CHARACTERIZATION OF PEDOLOGICALLY DEVELOPED TYPIC HAPLUSTEPTS AND HAPLUSTALFS SOILS IN KAITHAL DISTRICT OF HARYANA USING FIELD MORPHOLOGY RATING SYSTEM

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SUMMARY

Land use can significantly impact soil formation from similar parent material even under similar climate. The present study of rice and adjacent non-rice growing soils was carried out to evaluate the pedological development of soils in Kaithal district of Haryana with the help of field morphology rating system, focusing on the dynamics of soil morphological properties. A total of four pedons were excavated comprising of two rice and two adjacent non-rice pedons in the month of November 2024. To evaluate pedological development, a rating scale was used by comparing adjacent horizons for the relative horizon distinctness (RHD) and comparing horizons with the C-horizon for relative profile development (RPD) in different soil pedons. All the soil samples were alkaline in nature and none of the samples were saline in these pedons. The old alluvial soils of rice growing and adjacent non-rice growing pedons have RHD ratings varied from 3 to 12 and 1 to 5, respectively, and RPD ratings varied from 7 to 14 and 5 to 8, respectively, indicating that pedological development was in the order of rice growing pedons > adjacent non-rice growing pedons.

Keywords: Morphology, rice, pedons, relative horizon distinctness, relative profile distinctness and Kaithal (Haryana)

A soil profile may be defined as a vertical section of soil, showcasing the sequence of horizons or layers. These layers are distinct from one another, but are genetically connected and derived from the same parent material. Soil properties can differ both vertically and spatially. These variations are influenced by factors such as landscape position (slope), soil-forming factors and land management practices (land use). Rice soils can originate from various types of parent materials, but they are heavily modified by anthropogenic management practices during cultivation (Gong, 1983). Management practices like ploughing and puddling (tilling flooded soils), artificial submergence and drainage, along with the use of manures, lime and fertilizers, have significant influence on soil properties (Kirk, 2004; Yu, 1985; Ponnamperuma, 1972). The impact of land use and land cover change has emerged as a critical concern for the scientific community studying global environmental change (Lambin *et al.*, 2006). Therefore, exploring alternative land use options, particularly the cultivation of horticultural crops such as fruits, is essential for ensuring the efficient utilization of available lands. Soil morphology and relative development of profile have been used extensively for the determinations of degree of soil development and surficial depositions. Soil formation under different landforms and parent material discontinuities can be complex. Soil morphology reflects cumulative alterations by soil-forming processes. Bilzi and Ciolkosz (1977) developed a rating scale to evaluate soil morphology, assessing (1) Relative Horizon Distinctness (RHD) and (2) Relative Profile Development (RPD). RHD compares adjacent horizons to identify discontinuities, while RPD compares discrete horizons to the C horizon, correlating with soil age (Meixner and Singer, 1981). RHD ratings above 10 indicate parent material changes, while RPD increases with age, peaking in A horizons of younger soils and B horizons of older soils (Zayed *et al.*, 2021). Such systematic information in soils of Kaithal district is lacking. Therefore, this study was conducted to investigate the morphological properties of the soils and pedological variation in terms of developments of soils of across Kaithal district in Northern Haryana.

MATERIALS AND METHODS

This research was performed in Kaithal (old alluvial plains) region (refer to Fig. 1), specifically targeting rice and adjacent non-rice soils in the Kaul and Bata villages. The district is geographically situated between 29°31′ and 30°12′N latitude and 76°10′ and 76°42′E longitude. Four representative pedons were studied for present investigation *viz*. pedons 1 and 3 were excavated from rice growing fields; pedons 2 and 4 were excavated adjacent non-rice fields (specifically guava orchard soils), respectively. The district experiences a tropical steppe climate, characterized by its semi-arid conditions and high variability between summers with high temperatures and winters with low temperatures, as well as with a humid rainy period introducing soaked air from the ocean. The annual average of precipitation is approximately 512 mm, distributed relatively evenly throughout the whole year, with the south-western monsoon typically commencing in late June. The

