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Characterization and fertility assessment of soils of Chandauli district of Eastern Uttar Pradesh for sustainable land use planning

SEEMA[1], A K GHOSH[2] and SUNITA YADAV[3]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005, India

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ABSTRACT

Seven typical pedons representing major landforms in semi-arid and sub-tropical ecosystem of Chandauli district of Uttar Pradesh, *viz.* plains, mid lands and uplands developed from alluvium parent material under varying land uses were studied for their morphological characteristics, physical and chemical properties and soil classification. The colour of the soils ranged from light brown grey to brownish yellow red with a dominant hue of 10YR. These soils were acidic to moderately alkaline (pH 4.8 to 8.4) in reaction, non-saline, moderately deep to very deep and had isohyperthermic temperature and udic soil moisture regime. Texture and total organic carbon (TOC) ranged from silty loam to silty clay loam and 0.1 to 29.7 kg/ha respectively. Soils were medium in phosphorus (6.8 to 24.2 kg/ha) and available potassium (159 to 376 kg/ha). All the pedons had ochric epipedon and underlain by cambic horizon (P1 to P4) within the control section and as such they come under order Inceptisols, whereas profile 5 to profile 7 have argillic horizon so they come under order Alfisols. All soils of the study area fall in agricultural land under land capability classes III and IV having limitations of slope and erosion. On the basis of major soil constraints and potentials, suitable land use plan has been suggested.

Key words: Alfisol, Characterization, Classification, Inceptisols, Land use plan

Soil characterization provides the basic information of soil properties which are the outcome of several soil forming processes operating in a particular area. The type of the processes and their intensity is influenced by the basic soil forming factors as outlined by Jenny (1942). According to Wang *et al*. (2001), climate and geological history are the two important factors affecting soil properties on regional and continental scales while, land use may be the dominant factor of soil properties under small catchment scale. Land use system determines the type of vegetation and the soil management practices which in turn affect the processes of erosion, oxidation, mineralization and leaching. Maddonni *et al*. (1999) observed that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration and other similar physical and biochemical processes. Soil properties are continuously influenced by land uses with profound influence on its productivity and sustainability. Hence, knowledge on the impact of land uses on soil property is indispensable for sustainable agricultural production and soil health maintenance.

Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of experience and technology from one place to another and helps to compare soil properties. A good data bank on soil properties and related site characteristics is inevitable for one to be able to advise both current and potential land users on how to use the land in the best possible way. Soil fertility specialists need well characterized sites with similar soil and other ecological conditions in order to carry out meaningful fertilizer trails. Rice is an important staple food crop of tropical and subtropical climatic regions. In eastern India, rice is dominantly grown as rainfed kharif crop with the onset of south-west monsoon. Due to variation in physiography, the study area has all three types of rice cultivation, i.e. upland rice, mid-upland rice and lowland rice. Rice has got a potential to grow in various types of soils and under a wide range of climatic conditions. The wide variety of ecological conditions under which rice is growing is matched by the diversity of soils which support this crop, so that in reality there is probably no such thing as a 'rice soil'. The natural drainage varies from good to poor. The parent materials range from recent alluvium to well weathered residual materials in upland sites. Soil texture varies from heavy clay to sand;

[1]Research Scholar (e mail: seemachahar94@gmail.com), [2]Professor (e mail: amlankumar@yahoo.com), Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221 005, Uttar Pradesh, India,[3]Scientist (e mail: yadavsunita671@gmail.com) Center of Environment Science and Climate Resilient Agriculture, IARI New Delhi 110 012, India.

organic matter from less than 1 % to more than 50%; salt content from near 0 to 1 %; and pH from less than 3 to more than 10 (De Datta 1981). Thus it is likely that the crop can also be grown under various soil water regimes, which vary from near saturation to about 10-50 cm of standing water (MandaI 1984). The continuous submergence of soil causes changes in physical and chemical characteristics of the soils and these changes are distinctly different from those of mid-upland and upland rice growing soils (MandaI 1984). In view of the above facts, the present investigation was undertaken for characterization and fertility assessment of soils of Chandauli district, Uttar Pradesh for sustainable land use planning.

