | - | - | - | 6.49 | 0.12 |
| | B3 | 56-68 | g-s | 10YR 6/6 | ls | sbk 1 fn | NSNP | - | - | - | - | 6.52 | 0.09 |
| | Cq | 68-110+ | | 10YR 7/4 | s | sg | NSNP | - | - | | - | 6.56 | 0.07 |
| P4 (Painsal) | A | 0-11 | c-s | 10YR 7/3 | ls | sg | NSNP | - | - | - | - | 8.61 | 0.29 |
| | AC | 11-30 | g-s | 10YR 6/4 | ls | sg | NSNP | - | mp | - | - | 6.75 | 0.15 |
| | C1 | 30-45 | g-s | 10YR 7/4 | ls | sg | NSNP | - | - | - | - | 6.83 | 0.10 |
| | C2 | 45-70+ | | 10YR 7/4 | ls | sg | NSNP | - | - | - | - | 6.40 | 0.09 |
| P5 (Painsal NB) | Ap | 0-18 | c-s | 10YR 5/3 | sl | sbk 2 m | SSSP | - | ff | - | - | 6.17 | 0.12 |
| | B1 | 18-38 | g-w | 10YR 6/4 | sl | sbk 2 m | SSSP | - | ff | - | - | 6.75 | 0.09 |
| | B2 | 38-51 | g-w | 10YR 6/5 | sl | sbk 2 m | SSSP | - | ff | - | | 6.93 | 0.08 |
| | BC | 51-81 | g-s | 10YR 6/4 | sl | sbk 1 m | SSSP | - | ff | - | - | 7.27 | 0.12 |
| | C | 81-125+ | | 10YR 7/3 | ls | sbk 1 m | NSNP | - | - | - | - | 7.66 | 0.09 |
| P6 (Mustafabad) | A | 0-32 | c-s | 10YR 6/4 | sil | sbk 3 m | VSVP | - | mp | - | - | 6.60 | 0.19 |
| | Bt | 32-47 | c-w | 10YR 6/4 | scl | sbk 3 m | VSVP | - | mp | - | - | 6.90 | 0.17 |
| | B2 | 47-70 | g-s | 10YR 6/4 | sil | sbk 3 m | VSVP | - | vff | - | - | 7.06 | 0.22 |
| | B3 | 70-87 | g-s | 10YR 7/4 | l | sbk 2 m | MSMP | - | vff | - | v sl e | 7.45 | 0.25 |
| | C | 87-108+ | | 10YR 7/4 | l | sbk 2 m | MSMP | - | - | - | v sl e | 7.66 | 0.35 |