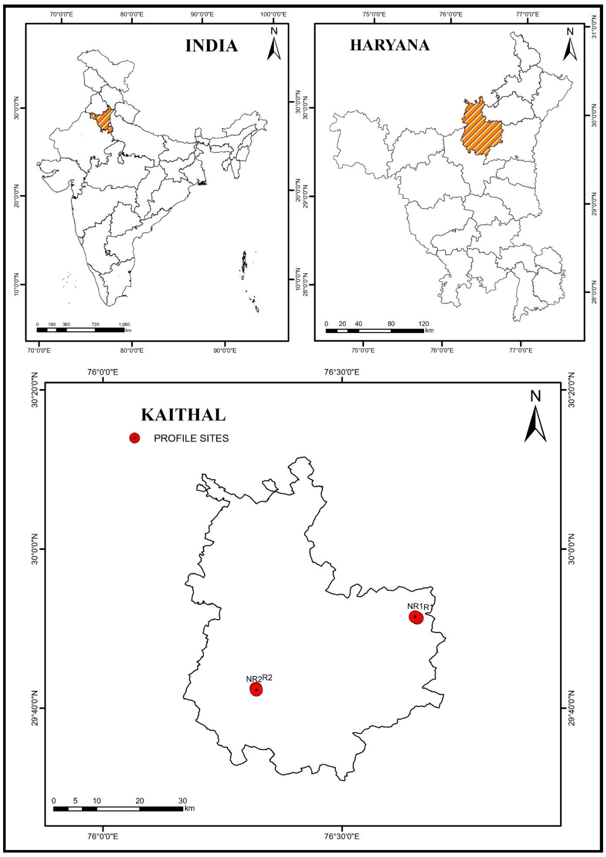

Fig. 1. Location map of the study area (various pedons in Kaithal district).

region is predominantly covered by sierozem soil types, with desert soils more common in the northern areas. In areas that receive irrigation, traditional crops such as moong beans, gram and maize have been largely exchanged by the cultivation of cotton, wheat and rice crops. Major crops in this area include sugarcane, sorghum, rice and wheat (Sharma *et al.,* 2024).

The relative indices of soil development *viz.* RHD and RPD were calculated from the soil morphological data as defined by Bilzi and Ciolkosz (1977). RHD was evaluated through comparing the morphological features of two adjacent horizons and RPD by comparing the morphological feature of each horizon with the C horizon within pedon. Soil pedons were studied in the field and classified in accordance with key to Soil Taxonomy. The soils morphological properties were evaluated and points assigned to them are described below:

1. Boundaries: The points assigned to the boundaries as per the distinctness of the horizon to the lower or shared horizon as: diffuse-0, gradual-1, clear-2, abrupt-3 and very abrupt-4.
2. Colour (dry and moist): The one point was assigned for any unit change in hue class and also for 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 two-fold class change, the one unit change in value, and two unit change in chroma.
3. Texture: One point is assigned for unit change in textural class as per the textural triangle. In addition, a change from non-gravelly to gravelly or very gravelly is assigned one or two points, respectively.
4. 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 (1 vf sbk) to moderate, medium angular blocky (2m abk) is assigned a value 4.
5. Consistence: Any unit change in wet consistence (so, ss, s, vs, po, ps, p, vp) is assigned one point.
6. Cutans: One point is assigned for any unit change in frequency or thickness at any single location.

7. Coarse Fragments/Stoniness: Points are assigned according to the volume of coarse fragments present in the matrix of the soil.
8. The chemical rating system was evaluated and points assigned according to Salem *et al.*, (1997) described as follows:

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

8.2. The pH value of soil paste: One point is assigned for unit 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 general characteristics, morphological features and chemical properties of soil pedons are presented in Table 1 and 2 and the results representing rice pedons (R1 and R2) and adjacent non-rice pedons (NR1 and NR2) of old alluvial plains. The data were analysed and prospective points were given as described by Bilzi and Ciolkosz (1997), Meixner and singer (1981) and Salem *et al.* (1997), and the soil rating scale are applied.