MATERIALS AND METHODS

The study was conducted in Chandauli District which lies between the parallels of $25^{0}10'$ and $25^{0}30'$ N and between the meridians of $83^{0}0'$E and $83^{0}30'$E in eastern Uttar Pradesh. The climate of the area is semi-arid and subtropical characterized by hot and humid summer and dry and cool winters. Mean annual temperature of the area is 25.75 °C with maximum temperature of 32.0 °C and a minimum of 19.25 °C. The average annual rainfall of the district is about 1060 mm. Thus, the area qualifies for hyperthermic soil temperature regime and udic soil moisture regime. Seven soil profiles were dug from the area under rice-wheat land uses (Fig 1). Soil profiles were exposed in rice-wheat land use site and genetic horizons were demarcated and morphological characteristics of the soils were studied in the field and described according to the Soil Survey Staff (2014). Horizon-wise collected soil samples were air-dried, ground with wooden pestle and mortar and sieved through 2-mm sieve (0.2 mm sieve for organic carbon), labelled and stored. The samples were analyzed for chemical parameters, *viz*. pH and electrical conductivity (EC) (Jackson 1973), organic carbon (OC) (Walkley and Black 1934), available nitrogen (N) (Subbiah and Asija 1956), available phosphorus (P) (Bray and Kurtz 1945; Olsen *et al.* 1954), available potassium (K) (Hanway and Heidal 1952) and characterized for important physical and available nutrient status using standard procedures (Jackson 1973). Soil porosity was calculated from its relationship with bulk and particle density. The soils were classified as per Keys to Soil Taxonomy (Soil Survey Staff 2014).

RESULTS AND DISCUSSION

Morphological characteristics

The morphological characteristics of the soils are presented in Table 1. The horizon differentiation and profile development trend of the soils under each land use is shown in Fig 2. The colour of the soils ranged from light brown grey to brownish yellow and dark brown with a dominant hue of 10YR. The hue of 10YR might be due to the presence of hydrated oxides of iron formed under humid condition (Karmakar and Rao 1999). The value of soil colour ranged from 5 to 6, while chroma varying from 3 to 4. The surface horizons of all the pedons exhibited low chroma (3 to 4) which tended to increase with the depth. Presence of few to many, faint, distinct mottles were observed in the subsurface horizons under rice-wheat land use reflecting alternate oxidation reduction conditions caused by fluctuating ground water table in the study area. The studied soils showed textural variations from loam to silty clay loam and it became heavier with depth particularly in soils under rice cultivation. Textural variation might be due to variation in parent material (granite-gneiss to alluvium), topography, *in-situ* weathering and translocation of clay by eluviations (Sireesha *et al.*2013). The observed soil structure was fine weak subangular to medium moderate subangular blocky except in the surface horizon (Ap) of P1& P2 (fine granular) under rice cultivation. The blocky structure, i.e. angular and sub-angular blocky were attributed to the presence of higher quantities of clay fraction (Sharma *et al.* 2004). The soil structure exhibited a trend of development with soil depth.

Physicochemical properties

The particle size distribution varied widely in these soils (Table 2). Sand fraction in the soils ranged from 44.5 to 61.9 %, highest being in Ap horizon of P4 (rice- wheat) and lowest in Bt1 horizon of P5 and P7. The highest amount of clay (27.5%) was observed in the Bt2 horizon of P6 & P7 while the surface horizon of P2 recorded the lowest amount of clay (11.8%). Sand fraction of all the soils did not exhibit a regular decreasing trend with soil depth except (P2 and P3)while did not follow any particular trend in all the pedons. Silt fraction (20.4 to 36.8%) did not follow any particular trend in all the pedons. The abrupt change in the sand/silt and sand/clay in lower most horizons of profiles indicated lithologic discontinuity (Sidhu *et al*. 1976).

