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CHARACTERIZATION AND DISTRIBUTION OF SALT-AFFECTED SOILS OF SULTANPUR DISTRICT, UTTAR PRADESH

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ABSTRACT

Using remote sensing technique, soil survey was carried out to characterize and delineate the salt-affected soils of Sultanpur district of eastern Uttar Pradesh occurring under various land forms for an appraisal of the causes of their development and management. Five soil series namely Pura Ausan Singh, Sayaid Nagar, Jagmalpur, Pura Subba Pandey and Dhanapur of salt-affected soils were identified. The salt affected soils occurring on old flood plain with fluctuating ground water and periodcal water logging are put under Pura Ausan Singh and characterized by formation of calcic horizon (Bk). The soils occurring on old flood plain with concave relief are put under Sayaid Nagar and Jagmalpur Series which are characterized by presence of mottling in their substratum due to oxidizing and reducing conditions. Salt affected soils occurring on old flood plain with high water table and on fluvial channels are put under Pura Subba Pandey and Dhanapur series, respectively. The soils were characterized by presence of reduced mottles in middle horizons just after 40 to 45 cm depth due to prevailing moist conditions in the soils. These soils were deep to very deep, moderately to imperfectly drained, dark greyish brown olive brown to yellowish brown in colour, sandy loam to clay loam in texture and have low to medium organic carbon. In general, soils under study were alkaline in nature having pH, EC and ESP higher in surface and decreased with depth. Further, the clay content was higher in substratum, which directly contributed to CEC. The soils under investigation wer e classified as Typic Calciustepts (P1), Natric Haplustepts (P2 and P3), Typic Halaquepts (P4) and Aeric Halaquepts (P5). Four categories of soil salinity/alkalinity were identified and delineated as moderately sodic, strongly sodic and strongly saline, strongly sodic and slightly saline and strongly sodic and moderately saline covering an area of 3.5, 2.1, 8.1 and 4.9 % of TGA of the district, respectively..

Key words: Salt-affected soil, characteristics, soil classification, soil distribution.

INTRODUCTION

Soil salinity/sodicity is one of the major problems of land degradation in irrigated area of the world. The primary process involved transportation and deposition of alkaline salts from the HIMALAYA and Shivalik to the Indo-Gangetic plain (Bhargava *et al.* 1980). In India salt-affected soils occur to the extent of 6.7 m ha in arid and semi-arid regions, out of this area nearly 40 % (2.8 m. ha) occurs in the Indo-Gangetic alluvial plain of Uttar Pradesh, Haryana, Punjab, Delhi and part of Rajasthan and Bihar (NRSA 1996). In the Uttar Pradesh state alone about 1.25 m ha area is salt-affected. These soils occur in association with the normal soils and either barren or under restricted cultivation. These soils if reclaimed will contribute a major share to total production of the state. The Sultanpur district was chosen for present study as the district is badly infested with salt-affected soils due to large scale in production of irrigation under Sharda Sahayak Command Area Project.

MATERIALS AND METHODS

Sultanpur district lies between 81°32' to 82°41' E and 25°59' to 26°40' N in eastern Uttar Pradesh and covers about 4.4 lakh hectare area with mean annual temperature of 25°C and mean annual rainfall of 1025 mm representing old and recent flood plain of Gomati river with elevation ranging from 95 to 111 m above MSL. As per the climatic classification suggested by Mandal *et al.* (1999) the district is semi-arid and soil moisture and temperature regimes are ustic and hyperthermic, respectively. A three-tier approach (Sehgal *et al.*, 1987) consisting of image interpretation, ground truth collection and laboratory characterization and cartographic output was made for the survey of the area using base maps consisting of physiographic delineation on 1:50,000 scale. To demarcate areas of similar soils, several auger holes and field checks were undertaken in each physiographic unit and representative pedon sites were selected for detailed investigation. The representative pedons of each soil series were sampled horizon wise for laboratory characterization using standard analytical techniques (Jackson, 1973 and Sarma *et al.*, 1987). Soils were classified taxonomically (Soil Survey Staff, 2010). Five representative pedons were selected for present study. Based on the values of EC_W and PH_w, soils were categorized and delineated.