Morphological Features

The morphology of the pedons of rice (R1 and R2) and adjacent non-rice (NR1 and NR2) cultivated area of pedons in Kaithal is presented in Table 1 and 2. The soils of old alluvial plains (R1 and NR1) were dark greyish brown to light yellowish brown in colour (Fig. 2a-2d). The pedons R1 (0-160 cm+) and NR1 (0-170 cm+) were very deep, had sandy clay loam to clay loam texture with well-developed A, B and C horizons and classified as fine loamy, mixed, calcareous, hyperthermic, *Typic*

TABLE 1

General characteristics, morphological feature and some chemical and physical properties of the studied rice and non-rice pedons

						R1						
Classification	Fine, Mixed, Calcareous, Hyperthermic, Typic Haplustepts			Erosion	Nil			Slope Direction		North-South		
Location	Kaul, Kaithal			Drainage	Imperfect			Parent Material		Alluvium		
Physiography	Old Alluvial plains			Slope	Nearly-level (0-1%)			Present land use		Rice		
Horizon	Depth (cm)	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Roots	Coarse fragment	Reaction	pH (1:2)	EC (dS/m)
Ap	0-20	a-s	10YR 4/2	cl	3 f sbk	VSVP	-	f fn	-	2	8.72	0.87
AB	20-50	a-s	10YR 4/4	cl	3 f sbk	VSVP	-	-	-	2	8.9	0.79
B1	50-87	c-w	10YR 4/4	cl	3 f sbk	VSVP	-	-	-	2	8.82	0.74
B2	87-118	c-w	10YR 4/4	cl	2 f sbk	SP	-	-	-	-	8.57	0.68
C1	118-150	c-w	10YR 5/3	scl	2 m sbk	VSVP	th (fe coating)	-	$CaCO_3$ 1%	3	8.77	0.71
C2	150-160+	c-w	10YR 5/4	scl	2 m sbk	SSSP	-	-	$CaCO_3$ 1-2%	3	9.1	0.82
						NR1						
Classification	Fine loamy, Mixed, Calcareous, Hyperthermic, Typic Haplustepts			Erosion	Nil			Slope Direction		North-South		
Location	Kaul, Kaithal			Drainage	Imperfect			Parent Material		Alluvium		
Physiography	Old Alluvial plains			Slope	Nearly-level (0-1%)			Present land use		Guava Orchard		
Horizon	Depth (cm)	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Roots	Coarse fragment	Reaction	pH (1:2)	EC (dS/m)
Ap	0-25	a-c	10YR 4/1	cl	2 m sbk	VSVP	-	f fn	-	2	8.13	0.49
AB	25-57	d-w	10YR 4/3	cl	2 m sbk	VSVP	-	-	-	-	8.27	0.56
B1	57-94	d-w	10YR 4/4	cl	2 m sbk	VSVP	-	-	-	2	8.51	0.77
B2	94-127	d-w	10YR 4/4	cl	2 m sbk	VSVP	-	-	-	-	8.43	0.58
B3	127-160	d-w	10YR 5/3	cl	2 m sbk	VSVP	-	-	$CaCO_3$ 1-2 %	3	8.32	0.57
C1	160-170+	d-w	10YR 5/4	cl	2 m sbk	VSVP	-	-	$CaCO_3$ 1-2%	3	8.62	0.68

TABLE 2

General characteristics, morphological feature and some chemical and physical properties of the studied rice and non-rice pedons