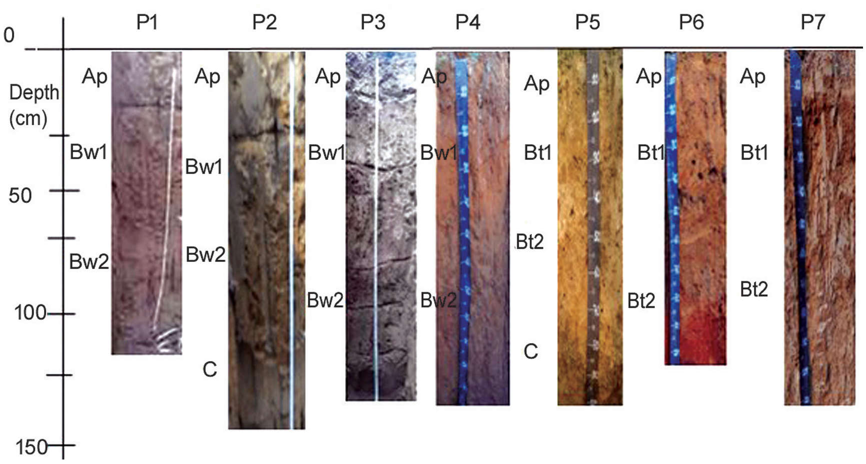

Fig 1 Horizon differentiation of the profiles

Table 1 Morphological properties of soils

Horizon	Depth (cm)	Colour (dry)	Texture	Structure			Effervescence	Other characteristics
				S	G	T		
P1 (rice- wheat): Dystric Eutrudepts								
Ap	0-20	10 YR 6/4	Sl	f		gr	-	
Bw1	20-40	10 YR 6/3	scl	m	2	sbk	e	
Bw2	40-120	10 YR 6/3	sicl	m	2	sbk	e	ffd
P2 (rice- wheat): Dystric Eutrudepts								
Ap	0-25	10 YR 6/3	Sl	f		gr	-	
Bw1	25-50	10YR 6/3	scl	m	2	sbk	-	
Bw2	50-100	10YR 6/3	scl	m	2	sbk	ev	f1f
C	100-140	10YR 6/4	l	m	2	sbk		
P3 (rice- wheat): Dystric Eutrudepts								
Ap	0-20	10 YR 5/4	Sill	m	2	sbk	-	
Bw1	20-40	10 YR 5/3	Sicl	m	2	sbk	ev	
Bw2	40-140	10 YR 5/4	Sill	m	2	sbk	ev	f1d
P4 (rice-wheat): Typic Eutrudepts								
Ap	0-20	10 YR 5/4	Sil	f		gr	-	
Bw1	20-50	10 YR 5/3	Sill	f	1	sbk	e	c1d
BW2	50-130	10 YR 5/3	l	f	1	sbk	e	f1f
P5 (rice- wheat)Typic Hapludalfs								
Ap	0-20	10 YR 5/4	scl	m	2	sbk	-	
Bt1	20-50	10 YR 5/4	sic	m	2	sbk	ev	f1f
Bt2	50-100	10 YR 5/4	sic	m	2	sbk	ev	c2d
C	100-130	10 YR 5/3	scl	m	2	sbk	e	c2d
P6 (rice- wheat)Typic Hapludalfs								
Ap	0-20	10 YR 5/6	l	f		gr	-	
Bt1	20-60	10 YR 5/4	sic	f	1	sbk	e	c1d
Bt2	60-125	10 YR 5/4	sic	f	1	sbk	e	f1f
P7 (rice- wheat)Typic Hapludalfs								
Ap	0-20	10 YR 5/4	l	f	1	sbk	-	
Bt1	20-60	10 YR 5/4	l	m	1	sbk	e	f1d
Bt2	60-130	10 YR 5/4	Scl	m	1	sbk	e	f1d