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RESULT AND DISCUSSION

Morphological characteristics

Morphological characteristics of various pedons under study are presented in Table 1. Pedon 1 (Pura Ausan Singh Series) is occurring on old flood plain with fluctuating ground water and periodical water logging which are moderately well drained, greyish, brown to olive brown in colour. The texture is sandy loam (surface) and is dominantly clay loam in the subsoil. Soil structure is granular in surface and sub-angular blocky in rest of the soil profiles. Fe-Mn nodules are present in lower horizons. Lime concretions of different sizes in the form of thick compact layer (calcic layer) observed in the subsoil creating several physical impediments for capillary movement of moisture and downward growth of the roots (Sharma *et al.*, 1996, Pal *et al.*, 1999, West *et al.*, 1988). Taxonomically these soils are classified as fine loamy, mixed (cal), hyperthermic, typic calciuslepts. Pedon 2 (Saiyad, Nagar Series) and Pedon 3 (Jagmalpur Series) occurring on old flood plain with concave relief were imperfectly drained, yellowish brown to olive brown in colour. The surface texture is sandy loam (P2) to loamy sand (P3) and subsoil is sandy loam (P3) to loam (P2). The structure is sub-angular blocky. The soils are calcareous and alkaline in nature. The Fe-Mn nodules and mottling in their substratum associated with alternate oxidizing and reducing conditions (Gotoh and Patrick, 1972) subject to repeated dry and wet cycles particularly during summer and rainy seasons. The soils are classified as fine loamy, mixed (cals, hyperthermic, Natric Haplustepts (P2) and coarse loamy, mixed (cal), hyperthermic Natric Haplustepts (P3). Pedon 4 (Pura Subba Pandey Series) occurring on old flood plain with high water table which are imperfectly drained, dark greyish brown to light olive brown in colour. The texture was clay loam

Table 1: Morphological characteristics of soils*

Horizon	Depth (cm)	Colour	Texture	Structure	Consistency			Lime concretion		Root		Effervescence with dil. HCl	Mottles	Other features
					D	M	W	S	Q	S	Q			
Pedon 1 (Pura Ausan Singh Series) Fine loamy, mixed (calcareous), hyperthermic, Typic Calciustepts														
Ap	0-20	2.5Y5/2	sl	granular	Sh	fr	ss ps	-	-	f	m	nil	-	-
Bw1	20-33	2.5Y4/4	cl	m 2 sbk	-	Fr	sp	-	-	f	m	e	-	-
Bw2	33-47	2.5Y4/4	cl	m 2 sbk	-	fr	sp	f	f	f	c	e	-	-
Bw3	47-62	2.5Y4/4	cl	m 2 sbk	-	fr	Fr sp	f	f	f	f	e	-	-
Bk	62-98	2.5Y4/4	gl	m 2 sbk	-	fr	fr sp	f	f	-	-	ev	-	> 35% lime kankars
Bm	98+	An impervious lime coated concretion layer.												
Pedon 2 (Saiyad Nagar Series) Fine loamy, mixed (calcareous), hyperthermic, Natric Haplustepts														
Ap	0-16	10YR6/6	sl	m 1 sbk	sh	vfr	so po	-	-	f	c	e	-	-
AB	16-40	10YR6/6	l	f 1 sbk	-	fr	ss ps	f	f	f	f	e	-	-
Bw1	40-64	10YR5/6	l	m 2 sbk	-	fr	sp	f	f	f	f	e	-	-
Bw2	64-89	10YR5/6	l	m 2 sbk	-	fr	sp	f	f	f	f	e	f f d	-
Bw3	89-120+	10YR5/6	l	m 2 sbk	-	fr	sp	f	f	vf	f	e	f f d	-
Pedon 3 (Jagmalpur Series) Coarse loamy, mixed (calcareous), hyperthermic, Natric Haplustepts														
Ap	0-15	2.5Y6/2	ls	-	sh	vfr	sopo	-	-	f	m	e	-	-
Bw1	15-36	2.5Y6/4	sl	f 1 sbk	-	fr	sopo	-	-	f	m	es	-	-
Bw2	36-58	2.5Y4/4	sl	m 2 sbk	-	fr	ssps	f	f	vf	m	es	-	-
Bw3	58-85	2.5Y4/4	sl	m 2 sbk	-	fr	sp	c	m	vf	c	e	-	-
Bw4	85-110	2.5Y4/4	sl	m 2 sbk	-	fr	sp	c	m	vf	f	e	f f d	-
Bw5	110-145	2.5Y4/4	sl	m 2 sbk	-	fr	sp	-	-	-	-	ev	f f d	> 15% lime kankars
Pedon 4 (Pura Subba Pandey Series) Fine loamy, mixed (calcareous), hyperthermic, Typic Halaquepts														
Ap	0-13	2.5Y5/2	cl	m 2 sbk	-	fr	sp	-	-	f	m	es	-	-
Bw1	13-38	2.5Y4/2	cl	m 2 sbk	-	fi	sp	-	-	f	m	es	-	-
Bw2	38-65	2.5Y4/2	cl	m 3 abk	-	fi	sp	f	f	f	c	es	f f d	-
Bw3	65-86	2.5Y5/4	cl	m 3 abk	-	fi	sp	f	c	f	c	es	c f d	-
Bw4	86-115	2.5Y5/4	cl	m 3 abk	-	fi	sp	f	c	f	c	es	c m d	-
Bw5	115-150	2.5Y5/4	cl	m 2 sbk	-	fi	sp	f	c	f	f	es	c m d	-
Pedon 5 (Dhanapur Series) Fine loamy, mixed (calcareous), hyperthermic, Aeric Halaquepts														
Ap	0-17	10YR5/2	SL	f 1 sbk	sh	fr	sspo	-	-	f	m	ev	-	-
AB	17-38	2.5Y4/2	l	m 2 sbk	sh	fr	sps	-	-	f	f	ev	-	-
Bw1	38-60	2.5Y6/3	l	m 2 sbk	-	fr	sp	fm	F	vf	f	ev	f f f	-
Bw2	60-84	2.5Y6/3	l	m 2 sbk	-	fr	ssps	fm	c	vf	f	ev	f f f	-
Bw3	84-103	2.5Y6/4	sl	m 2 sbk	-	fr	sssp	c	c	vf	f	ev	c f d	-
Bw4	103-148	2.5Y4/4	l	m 2 sbk	-	fr	sp	c	c	vf	f	ev	c m d	-