**Cont...**

**Table 2.** Morphological and physico-chemical properties of the studied pedons

| Soil profile | Horizon | Depth (cm) | Horizon boundary | Colour (Dry) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction | pH | EC (dSm-1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P7 (Ishargarh) | A | 0-22 | g-s | 10YR 6/3 | l | sbk 2 m | MSMP | - | fp | - | - | 6.78 | 0.12 |
| | A/B | 22-39 | g-s | 10YR 5/3 | l | sbk 2 m | MSMP | - | ff | - | - | 6.82 | 0.08 |
| | B | 39-75 | g-s | 10YR 5/4 | ls | sbk 1 fn | NSNP | - | ff | - | - | 6.63 | 0.05 |
| | Bq | 75-140 | c-s | 10YR 7/3 | ls | sbk 1 fn | NSNP | - | - | - | - | 6.94 | 0.05 |
| | Cq | 140-154+ | | 10YR 6/4 | ls | sbk 1 fn | NSNP | | | | | 7.07 | 0.05 |
| P8 (Mangna) | A | 0-20 | c-s | 10YR 6/3 | sic | abk 3 m | VSVP | - | - | - | - | 6.78 | 0.21 |
| | Bt1 | 20-39 | g-s | 10YR 6/3 | cl | abk 3 m | VSVP | - | - | - | - | 6.69 | 0.16 |
| | Bt2 | 39-70 | g-s | 10YR 7/4 | cl | abk 3 m | VSVP | - | - | - | - | 6.56 | 0.12 |
| | B | 70-97 | g-s | 10YR 6/4 | cl | sbk 3 m | VSVP | - | - | - | - | 7.00 | 0.21 |
| | C | 97-127+ | | 10YR 7/4 | cl | sbk 2 m | VSVP | - | - | - | - | 6.75 | 0.21 |
| P9 (Kaekor) | A | 0-20 | c-s | 10YR 6/4 | sic | abk 3 m | VSVP | - | - | - | - | 6.09 | 0.10 |
| | B1 | 20-35 | g-s | 10YR 5/4 | sic | abk 3 m | VSVP | - | - | - | - | 6.10 | 0.10 |
| | B2 | 35-74 | g-s | 10YR 5/6 | sl | abk 2 m | VSVP | - | - | - | - | 6.48 | 0.06 |
| | B3 | 74-98 | g-s | 10YR 7/4 | l | sbk 2 m | VSVP | - | - | - | - | 6.58 | 0.08 |
| | C | 98-131+ | | 10YR 7/4 | l | sbk 2 m | VSVP | - | - | - | - | 6.87 | 0.09 |
| P10 (Birdhana) | Ap | 0-15 | a-s | 10YR 6/2 | l | sbk 2 m | VSVP | - | - | - | st e | 7.96 | 0.31 |
| | Bt1 | 15-38 | g-s | 10YR 6/3 | cl | sbk 3 m | VSVP | - | - | - | sl e | 8.35 | 0.52 |
| | Bt2 | 38-79 | g-s | 10YR 6/3 | cl | sbk 3 m | VSVP | - | - | - | sl e | 8.37 | 0.55 |
| | C1 | 79-88 | g-s | 10YR 6/4 | l | sbk 2 m | VSMP | - | - | - | sl e | 8.60 | 0.80 |
| | C2 | 88+ | | 10YR 6/4 | l | sbk 2 m | MSMP | - | - | - | sl e | 8.62 | 0.86 |
| P11 (Farwai) | A | 0-25 | c-s | 10YR 6/3 | l | sbk 2 m | VSVP | - | fa | - | st e | 6.68 | 0.24 |
| | AB | 25-51 | g-s | 10YR 6/3 | cl | gr 2 m | VSVP | - | fp | - | st e | 6.78 | 0.31 |
| | B1 | 51-65 | g-s | 10YR 6/4 | sl | gr 2 m | MSMP | - | ff | - | st e | 6.83 | 0.27 |
| | B2 | 65-109 | g-s | 10YR 6/4 | l | sbk 2 m | SSSP | - | ff | - | st e | 6.84 | 0.26 |
| | B3 | 109-125 | g-s | 10YR 5/3 | l | sbk 2 m | SSSP | - | - | - | st e | 6.95 | 0.31 |
| | C | 125+ | | 10YR 6/2 | s | sg | NSNP | | - | | ve | 6.50 | 0.23 |
| P12 (Farwai NB) | Ap | 0-29 | c-s | 10YR 5/3 | sl | sbk 2 m | SSSP | - | - | - | st e | 6.06 | 0.29 |
| | Bu1 | 29-50 | g-s | 10YR 6/2 | sl | sbk 2 m | SSSP | - | - | - | st e | 7.00 | 0.32 |
| | Bu2 | 50-80 | g-w | 10YR 6/2 | sl | sbk 2 m | SSSP | - | - | - | st e | 7.13 | 0.31 |
| | C1 | 80-122 | g-s | 10YR 6/4 | l | sbk 3 m | SSSP | - | - | - | st e | 7.26 | 0.29 |
| | C2 | 122-140+ | | 10YR 6/4 | scl | sbk 3 m | MSMP | - | - | - | st e | 7.40 | 0.29 |

Horizon Boundary {[ Distinctness (a: abrupt, c: clear, g: gradual and d: diffuse)] and [Topography (s: smooth and w: wavy)]}, {[ Colour (YR-yellow red)]}, {[Texture (s: sand, ls: loamy sand, sl: sandy loam, l: loam, sil: silt loam, sic: silty clay, scl: sandy clay loam and cl: clay loam)]}, {[Structure (S: Size (m: medium, f: fine and c: coarse)]}, [(G: Grade (1: week, 2: moderate and 3: strong))], [(T: Type (abk: angular blocky, sbk: sub angular blocky and sg: single grain)]}, {Consistency [Stickiness (ns: non-sticky, ss: slightly sticky, ms: moderately sticky and vs: very sticky,)] and [Plasticity (np: non plastic, sp: slightly plastic, mp: moderately plastic and vp: very plastic)]}, {Roots [S: size (vf: very fine, f: fine, m: medium and c: coarse)] and [Q: Quantity (f: few, c: common and m: many)]}, {[ Coarse fragment (Nature ( st: stone and gr: gravel), [Size (vf: very fine, f: fine, m: medium and c: coarse)] and [Abundance (f: few, c: common and m:many)]} and {[Effervescence (e: slight, es: strong and ev: violent)]}

upper horizons to lower horizons by percolating (Sawhney et al., 2000). The clay content increased with depth due to downward translocation of finer particles from the surface layers as reported by Nasre et al., (2013).