Texture: sl: sandy loam; scl: sandy clay loam: sicl: Silty clay loam, sil- silt,l: Loam, gl: Gravelly loam, sill: Silty loam; sic: Silty clay; Structure: Size(s)- f- fine, m-medium, c-coarse; Grade(G)- 1-weak, 2-moderate,3-strong; Type(T) m-massive, sbk-subangular blocky, ply-platy, abk- angular blocky; gr: granular; Effervescence: e- slight effervescence; es- strongeffervescence, ev- violent effervescence; Mottles Abundance: c-comman, f-few, m- many,; size 1-fine, 2- medium; Contrast: f-faint, d- distinct

Most of the soils had texture of sandy loam and sandy clay-loam in the surface soil and sandy clay to gravelly clay and clay in subsoil (Naidu *et al.*1994). Subsurface horizons of all the profiles except P5 (C horizon) exhibited higher bulk density as compared to surface horizons within a profile. The highest profile weighted mean clay content was found to be in P5 (25.9%) and P7 showed the lowest bulk density (1.40 Mg/m^3) while P1 had the highest porosity (44.07%). The particle density varied from 2.30 to 2.65 Mg/m^3 which is indicative of dominance of light minerals in these soils (Table 2). The amount of total organic carbon was higher in the surface horizons (14.4 to 29.7 g/kg) as compared to sub-surface horizons (0.1 to 1.1 g/kg) (Table 3). Generally surface soils were rich in organic carbon (Ponnamperuma 1972). The highest amount of total organic carbon (19.7 g/kg) in the surface horizon (P6) may be attributed to high

Table 2 Physical characteristics of soils

Horizon	Depth (cm)	Particle size distribution (%)			Bulk density (Mg/m^3)	Particle density (Mg/m^3)	Porosity (%)
		Sand	Silt	clay			
P1 (rice-wheat): Dystric Eutrudepts							
Ap	0-20	59.4	27.8	12.8	1.45	2.57	43.58
Bw1	20-40	49.5	24.3	26.2	1.41	2.61	45.98
Bw2	40-120	53.6	21.2	25.2	1.52	2.65	42.64
PWM*		54.2	24.4	21.4	1.46	2.61	44.07
P2 (rice-wheat): Dystric Eutrudepts							
Ap	0-25	60.4	27.8	11.8	1.48	2.51	41.04
Bw1	25-50	50.5	23.3	26.2	1.43	2.42	40.91
Bw2	50-100	52.8	20.4	26.8	1.49	2.53	41.11
C	100-140	47.5	36.0	16.5	1.49	2.54	41.34
PWM*		52.8	26.9	20.3	1.47	2.50	41.10
P3 (rice-wheat): Dystric Eutrudepts							
Ap	0-20	52.5	24.5	23.0	1.38	2.45	43.67
Bw1	20-40	48.5	25.6	25.9	1.49	2.51	40.64
Bw2	40-140	46.5	27.5	26.0	1.52	2.58	41.09
PWM*		49.2	25.9	25.0	1.46	2.51	41.80
P4 (rice-wheat): Typic Eutrudepts							
Ap	0-20	61.9	24.6	13.5	1.46	2.53	42.29
Bw1	20-50	53.8	31.8	14.4	1.69	2.52	32.94
BW2	50-130	47.7	36.8	15.5	1.80	2.54	29.13
PWM*		54.4	31.0	14.4	1.65	2.53	34.79
P5 (rice-wheat)Typic Hapludalfs							
Ap	0-20	49.8	27.2	23.0	1.36	2.30	40.87
Bt1	20-50	47.2	26.7	26.1	1.66	2.44	31.97
Bt2	50-100	44.5	28.3	27.2	1.92	2.48	22.58
C	100-130	48.1	24.8	27.1	1.65	2.41	31.81
PWM*		47.4	26.8	25.9	1.60	2.40	31.80
P6 (rice-wheat)Typic Hapludalfs							
Ap	0-20	49.1	30.6	20.3	1.67	2.43	31.28
Bt1	20-60	44.5	30.5	25.0	1.73	2.48	30.24
Bt2	60-125	47.4	25.1	27.5	1.92	2.56	25.00
PWM*		47.0	28.7	24.2	1.77	2.49	28.84
P7 (rice-wheat)Typic Hapludalfs							
Ap	0-20	49.1	30.6	20.3	1.35	2.34	42.3
Bt1	20-60	44.5	30.5	25.0	1.41	2.42	41.73
Bt2	60-130	47.4	25.1	27.5	1.45	2.46	41.05
PWM*		47.0	28.7	24.2	1.40	2.41	41.69

