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Pedological characterization and soil classification of salt-affected soils of Faizabad District, Uttar Pradesh, (India)

Maneesh Kumar, Neeraj Kumar and Ram Bharose

Abstract
The study aimed at provision of research information by pedological characterization of Salt affected soils of Faizabad District, Uttar Pradesh. Six soil profile were selected coupled with field detailed survey. The studies on morphological characteristics physical and chemical properties of soils were undertaken through profile sampling. Based on the data obtained, the soils were categorized and classified up to soil series level Salt-affected soils, in general, were clay loam to sandy clay loam in texture. The colour of soil samples was hue 10 YR with value varied from 4 to 7 and chroma 1 to 6. The pH of surface horizon varied from 7.57 to 8.98 whereas in the subsurface horizons it ranged from 8.76 to 10.02. Electrical conductivity (EC) indicates that the soils are non-saline and which varied from 0.12 to 1.16 dS m^{-1}. The organic carbon (OC) content is generally low in surface and very low in subsurface horizons in both the soils of ustic and udic moisture regime. The cation exchange capacity (CEC) values of the soils varied from 8.9 to 29.0 cmol (p+) kg^{-1} and the values increased with the depth. The exchange complex of all the pedons was dominated by Na^{+} followed by Ca^{++}, Mg^{++}, K^{+} and ESP, the value of exchangeable bases also increased from surface downwards. The exchangeable bases in all the pedons were in order of $Na^{+} > Ca^{+2} > Mg^{+2} > K^{+}$ on the exchange complex. Based on soils characteristics, the soils are classified as Typic Agriustept, Typic Natrustept.

Keywords: Salt-affected soils (SAS), morphology characteristics, physico-chemical characteristics, Faizabad district

1. Introduction
Soil is a component of the lithosphere and biosphere system. Soils are derived from chemical and physical weathering of rocks and other geological and organic materials. It is a vital natural resource on which supporting life systems and socio-economic development depends. In the recent past, productivity of agricultural soils worldwide in general is on the decline. This prompted the per capita availability of food grain fall from 510 g per day (1991) to 463 g per day (2004). These declining trends across the world are attributed to ever growing population, raising incomes of populous Asian nations and discovery of new uses such as biofuels, besides weather based abnormalities owing to climate change (Sidhu and Kamal Vatta, 2007) [10]. Worldwide, more than 800 million hectares of land are estimated to be salt-affected. In India about 7 million hectares of land was affected by salinity/alkalinity conditions. These soils are known at some place as 'reh' and in others as 'thur'. Based on the physico-chemical properties, salt-affected soils have been grouped in to three categories like saline, sodic and saline-sodic. In the Indo-Gangetic alluvial plains where about 40 per cent of the total affected area is encountered.

Salt-affected soils (SAS) are widespread all over the world. In addition to the constraints of scarcity or too much water in these soils, the basic fertility and land use capability of these soils is directly related to a few chemical properties, such as salinity and sodicity (Szabolcs, 1971) [16]. It is the reason why the study of SAS, as a pioneering branch of pedology, soil mapping, remote sensing, soil reclamation, soil utilization, has received so much attention (e.g. Richards, 1954, Bresler *et al*., 1982, Shainberg and Letey, 1984, Sumner and Naidu, 1998, Tinker and Nye, 2000) [8, 1, 9, 15, 19]. As some tenths of Hungary's complete territory is covered by such soils, there has been and there is now a detailed work going on SAS (Szabolcs, 1971, Szendrei, 1999, Pasztor *et al*., 2000) [16, 17]. The present investigation was therefore conducted under Faizabad district, U.P. with the objective to know the morphology, physico-chemical properties and classification of salt-affected soils.

Materials and Methods

The study area lies between $26^0$58.234′ to $26^0$76.035′N latitude and $81^0$63.942′ to $82^0$29.864′E longitude covering parts of Faizabad district. The climate of the study area is semi arid with an average rainfall of 550-900mm. Six pedons encompassing Kalyanpur Barauli (Maya Bajar) (Padon 1), Bahadurpur (Tarun) (Padon 2), Nevra Bajar (Mawai) (Padon 3), Pirkhauli (Sohawal) (Padon 4), Dili Saray (Amaniganj) (Padon 5) and Amarganj (Amaniganj) (Padon 6) representing salt-affected soils were selected and profiles were exposed to study morphological characteristics. Soil colour of the pedons was measured both under dry and moist condition using Munsell soil colour chart. Other morphological characteristics studied were depth of solum, depth of each horizon, texture, structure, consistency at dry, moist and wet conditions, *etc.*