R2												
Classification	Fine loamy, Mixed, Calcareous, Hyperthermic, Typic Haplustepts			Erosion	Nil			Slope Direction		North-South		
Location	Bata, Kaithal			Drainage	Imperfect			Parent Material		Alluvium		
Physiography	Old Alluvial plains			Slope	Nearly-level (0-1%)			Present land use		Rice		
Horizon	Depth (cm)	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Roots	Coarse fragment	Reaction	pH (1:2)	EC (dS/m)
Ap	0-20	a-c	10YR 4/1	l	2 m sbk	SP	-	f fn	-	-	7.85	0.44
AB	20-60	a-c	10YR 4/3	l	2 m sbk	SP	-	-	-	-	8.13	0.36
B1	60-100	a-c	10YR 6/4	l	2 m sbk	SP	-	-	-	1	8.09	0.32
B2	100-127	d-w	10YR 6/4	cl	3 m sbk	VSVP	-	-	$CaCO_3$ 1-2 %	2	8.21	0.38
C1	127-137+	d-w	10YR 5/3	cl	3 m sbk	VSVP	-	-	$CaCO_3$ 1-2%	3	8.44	0.42
NR2												
Classification	Fine loamy, Mixed, Calcareous, Hyperthermic, Typic Haplustepts			Erosion	Nil			Slope Direction		North-South		
Location	Bata, Kaithal			Drainage	Imperfect			Parent Material		Alluvium		
Physiography	Old Alluvial plains			Slope	Nearly-level (0-1%)			Present land use		Mango Orchard		
Horizon	Depth (cm)	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Roots	Coarse fragment	Reaction	pH (1:2)	EC (dS/m)
Ap	0-30	c-w	10YR 4/2	l	2 m sbk	SP	-	f fn	-	-	8.05	0.4
B1	30-70	c-w	10YR 5/4	l	2 m sbk	SP	-	f fn	-	1	8.11	0.42
B2	70-125	d-w	10YR 5/4	l	2 m sbk	SP	-	-	-	-	8.06	0.32
B3	125-160	c-w	10YR 5/4	l	2 m sbk	SP	-	-	$CaCO_3$ 1-2 %	2	8.3	0.51
C1	160-170+	c-w	10YR 6/3	l	2 m sbk	SP	-	-	$CaCO_3$ 1-2%	3	8.33	0.54

Haplustepts, also supported by Gill *et al.* (2022). Whereas, pedon R2 and NR2 were deep (100-150+ cm), had loam to clay loam texture with A, B and C horizons and classified as fine loamy, mixed, hyperthermic, *Typic Haplustalfs* and the findings were also lined with Chakraborty *et al.* (1979), Reza *et al.* (2010), Dinesh *et al.* (2017) and Sawhney *et al.* (2000).

Chemical properties

Soil pH

The pH values of the soils of pedons R1 and R2 were found to be 8.72 and 7.85 at the surface, respectively, and varied from 8.57 to 9.10 in R1 and 8.09 to 8.44 in R2 in the sub-surface horizons (Table 1 and 2). In the case of non-rice soils, the pH values of the soils of pedons NR1 and NR2 were 8.13 and 8.05 at the surface, respectively, while they ranged from 8.27 to 8.62 in NR1 and from 8.06 to 8.33 in NR2 in the sub-surface horizons (Table 1 and 2). All soil samples were alkaline in nature and none of the samples were acidic in nature in these profiles. The presence of basic parent materials and interactions between soil colloidal particles and applied chemical fertilisers leading to the build-up of basic ions on the exchangeable sites, were probably the causes of the alkaline character of these soils (Sharma *et al.* 2024).

Soil electrical conductivity (EC)

The EC values of the R1 and R2 pedons in rice soils were found to be 0.87 and 0.44 dS/m at the surface, respectively, and varied from 0.68 to 0.82 in R1 and 0.32 to 0.42 in R2 in the sub-surface horizons (Table 1 and 2). In the case of non-rice soils, the EC values of the NR1 and NR2 pedons were 0.49 and 0.40 at the surface, respectively, while they ranged from 0.56 to 0.68 in NR1 and from 0.32 to 0.54 in NR2 in the sub-surface horizons (Table 1 and 2). None of the samples were saline in these pedons. This suggested that all the soil specimens of these pedons were in normal EC range (<1 dS/m). As a result of intense cultivation producing well-drained soils, surplus salts were effectively removed through percolation, which accounted for the observed normal EC levels (Prem *et al.* 2017; Sharma *et al.* 2024).