PWM*- profile weighted mean

amount of biomass. Continuously cultivated soils (P2 and P5) contained lower amount of organic carbon which is also reflected in the profile weighted means. A regular decreasing pattern of organic carbon was observed with depth. All the pedons were acidic to moderately alkaline in reaction, with pH ranging from 4.8 to 8.4. All the pedons had low electrical conductivity values ranging from 0.48 to 0.79 dS/m, indicating non-saline nature. The low electrical conductivity may be due to free drainage conditions which favoured the removal of released bases by percolating and drainage water. The available P varied between 6.8 and 24.2 kg/ha in all the pedons. However, the highest available P was observed in the surface horizons and decreased with depth. The lower P in sub-surface horizons compared to surface horizon was due to the fixation of released P by clay minerals and oxides of iron and aluminum (Devi *et al.* 2015). Available K of soils ranged from 159 to 376 kg/ha. The highest available K content was observed in the surface

Table 3 Physicochemical properties of the soils

Horizon	Depth (cm)	pH (1:2.5)	EC (dS/m)	Total organic carbon (g/kg)	Available P (kg/ha)	Available K (kg/ha)
P1 (rice- wheat): Dystric Eutrudepts						
Ap	0-20	8.1	0.70	18.3	19.4	345
Bw1	20-40	8.3	0.71	4.6	12.5	281
Bw2	40-120	8.4	0.74	0.4	11.2	238
PWM*		8.3	0.72	7.8	14.4	288
P2 (rice-wheat): Dystric Eutrudepts						
Ap	0-25	8.1	0.71	13.4	19.4	341
Bw1	25-50	7.9	0.69	2.4	8.3	288
Bw2	50-100	7.7	0.69	1.0	7.4	166
C	100-140	8.1	0.71	0.1	7	161
PWM*		8.0	0.70	4.2	10.5	239
P3 (rice-wheat): Dystric Eutrudepts						
Ap	0-20	7.6	0.65	18.2	18	376
Bw1	20-40	7.3	0.63	0.60	16	247
Bw2	40-140	6.8	0.62	0.9	11.2	245
PWM*		7.2	0.63	6.6	15.1	289
P4 (rice-wheat): Typic Eutrudepts						
Ap	0-20	7.2	0.57	15.3	13	292
Bw1	20-50	7.4	0.53	4.1	8.6	152
BW2	50-130	7.4	0.48	1.0	9.5	159
PWM*		7.3	0.53	6.8	10.4	201
P5 (rice-wheat) Typic Hapludalfs						
Ap	0-20	6.8	0.73	17.8	24.2	323
Bt1	20-50	6.7	0.72	3.9	8.2	253
Bt2	50-100	6.6	0.69	1.0	7.1	196
C	100-130	6.7	0.71	0.4	6.8	168
PWM*		6.7	0.73	5.8	11.6	235
P6 (rice-wheat) Typic Hapludalfs						
Ap	0-20	4.8	0.55	19.7	9.00	265
Bt1	20-60	6.2	0.57	5.3	8.00	178
Bt2	60-125	6.2	0.57	1.1	7.00	146
PWM*		5.7	0.56	8.7	8.0	196
P7 (rice-wheat) Typic Hapludalfs						
Ap	0-20	6.8	0.79	16.7	20	276
Bt1	20-60	7.4	0.68	3.5	13.3	220
Bt2	60-130	7.3	0.76	0.7	10.6	175
PWM*		7.2	0.74	7.0	14.6	223

horizons and showed more or less a decreasing trend with depth. This might be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary raise of ground water (Sharma *et al.* 2003; Vedadri *et al*. 2018).