The morphology of the soils was described in the field by following the procedures outlined by the Soil Survey Division Staff (1995) [12]. Soil samples from different horizons were collected, air-dried, crushed and passed through a 2-mm sieve. Soil samples were analyzed for bulk density (Core method), hydraulic conductivity (Constant Head Method), field capacity and permanent wilting point (Pressure membrane apparatus), pH, EC (1:2.5 ratio of soil: water), organic carbon (wet oxidation), K^+, Na^+, Mg^{2+} and Ca^{2+} were determined by adopting standard methods (Richards 1954, Jackson 1973) [8]. Cation exchange capacity and ammonium acetate (pH 7.0) extractable bases were determined using method of Richards (1954) [8] and particle size distribution by Bouyoucous hydrometer method. The soils were classified according to Soil taxonomy (Soil Survey Staff 1998) [13, 14].

Result and Discussion

Morphological Characteristics

The important morphological characteristics of the salt-affected soils showed that the colour of the pedons with 10 YR hue. The values ranged from 4 to 7, whereas chromas were 6 or less (Table 1). The soil colour of the surface horizon was light gray (10YR 7/2, dry) and pale brown (10YR 6/3, moist) all pedons. The sub-surface horizon of Pedon 1and 3 has light brownish gray (10 YR 6/2, dry) and dark gray brown colour (10 YR 4/2, moist). The sub-surface horizon of Pedon 2 and 5 has pale brownish (10 YR 6/3, dry) and dark brown colour (10 YR 4/3, moist), whereas sub-surface horizons of Pedon 4 and 6 had brownish yellow (10 YR 6/6, dry) and yellowish brown colour (10 YR 5/6, moist). The texture varied from clay loam to sandy clay loam in all pedons (Table 1). This variation in texture is mainly due to differences in physiography. These results are in conformity with the findings of Nayak *et al*. (2002) [5]. The surface soil structure of the pedon 1 was moderate, fine, sub-angular blocky, whereas in sub-surface horizons moderate, medium, sub-angular blocky. The soil structure in surface horizon of padon 2 and 5 was strong, medium, granular, whereas in sub-surface horizons moderate, medium, sub-angular blocky. In pedon 3, soil structure in surface horizon was strong, medium, sub-angular blocky, whereas in sub-surface horizons moderate, medium, sub-angular blocky. The surface soil structure of the pedon 4 was moderate, fine, granular, whereas in sub-surface horizons moderate, medium, sub-angular blocky. In pedon 6, soil structure in surface horizon was moderate, fine, prismatic, whereas in sub-surface horizons strong, medium, prismatic. The C horizon of all the pedons had predominately massive structure (Mandal and Sharma 2013) [4].

The consistence of soils varied from slightly hard to very hard, firm to very firm and non-sticky and non-plastic to sticky and plastic in dry, moist and wet conditions respectively. This physical behavior of soils influenced by dry, moist and wet conditions was not only due to the textural make up by also due to type of clay minerals present in these soils. The C horizon of all the pedons had shown non-sticky and non-plastic or slightly sticky and slightly plastic consistence, which might be due to less amount of clay. Similar findings were also reported by Thangasamy *et al*. (2005) [18] in the soils of Sivagiri microwatershed and Chandra Sekhar *et al*. (2017) [2] for Prakasham district of Andhra Pradesh.

Physico-chemical Characteristics

Sand content in all the pedons decreased from the surface downwards 58.42 to 20.00 per cent. Silt content ranged from 57.35 to 20.14 per cent. In pedons 1, 4, 5 and 6 decreased from surface downwards and pedon 2 and 3 increased with depth (Table 2). This might be due to variation in weathering of parent material. The clay content in all pedons increased with depth 13.05 to 37.55 per cent. The physical characteristics indicated that the soils are sandy clay loam to clay loam in texture, with bulk density 1.35 to 1.57 Mg m^{-3}. The pH of surface horizon varied from slightly alkaline (pH 7.57) to strong alkaline (pH 8.98) whereas in the subsurface horizons varied from strong alkaline (pH 8.76 to 10.02) (Table 2). Electrical conductivity indicates that the soils are non-saline and which varied from 0.12 to 1.16 dS m^{-1}. The organic carbon content is generally low in surface and very low in subsurface horizons in both the soils of ustic and udic moisture regime. The cation exchange capacity (CEC) values of the soils (Table 2) varied from 8.9 to 29.0 cmol (p+) kg^{-1} and the values increased down the depth (Verma *et al*. 2014). The exchange complex of all the pedons was dominated by Na^+ followed by Ca^{++}, Mg^{++}, K^+ and ESP the value of exchangeable bases also increased from surface downwards.