** Symbols used according to Soil Survey Manual notations (Soil Survey Division Staff 2004)*

and sub-angular to angular blocky in structure. Pedon 5 (Dhanapur series) occurs on fluvial channels which were imperfectly drained, dark greyish brown to light yellowish brown in colour. The texture was sandy loam in surface and dominantly loam in sub surface horizons having sub-angular blocky structure. Both the soils (Pedon 4 and Pedon 5) were highly calcareous and alkaline is nature and presence of Fe-Mn nodules and reduced mottles, just after 38 cm depth are evidents to prevailing moist conditions in the soil (Mehta *et al.*, 1969 and Garg *et al.* 2000). The soils were classified as fine loamy, mixed (cal), hyperthermic, typic Halaquepts (P_4) and fine loamy, mixed (cal) hyperthermic, aeric Halaquepts (Pedon 5).

Table 2: Physico-chemical characteristics of soils

Horizon	Particle size			pH	EC (dSm^{-1})	O.C. ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)	Exchangeable Cations [cmol (p+) kg^{-1}]				CEC cmol (p+) kg^{-1}	ESP
	Sand	Silt	Clay					Ca	Mg	Na	K		
Pedon 1 (Pura Ausan Singh Series) Fine loamy, mixed (calcareous), hyperthermic, Typic Calciustepts													
Ap	53.4	28.3	18.2	8.4	4.65	4.8	1.0	3.54	1.12	1.30	0.64	6.60	16.0
Bw1	36.6	28.9	34.5	9.0	2.35	4.0	4.0	6.87	4.06	2.93	1.75	15.61	22.0
Bw2	32.9	31.3	35.8	9.2	2.10	2.4	9.0	7.27	3.84	2.82	1.48	14.41	21.0
Bw3	38.6	28.4	33.0	9.5	1.10	1.8	15.0	6.96	4.55	3.15	2.11	16.77	24.0
Bk	44.8	29.9	25.3	9.7	1.10	1.0	353.3	6.20	4.03	4.41	1.21	15.85	23.0
Pedon 2 (Saiyad Nagar Series) Fine loamy, mixed (calcareous), hyperthermic, Natric Haplustepts													
Ap	60.7	25.0	14.3	10.3	3.20	2.0	8.5	3.46	0.81	3.47	0.89	8.91	39.0
AB	46.6	31.1	22.3	10.1	1.80	1.4	9.0	4.42	1.87	4.78	2.04	13.89	34.0
Bw1	43.3	30.9	25.8	9.6	1.10	1.2	9.0	4.24	2.00	4.02	1.72	12.56	32.0
Bw2	47.6	33.1	19.3	8.3	0.30	1.0	9.0	4.00	1.37	1.95	1.02	9.37	21.0
Bw3	46.9	33.3	19.8	8.2	0.17	1.0	12.5	3.39	1.49	1.84	0.83	8.69	21.0
Pedon 3 (Jagmalpur Series) Coarse loamy, mixed (calcareous), hyperthermic, Natric Haplustepts													
Ap	80.1	11.2	8.8	10.1	1.50	4.3	13.5	2.58	2.10	2.19	0.38	7.80	28.0
Bw1	59.9	28.2	12.0	10.3	1.70	1.6	22.5	4.28	2.54	2.60	0.38	10.90	24.0
Bw2	50.8	30.7	18.5	10.3	1.50	0.2	45.0	5.41	3.84	2.80	0.44	13.65	21.0
Bw3	50.5	36.5	13.0	9.8	1.20	0.2	4.5	3.49	3.54	2.71	0.59	11.43	24.0
Bw4	59.6	29.4	11.0	9.0	0.24	0.2	9.0	4.01	4.04	3.06	0.32	11.48	21.0
Bw5	54.9	26.6	18.5	8.9	0.25	0.2	126.0	2.28	2.19	1.73	0.38	8.58	22.0
Pedon 4 (Pura Subba Pandey Series) Fine loamy, mixed (calcareous), hyperthermic, Typic Halaquepts													
Ap	38.8	31.5	29.8	9.6	0.67	4.1	63.0	2.67	1.34	4.35	0.96	10.30	42.0
Bw1	24.9	41.3	33.8	9.4	0.54	2.2	40.5	1.62	1.17	4.56	1.28	9.55	48.0
Bw2	23.8	46.7	29.5	9.3	0.68	1.6	18.0	2.14	1.60	4.87	1.09	10.90	45.0