Relative Horizon Distinctness (RHD)

The values of RHD rating are presented in Table 3 and plotted at the boundary between horizons to give graphical representation of the relative horizon distinctness of the soils (Fig. 3). The soils of all the pedons of old alluvial plains have RHD value ranging from 1 to 12, revealed moderate distinctness within the soil profiles. The distinctness of the horizon boundary, variations in moist colour, texture, structure and consistency contributed for most of the ratings. Soils of pedon R1 and R2 have RHD ratings 3 to 10 and 4 to 12, respectively, whereas of pedon NR1 and NR2 have RHD ratings (1 to 5) and (1 to 5), respectively. RHD value have contributed by horizon boundary, variations in moist colour, texture, structure pH and E.C. But, the distinctness of the horizon boundaries and colour has contributed mostly to the ratings in these pedons (Pal *et al.*, 2022). Sarkar *et al.* (1997) also found similar results. Based on the RHD values the soil of rice and non-rice pedons of old alluvial plains can be arranged in a sequence i.e. R1 > R2 > NR2 > NR1 might be due to change of structural differences, also influenced by pedological processes (Reza *et al.*, 2010; Zyed *et al.*, 2021). While the current study may be affected by an ustic moisture regime (Mean annual precipitation of 511 mm) and thermic temperature regime (Mean annual temperature of 29.12°C).

Relative Profile Distinctness (RPD)

The values of RPD rating of the soils of studied pedons are presented in Table 4 and plotted in (Fig. 4). The RPD values of all the profiles were found higher in A horizon due to the higher pedological development in the surface horizon as influenced by weathering cultivation and land use (Deka *et al*. 2009; Dinesh *et al.*, 2017), except pedon NR2 where B2 horizon have equal values than the surface horizon, which may be due to slight stratification resulting from flooding in past that created effect on the soil colour (thus became the deciding factor of higher value) or this may be due to effect of organic matter contents in deeper layers too (Zayed *et al*., 2021) and also the findings were ascertained by Pal *et al.* (2022) in Chhachhrauli region. Old alluvial soils of pedon R1 and R2 have RPD ratings (9 to 10) and (7 to 14), respectively, whereas of pedon NR1 and NR2 have RPD ratings (4 to 8) and (5 to 6), respectively. Based on the RPD values the soil of rice and non-rice pedons of old alluvial plains can be arranged in a sequence i.e. R2 > R1 > NR1 > NR2. This may also be ascribed to the temporary or permanent accumulation of water due to paddy cultivation creates conditions that are significantly different from those of adjacent non-paddy soils (Willet, 1979; Gong, 1983). Also, stratification might be the reason for this difference in RPD values Reza *et al.* (2010). The RPD values of different pedons in old alluvial plains varied from 4 to 14, contributed by horizon boundary, variations in moist colour, texture, structure, consistency, pH and EC and similar findings were also reported by Zayed *et al.* (2021). The larger the rating scale values for particular horizon, the greater was its pedological development. Under the stable landform condition, soil profile development results in the changes of different soil morphological parameters thereby resulting to more RPD values.

(a) Pedon R1 Rice (Kaul) **(b) Pedon NR1 Non-rice (Kaul)** **(c) Pedon R2 Rice (Bata)** **(d) Pedon NR2 Non-rice (Bata)**

Fig. 2a-2d Representative pedons from Kaithal, Haryana.

TABLE 3
Relative Horizon Distinctness (RHD) ratings of the studied rice and non-rice pedons

Horizon	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Coarse fragment	pH	EC	RHD
R1 (Kaul-Rice soil): Typic Haplustepts										
Ap/AB	3	2	0	0	0	0	0	0	1	6
AB/B1	3	0	0	0	0	0	0	0	0	3
B1/B2	2	0	0	1	2	0	0	0	0	5
B2/C1	2	2	1	1	2	1	0	0	0	9
C1/C2	2	1	0	0	4	1	0	1	1	10
NR1 (Kaul- Non-Rice soil): Typic Haplustepts										
Ap/AB	3	2	0	0	0	0	0	0	0	5
AB/B1	0	1	0	0	0	0	0	1	0	2
B1/B2	0	0	0	0	0	0	0	1	0	1
B2/B3	0	2	0	0	0	0	0	0	0	2
B3/C1	0	1	0	0	0	0	0	1	0	2
R2 (Bata-Rice soil): Typic Haplustalfs										
Ap/AB	3	2	0	0	0	0	0	0	1	6
AB/B1	3	1	0	0	0	0	0	0	0	4
B1/B2	3	2	4	1	2	0	0	0	0	12
B2/C1	0	2	0	0	0	0	0	1	1	4
NR2 (Bata- Non-Rice soil): Typic Haplustalfs										
Ap/B1	2	3	0	0	0	0	0	0	0	5
B1/B2	2	0	0	0	0	0	0	0	1	3
B2/B3	0	0	0	0	0	0	0	0	1	1