Soil classification

Based on morphological, physical and chemical characteristics (Table 1 & 2) the soils under study have been classified according to Soil Taxonomy (Soil Survey Staff 1998) [13, 14]. All pedons were classified into order Inceptisols and suborder Ustepts. All pedons have been classified into soil order Inceptisols having Ochric epipedon (less than 1.00 per cent organic matter) and argillic as well as nitric sub-surface diagnostic horizon. The argillic horizon has developed due to clay illuvation and was identified by the presence of clay cutans and the thickness of the horizon as more than 7.5 cm and also more than one-tenth as thick as the sum of the thickness of all the overlying horizons. As per criteria listed the moisture regime has been identified as Ustic. Hence all pedon at sub-ordered has been classified as Ustepts.

Table 1: Morphological characteristics of the studied pedons

Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Other features
		Dry	Moist			Dry	Moist	Wet	
Padon- 1: Kalyanpur Barauli (Maya Bajar)									
A_p	0 – 20	10 YR 7/2	10 YR 6/3	cl	2 f sbk	sh	vfi	s p	Thin roots are present at a depth of 0-22 cm. Thick roots are present at a depth of 0-45 cm.
B_1	20 – 40	10 YR 7/1	10 YR 6/3	cl	2 f sbk	sh	fi	s p	
B_2	40 – 80	10 YR 6/6	10 YR 5/6	cl	2 m sbk	h	fi	s p	
B_3	80– 100	10 YR 6/3	10 YR 4/3	cl	2 m sbk	h	fi	ss sp	
C	100 – 150	10 YR 6/2	10 YR 4/2	cl	Massive	vh	fi	ss po	
Padon- 2: Bahadurpur (Tarun)									
A_p	0 – 20	10 YR 7/1	10 YR 6/3	scl	3 m gr	sh	sfi	vs p	Thin roots are present in depth of 0-25 cm.
B_1	20 – 45	10 YR 7/1	10 YR 6/3	scl	2 m sbk	h	fi	s sp	
B_2	45 – 75	10 YR 6/6	10 YR 5/6	scl	2 m sbk	h	fi	ss po	
B_3	75 – 95	10 YR 6/3	10 YR 5/6	scl	2 m sbk	h	fi	ss po	
C	95 – 150	10 YR 6/3	10 YR 4/3	scl	Massive	vh	fi	ss sp	
Padon- 3: Nevra Bajar (Mawai)									
A_p	0 – 18	10 YR 7/2	10 YR 6/3	sil	3 m sbk	h	fi	so po	Thin roots are present in depth of 0-25 cm and Effervescence with dilute HCl at a depth of 68-95 cm.
B_1	18 – 38	10 YR 7/1	10 YR 6/3	sil	2 m sbk	h	fi	ss p	
B_2	38 – 68	10 YR 6/3	10 YR 4/3	sil	2 m sbk	h	fi	ss po	
B_3	68 – 95	10 YR 6/3	10 YR 4/3	sil	2 m sbk	h	fi	ss po	
C	95 – 150	10 YR 6/2	10 YR 4/2	sil	Massive	vh	fi	ss po	
Padon- 4: Pirkhauli (Sohawal)									
A_p	0 – 22	10 YR 7/2	10 YR 6/3	cl	2 f gr	sh	fi	s p	Thin roots are present at a depth of 0-25 cm. Thick roots are present at a depth of 0-40 cm.
B_1	22 – 45	10 YR 7/1	10 YR 6/3	cl	2 m sbk	h	fi	vs vp	
B_2	45 – 72	10 YR 6/6	10 YR 5/6	cl	2 m sbk	h	fi	ss sp	
B_3	72 – 95	10 YR 6/6	10 YR 5/6	cl	2 m sbk	h	fi	so sp	
C	95 – 150	10 YR 6/6	10 YR 5/6	cl	Massive	h	fi	so po	
Padon- 5: Dili Saray (Amaniganj)									
A_p	0 – 20	10 YR 7/2	10 YR 6/3	cl	3 m gr	sh	sfi	vs p	Thin roots are present in depth of 0-22 cm.
B_1	20 – 50	10 YR 7/1	10 YR 6/3	cl	3 m sbk	h	fi	s sp	
B_2	50 – 75	10 YR 6/6	10 YR 5/6	cl	2 m sbk	h	fi	ss po	
B_3	75 – 95	10 YR 6/3	10 YR 4/3	cl	2 m sbk	h	fi	ss po	
C	95 – 150	10 YR 6/3	10 YR 4/3	cl	Massive	vh	fi	ss sp	
Padon- 6: Amarganj (Amaniganj)									
A_p	0 – 18	10 YR 7/1	10 YR 6/3	cl	2 f pr	sh	fi	s p	Thin roots are present in depth of 0-22 cm. Effervescence with dilute HCl at a depth of 80-100 cm.
B_1	18 – 35	10 YR 7/1	10 YR 6/3	cl	2 f pr	sh	fi	s p	
B_2	35 – 80	10 YR 6/6	10 YR 5/6	cl	3 m pr	h	fi	ss sp	
B_3	80– 100	10 YR 6/6	10 YR 5/6	cl	3 m pr	h	fi	ss sp	
C	100 – 150	10 YR 6/6	10 YR 5/6	cl	Massive	h	fi	ss po	