The structure of the studied pedons varied from single grain, granular, angular blocky to sub-angular blocky in type, structureless to strong in grade and fine to medium in class. Soils of pedons 1, 2, 3, 5, 6, 7, 10 and 12 and surface horizon of pedon 11 exhibited sub-angular blocky structure due to low clay and low organic carbon content. Similar results were also observed by Sitanggang et al. (2006). Pedon 8 and 9 showed angular blocky to sub-angular blocky structure and B horizon of pedon 11 showed granular structure due to more clay content and increased amount of organic matter. Pedon 4 showed single grain structure with structureless grade due to very coarse texture and lack of organic matter. Kumar and Philip (2021) also obtained similar findings. The structure grade in all other pedons was varying from to moderate to strong. The existing minor variability in structure could be related to the topographic position of the profile in the landscape and horizons in the profile, and the contents of OM. (Singh and Aggarwal 2005, Rao et al., 2008).

The soils of pedon 1, 2 and 5 showed slightly sticky non-plastic consistence in upper horizon, non-sticky non-plastic in middle & lowermost horizon and in pedon 12, the consistence was slightly sticky slightly plastic in all horizons due to low amount of clay content except in C2 horizon where moderately sticky moderately plastic consistency was because of more clay content in these horizons as a result of eluviation process. The soils of pedon 4 showed non-sticky non-plastic in all the layers because of very coarse texture of soil. The soils of pedon 3 showed moderately-sticky slightly plastic in the first layer due to higher amount of clay content as compare to the pedon 1,2,5 and 12. In pedon 7, the consistency was moderately-sticky moderately plastic in the first two layer and non-sticky non-plastic in rest of the layers. The consistence soils of pedon 6, 8, 9, 10 & 11 was very sticky very plastic to moderately sticky moderately plastic throughout the solum because of high amount of clay in the soil. This physical behaviour of soils influenced by dry, moist and wet conditions was not only due to the textural make up but also due to type of clay minerals present in these soils (Dasog and Patil 2011). Coarse fragments were absent in all the horizons of all the pedons except surface horizon of pedon 1.

The calcium carbonate concretions were present in pedon 10, 11 and 12 due to calcium containing parent rock which released calcium upon weathering and soil formation. Relatively higher calcium carbonate content was found in the subsurface layers as compared to the surface soil; this might be due to the parent material. Similar findings were recorded by Sebnie et al. (2021).

**Relative horizon distinctness:** The RHD value of soils of P1 to P3 ranged from 1-9 whereas for P4 the values ranged from 1-4. The slope of the land ranged from 3-5% (Gently sloping lands) in P1-P4 profile sites (Table 3, Fig. 2). The