TABLE 4
Relative Profile Distinctness (RPD) ratings of the studied rice and non-rice pedons

Horizon	Horizon Boundary	Colour (moist)	Texture	Structure	Consistence	Cutans	Coarse fragment	pH	EC	RHD
R1 (Kaul-Rice soil): Typic Haplustepts										
Ap/C1	3	2	1	2	0	1	0	0	1	10
AB/C1	3	2	1	2	0	1	0	0	0	9
B1/C1	3	2	1	2	0	1	0	0	0	9
B2/C1	3	2	1	1	2	1	0	0	0	10
NR1 (Kaul- Non-Rice soil): Typic Haplustepts										
Ap/C1	3	4	0	0	0	0	0	1	0	8
AB/C1	3	2	0	0	0	0	0	1	0	6
B1/C1	3	1	0	0	0	0	0	0	0	4
B2/C1	3	1	0	0	0	0	0	1	0	5
B3/C1	3	1	0	0	0	0	0	1	0	5
R2 (Bata-Rice soil): Typic Haplustalfs										
Ap/C1	3	3	4	1	2	0	0	1	0	14
AB/C1	3	1	4	1	2	0	0	1	1	13
B1/C1	3	2	4	1	2	0	0	1	1	14
B2/C1	3	2	0	0	0	0	0	1	1	7
NR2 (Bata- Non-Rice soil): Typic Haplustalfs										
Ap/C1	3	3	0	0	0	0	0	0	0	6
B1/C1	3	2	0	0	0	0	0	0	0	5
B2/C1	3	2	0	0	0	0	0	0	1	6
B3/C1	3	2	0	0	0	0	0	0	0	5

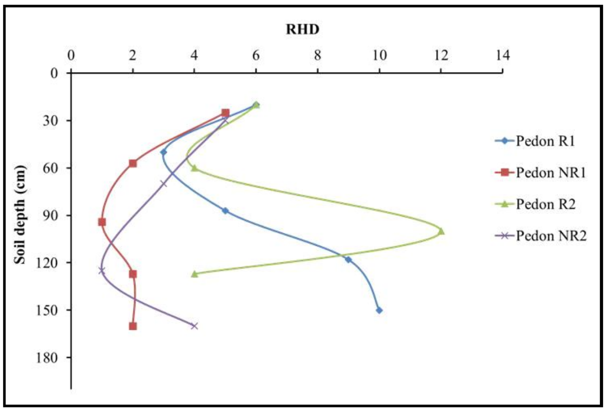

Fig. 3. Relative Horizon Distinctness (RHD).

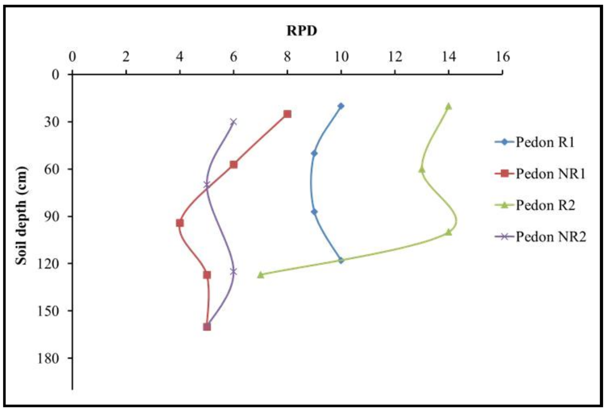

Fig. 4. Relative Profile Distinctness (RPD).

CONCLUSION

The present study revealed a close relationship between land-management practices and profile development of the study area *i.e.* rice growing and adjacent non-rice growing soils of old alluvial plains. Thus, soils of pedons R1 and R2 appeared more pedogenically developed than soils of NR1 and NR2. The pedogenic development of the soils assessed through field morphological rating system revealed that the RHD and RPD values of the pedons help in judging the profile development of the soils of a particular area. This may help to determine the effective factors and their rate to be able to calculate the degree of development. So, studying of pedological development needs more attempts to include changes around the world.

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