Texture: CL- clay loam; SiL- silt loam; SCL- sandy clay loam; **Structure:** Size (S) f-fine; m-medium; Grade (G) 2-moderate; 3-strong; Type (T) gr-granular; pr- prismatic;
sbk-sub angular blocky; **Consistency:** Dry (D), sh-slightly hard; h-hard; vh-very hard; Moist (M), fi-firm; vfi-very firm; vfr-very friable; sfi-slightly firm; Wet (W), so-non sticky; ss-slightly sticky; s-sticky; vs-very sticky; po-non plastic; sp-slightly plastic; p-plastic; vp-very plastic.

Table 2: Physico-chemical characteristics of the studied pedons

Horizon	Depth (cm)	Textural composition (%)			B.D. ($Mg\ m^{-3}$)	pH Soil:H_2O (1:2.5)	EC ($dS\ m^{-1}$) Soil:H_2O (1:2.5)	O.C. ($g\ kg^{-1}$)	CEC	Exchangeable cations				ESP (%)
		Sand (>50µm)	Silt (2-50µm)	Clay (<2µm)						Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
										[cmol (p^{+})kg^{-1}]				
Padon- 1: Kalyanpur Barauli (Maya Bajar)														
A_p	0 – 20	32.64	38.62	28.74	1.36	8.62	0.14	3.60	10.9	3.9	3.6	2.4	0.6	22.01
B_1	20 – 40	32.00	36.44	31.56	1.43	8.69	0.19	3.40	11.7	4.0	3.7	2.9	0.6	24.78
B_2	40 – 80	30.53	35.87	33.60	1.49	8.77	0.17	3.10	12.6	4.1	3.8	3.6	0.7	28.57
B_3	80– 100	29.95	34.72	35.33	1.53	8.85	0.15	2.50	14.8	4.2	3.9	4.8	0.8	32.43
C	100 – 150	28.60	33.85	37.55	1.57	8.82	0.13	1.80	13.4	4.1	3.8	4.1	0.6	30.59
Padon- 2: Bahadurpur (Tarun)														
A_p	0 – 20	58.42	20.14	21.44	1.35	8.58	0.12	4.20	11.5	4.3	3.9	2.2	0.6	19.13
B_1	20 – 45	55.72	20.58	23.70	1.41	8.69	0.18	3.70	12.1	4.4	3.9	3.0	0.7	24.79
B_2	45 – 75	52.63	21.72	25.65	1.47	8.83	0.13	3.40	14.8	4.5	4.1	4.7	0.8	31.75
B_3	75 – 95	49.55	22.00	28.45	1.51	8.97	0.13	2.60	14.8	4.4	3.9	5.7	0.7	38.51
C	95 – 150	46.62	22.88	30.50	1.55	8.93	0.19	2.00	16.9	4.6	4.2	6.2	0.8	36.68
Padon- 3: Nevra Bajar (Mawai))														
A_p	0 – 18	34.67	52.28	13.05	1.42	8.73	0.21	3.30	12.7	4.1	4.0	3.3	0.7	25.98
B_1	18 – 38	30.80	53.65	15.55	1.44	8.87	0.23	2.90	13.0	4.0	3.8	4.2	0.7	32.30
B_2	38 – 68	26.76	55.14	18.10	1.49	8.95	0.22	2.40	15.4	4.2	4.0	5.8	0.8	37.66
B_3	68 – 95	22.73	56.44	20.83	1.50	9.18	0.23	2.10	18.5	4.4	4.1	8.4	0.9	45.40
C	95 – 150	20.00	57.35	22.65	1.54	9.27	0.26	1.50	19.9	4.5	4.2	9.8	1.0	49.24
Padon- 4: Pirkhauli (Sohawal)														
A_p	0 – 22	39.20	33.15	27.65	1.36	7.57	0.31	3.10	9.1	4.0	3.4	0.3	0.4	3.29
B_1	22 – 45	38.59	32.37	29.04	1.41	7.70	0.28	2.20	8.9	4.1	3.5	0.4	0.5	4.49
B_2	45 – 72	37.44	31.94	30.62	1.48	8.50	0.33	1.80	11.3	4.4	3.8	1.7	0.6	15.04
B_3	72 – 95	37.35	29.40	33.25	1.52	8.57	0.41	1.60	11.3	4.5	3.8	2.1	0.7	18.58
C	95 – 150	35.50	28.10	36.40	1.53	8.76	0.34	1.60	12.6	4.5	3.7	3.5	0.7	27.77