Bw3	22.9	39.5	37.5	9.5	0.65	1.4	22.5	5.24	1.97	5.91	0.76	15.00	39.0
Bw4	26.5	46.2	27.3	9.3	0.92	1.0	36.0	5.31	1.90	4.26	1.21	13.56	31.0
Bw5	22.1	48.4	29.5	9.1	0.65	0.8	171.0	4.67	2.82	3.36	0.76	12.26	27.0
Pedon 5 (Dhanapur Series) Fine loamy, mixed (calcareous), hyperthermic, Aeric Halaquepts													
Ap	66.8	20.7	12.5	10.2	1.05	6.8	85.5	1.86	1.09	1.25	1.15	5.50	23.0
AB	47.9	27.5	24.5	9.9	0.37	6.3	93.5	1.59	1.98	1.89	0.64	6.50	29.0
Bw1	42.5	31.5	26.0	9.3	0.19	4.0	82.5	3.56	1.92	1.87	0.64	8.90	21.0
Bw2	41.6	40.8	17.5	9.1	0.14	2.5	94.0	3.36	1.86	3.19	0.64	9.95	32.0
Bw3	69.2	12.3	15.5	9.0	0.14	1.5	74.0	3.23	1.50	1.65	0.70	6.80	24.0
Bw4	38.1	36.9	25.0	9.0	0.19	1.1	94.0	2.85	1.57	1.54	0.68	7.32	21.0

Physico-chemical characteristics

The physico-chemical characteristics of various pedons under study are presented in table 2. The clay content of these pedons ranged from 11.0 to 37.5 per cent. The % clay content was maximum in Pedon 4 and minimum in pedon 3. It is further inferred from the data that clay fraction, in general, is more concentrated in the subsurface layers of the various pedons. Clay accumulation in subsurface horizons may be due to mass movement of fine clay (Pal *et al.*, 1999) through the process of illuviation. These soils were strongly alkaline in nature as their pH of upper horizons (50 cm) is ranged from 9.5 to 10.4. The pH sharply decreased with depth except in Pedon 1. Electrical conductivity (EC) ranged from 0.67 to 4.65 dSm^{-1} in surface horizons of all the pedons and showed a decreasing trend with depth. This trend is probably caused by leaching of soluble salts (Garg *et al.*, 2000) resulting in amelioration of the soil. The organic carbon content ranged from 2.0 to 6.8 g kg^{-1} in the surface soils showing minimum value in Pedon 2 and maximum in Pedon 5.

Decreasing trend of organic carbon with depth in all the pedons was observed as found in central alluvial region of UP (Tiwari *et al.*, 1985). The $CaCO_3$ content of salt-affected soils varied from 0.10 to 35.5 %. In general, the $CaCO_3$ content in all the pedons increased with depth, which explain downward movement of $CaCO_3$ (Joshi and Kadrekar 1987, Pal *et al.*, 1999). Further, a higher amount of $CaCO_3$, in sub soils also deteriorates drainage conditions (Nayak *et al.*, 2000). The Cation Exchange Capacity (CEC) varied from 5.50 to 16.77 cmol (P^+) kg^{-1}. The CEC value in general, increased with increasing clay content, since the soils are low in organic carbon content. Among the exchangeable cations Ca^{2+} and Mg^{2+} were dominant cations followed by Na^+ and K^+. However, the exchangeable Na^+ was higher than Ca^{2+} and Mg^{2+} in Pedon 4 which is characterized by high values of ESP. However, ESP values were greater than 15 in all the pedons at varying depths.