Soil classification

Based on the field morphology and physicochemical characteristics, the studied soils were classified up to the subgroup level as per Keys to Soil Taxonomy (Soil Survey Staff 2014). All the pedons had ochric epipedon and underlain by cambic horizon (P1 to P4) within the control section and as such they come under order Inceptisols and P5 to P7 have argillic horizon so they come under order Alfisols. Due to the absence of any other diagnostic horizon except ochric epipedon and presence of Udic moisture regime soils were placed under suborder Udepts (P1 to P4) and Udalfs (P5 to P7) respectively. So the soils of all pedons were placed in the order Inceptisol and alfisols and suborder Udepts and Udalfs respectively. Chandauli soils have udic soil moisture regime hence fall under great group Eutrudepts and Hapludalfs respectively. The Eutrudepts that do not have free carbonates throughout any horizon within 100 cm of mineral surface are grouped under subgroup Dystric Eutrudepts and the soils that do not have 40 % or more carbonates but have free carbonates, are placed under subgroup Typic Eutrudepts and Typic Hapludalfs respectively.

Land capability classification

The land capability classification is an interpretative grouping of different soil units and plays an important role in land use planning to show the relative suitability of soils for cultivation of crops, pastures, forestry and also for focusing the problems which need preventive measures. It also helps in the management and improvement of different soil units for increasing production. The grouping of soils into capability classes and sub-classes is done mainly based on the number and severity of several limitations, viz. erosion risk (e), wetness (w), rooting zone (soils) limitations (s) and climatic limitations (c). Based on these criteria the soils of Chandauli district have been classified into two land capability sub-classes for better management of lands (Table 4). Pedon 2 was rated as IVs. Pedons 1, 3, 5 and 7 were placed in IIIs, pedons 4 and 6 were placed under IVe. The detailed description of land capability classes with potentials, limitations and suggested land use is given in Table 4. By adopting suggested land use in the respective areas sustained crop production can be achieved as it helps in the conservation of soil and water besides the improvement of physical properties of soils.

Based on morphological, physical, chemical and mineralogical data these soils were placed under two orders Alfisols and Inceptisols. The soils were classified as Typic Eutrudepts and Typic Hapludalfs. Texture and Total organic carbon (TOC) ranged from silty loam to silty clay loam, 0.1 to 29.7 g/kg respectively. Soils were medium in phosphorus (6.8 to 24.2 kg/ha) and available potassium (159 to 376 kg/ha). Land capability classes were evaluated and suitable land use plan was suggested for sustaining yields of the crops. Judicious use of organic manures on these soils is the way for achieving sustainable yields of crops and also maintain the soil health.

Table 4 Interpretation of soils of Chandauli district

Pedon No.	Land capability class with limitations	Description	Major limitations	Suggested land use
P2	IVs	Fairly good cultivable land for sustainable agriculture	Low organic matter content, alkaline, low in phosphorus, Sandy loam texture	Cultivation of crops including legumes in rotation, addition of fertilizers and manures and adoption moderate soil conservation measures, addition of organic manures.
P1,P3,P5, P7	III s	Moderately good cultivable land for sustainable agriculture	Sandy loam and silty texture, low water holding capacity, poor fertility status, and moderately drained	Moderate soil conservation measures, application of organic manures; rice and wheat can be grown with suitable soil and crop rotation that includes grasses and legumes, growing of green manure crops and stubble mulching; water management practices,
P4	IVs	Moderately good cultivable land for sustainable agriculture	Low in phosphorus, medium in organic matter, silty texture, low water holding capacity	Crop rotation that includes grasses and legumes, growing of green manure crops and stubble mulching;
P6	IVs	Fairly good cultivable land for sustainable agriculture	Low in phosphorus, acidic pH, low porosity, poor aeration, moderate run-off	Crop rotation that includes grasses and legumes, growing of green manure crops and stubble mulching; addition of fertilizers and manures and adoption moderate soil conservation measures

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