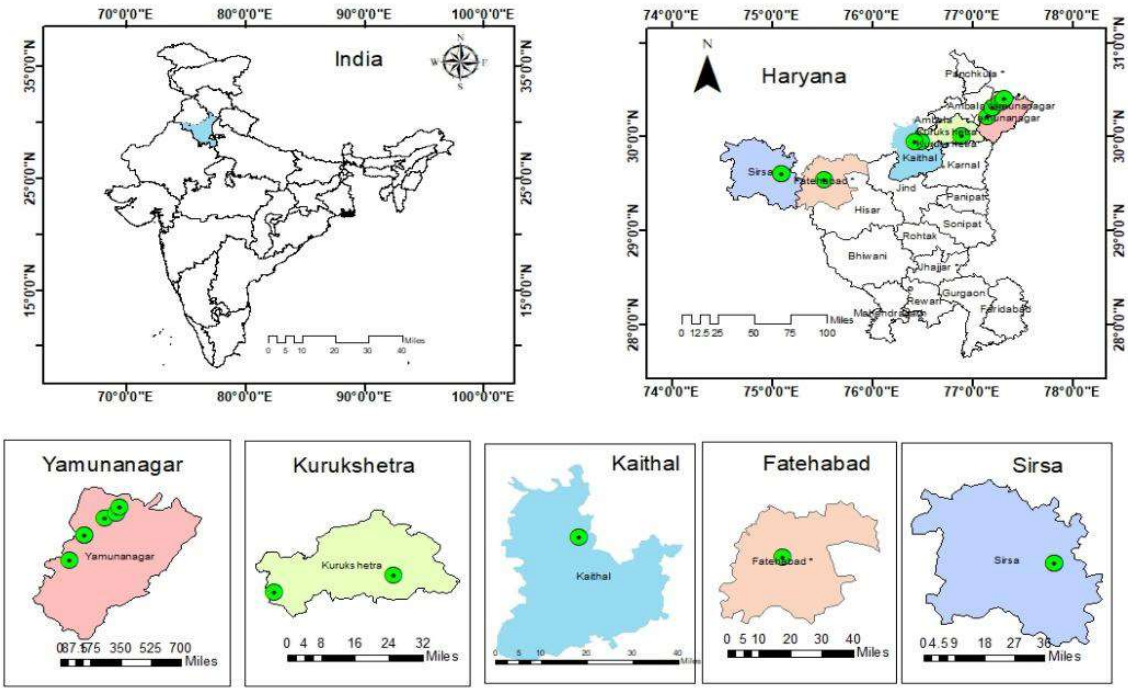


**Fig. 1.** Location of the studied area

**Table 3.** Relative horizon distinctness ratings

| Profile No. | Horizon | Horizon boundary | Colour | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | CaCO3 | EC | pH | RHD | RHD (Total) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 (Ranipur) | Ap1/Ap2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 12 |
| | Ap2/AC1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| | AC1/AC2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| | AC2/C1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| | C1/C2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| P2 (Mugalwali) | Ap/B1 | 2 | 3 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 9 | 20 |
| | B1/B2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| | B2/B3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | |
| | B3/C | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | |
| P3 (Bansewala) | Ap/B1 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 20 |
| | B1/B2 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | |
| | B2/B3 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| | B3/Cq | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | |
| P4 (Painsal) | A/AC | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 8 |
| | AC/C1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | |
| | C1/C2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| P5 (Painsal NB) | Ap/B1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 17 |
| | B1/B2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| | B2/BC | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| | BC/C | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | |
| P6 (Mustafabad) | Ap/Bt | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 16 |
| | Bt/B2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | |
| | B2/B3 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | |
| | B3/C | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| P7 (Ishargarh) | A/A/B | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 19 |
| | A/B/B | 1 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | |
| | B/Bq | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| | Bq/Cq | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| P8 (Mangna) | A/Bt1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 14 |
| | Bt1/Bt2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | |
| | Bt2/B | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | |
| | B/C | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| P9 (Kaekor) | A/B1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 20 |
| | B1/B2 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | |
| | B2/B3 | 1 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | |
| | B3/C | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | |
| P10 (Birdhana) | Ap/Bt1 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 7 | 16 |
| | Bt2/Bt2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| | Bt2/C1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | |
| | C1/C2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| P11 (Farwai) | A/AB | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | 29 |
| | AB/B1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | |
| | B1/B2 | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | |
| | B2/B3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| | B3/C | 1 | 2 | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 9 | |
| P12 (Farwai NB) | Ap/Bu1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 14 |
| | Bu1/Bu2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| | Bu2/C1 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | |
| | C1/C2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | |

Zero value in a column means there is no difference in the attribute in question when compared to the below horizon

**Table 4.** Relative profile development ratings

| Profile No. | Horizon | Horizon boundary | Colour | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | CaCO3 | pH | EC | RPD | RPD (Total) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 (Ranipur) | Ap1/C2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 19 |
| | Ap2/C2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| | AC1/C2 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| | AC2/C2 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | |
| | C1/C2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| P2 (Mugalwali) | Ap/C | 2 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 9 | 32 |
| | B1/C | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | |
| | B2/C | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 7 | |
| | B3/C | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 8 | |
| P3 (Bansewala) | Ap/Cq | 2 | 1 | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 31 |
| | B1/Cq | 2 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | |
| | B2/Cq | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | |
| | B3/Cq | 1 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | |
| P4 (Painsal) | A/C2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 7 | 13 |
| | AC/C2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 4 | |
| | C1/C2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | |
| P5 (Painsal NB) | Ap/C | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 10 | 33 |
| | B1/C | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 8 | |
| | B2/C | 1 | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 9 | |
| | BC/C | 1 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | |
| P6 (Mustafabad) | Ap/C | 2 | 1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 10 | 30 |
| | Bt/C | 2 | 1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 10 | |
| | B2/C | 1 | 1 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 9 | |
| | B3/C | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| P7 (Ishargarh) | A/Cq | 1 | 1 | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 26 |
| | A/B/ Cq | 1 | 2 | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 10 | |
| | B/Cq | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | |
| | Bq/Cq | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| P8 (Mangna) | A/C | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 16 |
| | Bt1/C | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | |
| | Bt2/C | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | |
| | B/C | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| P9 (Kaekor) | A/C | 2 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 26 |
| | B1/C | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | |
| | B2/C | 1 | 4 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 | |
| | B3/C | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | |
| P10 (Birdhana) | Ap/C2 | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 8 | 22 |
| | Bt2/C2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | |
| | Bt2/C2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | |
| | C1/C2 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | |
| P11 (Farwai) | A/C | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 7 | 33 |
| | AB/C | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 7 | |
| | B1/C | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 6 | |
| | B2/C | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | |
| | B3/C | 1 | 2 | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 9 | |
| P12 (Farwai NB) | Ap/ C2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 10 | 28 |
| | Bu1/ C2 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | |
| | Bu2/C2 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | |
| | C1/C2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | |

Zero value in a column means there is no difference in the attribute in question when compared to the below horizon

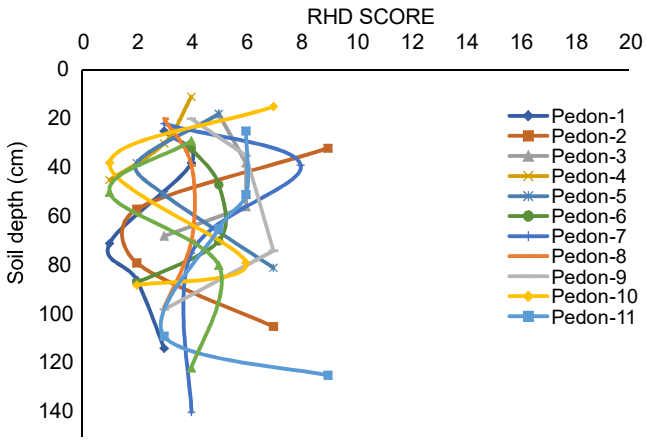


**Fig. 2.** Relative horizon distinctness

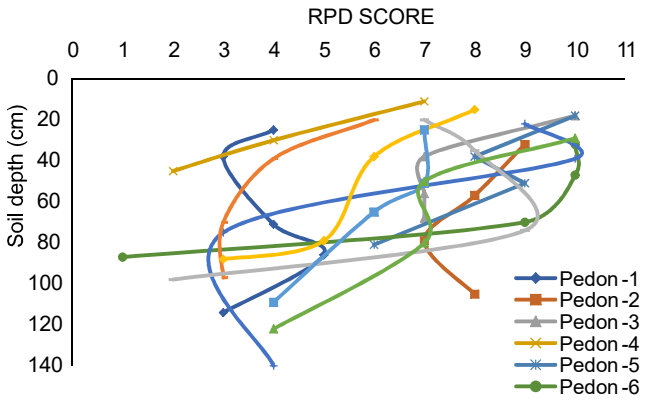


**Fig. 3.** Relative profile development

majority of the field morphological assessments were influenced by the horizon boundary's development as well as differences in colour, texture, structure, and consistency. The degree of pedological development is positively correlated with the size of the rating scale values for a certain horizon. The soils of pedon 2, 3, and 9 have a RHD (total) of 20 each, pedon 7, 5, 6 and 10 have 19, 17, 16 and 16 respectively and pedon 12 & 8 was 14 each. Maximum RHD (total) value is shown by pedon 11 i.e. 29 and hence this profile shows maximum profile development not generally; since the order is Inceptisol but comparatively. The distinctness of the horizon boundaries may be due to weathering as influenced by more precipitation in the recent alluvial plains (Gill et al., 2022). The lowest value of RHD (total) is shown by pedon 4 i.e., 8 which shows least profile development among the other profiles. According to the RHD values, the variations in the different profiles may be the result of pedological processes rather than changes in the structure or texture of the earth (Reza et al., 2010).

**Relative profile development:** When a landform is stable, the growth of the soil profile alters several soil morphological features, producing more RPD values (Zayed et al., 2021). Due to the greatest pedological development driven by weathering, the RPD values of all the profiles were highest in the B horizon (Dinesh et al., 2017). The RPD (Total) value of the pedons under investigation varied from 16 to 33 being minimum in pedon 8 and maximum in pedon 11 and 5 (Table 4). The horizon boundary, differences in moist colour, texture, structure, consistency, pH, and EC all had a role in the rating variation (Deka et al., 2009).

## CONCLUSION

The RHD and RPD score of different pedon showed that the pedon 11 is comparatively more developed from other and pedon 4 is least developed. The soils of pedon 4 are very less developed since this part of palaeochannel has continuous accumulation of alluvio-fluvial material even now as represented by the presence of water within 50 cm depth. The horizon boundary, differences in moist colour, texture, structure, consistency, pH, and EC all had a role in the rating variation. The study also revealed significant difference in soil development when the soils are compared to in-situ soils which are well developed.

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