Distribution of salt-affected soils

The information on the degree and extent of salt-affected soils is basic for amelioration of such degraded soils. The following criteria are used for differentiating the degree of salinity and sodicity of salt-affected soils (Sidhu *et al.*, 1995).

Class	Sodicity (pH 1:2.5)	Salinity (EC dSm^{-1}, 1:2.5)
Normal	< 8.7	< 0.8
Slight	8.7 – 9.2	0.8 – 1.6
Moderate	9.3 – 9.5	1.7 – 2.5
Strong	> 9.5	> 2.5

Four kinds of salt-affected soils were identified and delineated (Table 3 and Fig. 1).

Table 3: Distribution of salt-affected soils

Soil salinity/ Sodicity class	Area (ha)	% of TGA*
Normal soils	339621	77.20
Moderately sodic	15184	3.50
Strongly sodic and strongly saline	9146	2.10
Strongly sodic and slightly saline	35615	8.10
Strongly sodic and moderately saline	21620	4.90

**TGA – Total Geographical Area of the district*

The data indicated that nearly 3.4 lakh hectare area (77.2 % of TGA) comes under the category of normal soils and 0.82 lakh hectare area (18.6 %) suffering from salinity/sodicity of TGA problems. About 3.5 % of TGA have a problem of moderate sodicity and about 15 % of TGA is suffered from strong sodicity and accompanied by varying degree of salinity and requiring gypsum or other amendments for their amelioration. However, provision of drainage is essential for the reclamation of these soils.

The study revealed that micro-relief, impeded drainage, repeated cycles of wetting and drying, high water table leads to accumulation of salts at the surface. Sodiumization begins of the surface and relatively low or absent in lower horizons in soils of relatively young geomorphic units but it increases with depth in soils of older surfaces in which sodiumization/salinization starts at the surface and deepens with the time indicating the movement of alkali salts solution or illuviation of deflocculated clay with advanced development.

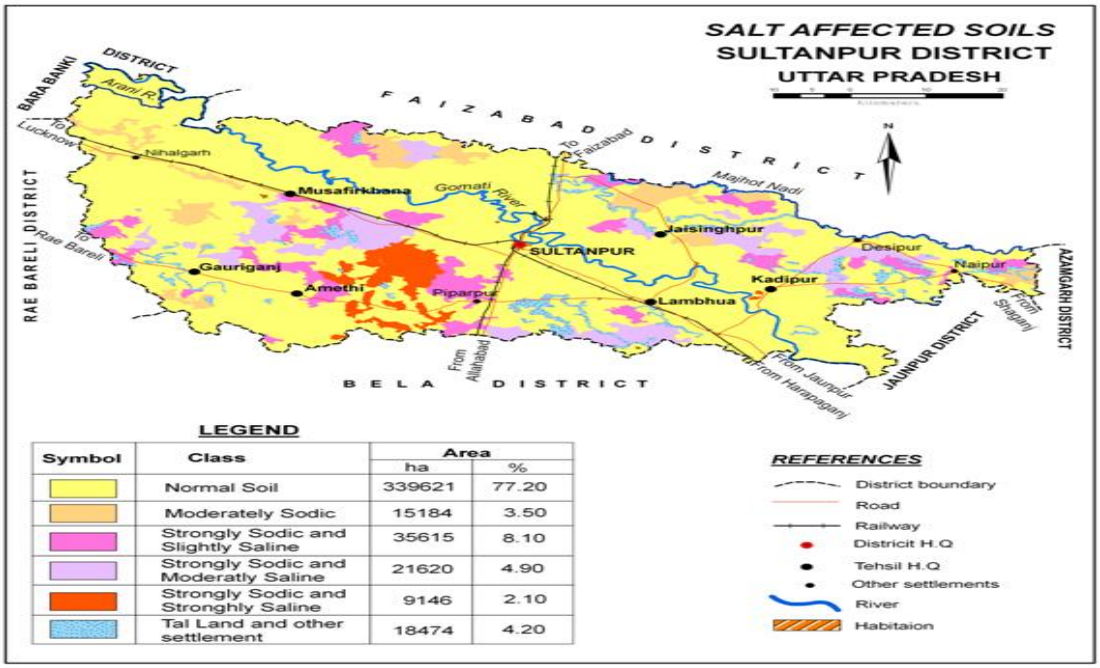

Fig 1: Distribution of salt affected soils

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