Padon- 5: Dili Saray (Amaniganj)														
A_p	0 – 20	40.63	32.27	27.10	1.37	8.57	0.27	3.20	11.3	4.3	3.7	2.1	0.8	18.58
B_1	20 – 50	40.37	30.59	29.04	1.43	8.73	0.33	2.90	12.7	4.2	3.8	3.3	0.9	25.98
B_2	50 – 75	38.45	31.05	30.50	1.48	8.89	0.25	2.50	15.3	4.4	4.0	5.3	1.1	34.64
B_3	75 – 95	38.00	29.00	33.00	1.52	9.13	0.29	2.10	17.2	4.3	3.9	7.7	1.1	44.76
C	95 – 150	36.50	28.25	35.25	1.56	9.05	0.31	1.60	16.0	4.2	3.8	6.5	1.2	41.25
Padon- 6: Amarganj (Amaniganj)														
A_p	0 – 18	41.28	31.68	27.04	1.35	8.98	1.16	3.40	14.6	4.1	3.5	5.7	0.5	39.04
B_1	18 – 35	40.54	30.13	29.33	1.42	9.12	1.11	2.30	16.8	4.3	3.8	7.4	0.6	44.04
B_2	35 – 80	38.20	30.80	31.00	1.45	9.57	1.15	2.30	19.4	4.2	3.7	10.6	0.7	54.63
B_3	80– 100	36.74	29.86	33.40	1.48	9.49	1.07	2.00	19.2	4.2	3.8	10.3	0.6	53.64
C	100 – 150	36.32	28.68	35.00	1.53	10.02	1.12	1.70	29.0	4.6	4.0	19.0	0.8	65.51

Table 3: Soil taxonomic classification of the studied pedons

Name of place	Pedon number	Order	Sub order	Great group	Sub group	Family	Series	Phase
Kalyanpur Barauli (Maya Bajar)	Pedon 1	Inceptisols	Ustepts	Agriustept	Typic Agriustept	Fine mixed hyperthermic	Kalyanpur Barauli	CL
Bahadurpur (Tarun)	Pedon 2	Inceptisols	Ustepts	Agriustept	Typic Agriustept	Fine mixed hyperthermic	Bahadurpur	SCL
Nevra Bajar (Mawai)	Pedon 3	Inceptisols	Ustepts	Agriustept	Typic Agriustept	Fine mixed hyperthermic	Nevra Bajar	SiL
Pirkhauli (Sohawal)	Pedon 4	Inceptisols	Ustepts	Agriustept	Typic Agriustept	Fine mixed hyperthermic	Pirkhauli	CL
Dili Saray (Amaniganj)	Pedon 5	Inceptisols	Ustepts	Agriustept	Typic Agriustept	Fine mixed hyperthermic	Dili Saray	CL
Amarganj (Amaniganj)	Pedon 6	Inceptisols	Ustepts	Natrustept	Typic Natrustept	Fine mixed hyperthermic	Amarganj	CL

Conclusion

It may be concluded that soils of Faizabad district were saline to alkaline in nature with low in organic carbon content, medium to high in cation exchange capacity and high in ESP, SAR and exchangeable sodium. The trends of exchangeable cations is in order; $Na^+ > Ca^{2+}$, $> Mg^{2+} > K^+$. The soils of all the pedons were classified as Inseptisols in order and Ustepts in sub order. However, the great group of Pedon 1, 2, 3, 4 and 5 was Argiustepts while of pedon 6 Natrustepts.

It is recommended that farmers should avoid over irrigation, stop using chemical fertilizer, use drip irrigation system, and apply FYM, green manure, bio-fertilizer and warmi compost.

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