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Characteristics and reclaimability of sodic soils in the alluvial plain of Etah district, Uttar Pradesh

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Abstract : Sodic soils are wide spread in the alluvial plains of the Ganga basin primarily located in Uttar Pradesh. The survey conducted using remote sensing data (IRS LISSS II) estimated about 43040 ha (9.7%) of sodic soils in the old alluvial plain, 7594 ha (1.7%) in recent alluvial plain and 2102 ha (0.5%) in the active alluvial plain of Etah district, Uttar Pradesh. Excessively high values of pH, ESP, high precipitation of lime, development of a natric horizon and platy soil structure testifed the complete saturation of exchange complex with Na in sodic soils of the old alluvial plains. The moderate pH and ESP, concentration of Na ions greater than CO_3^- plus HCO_3^- ions in the soil solution, higher amount of amorphous lime than concretions, blocky soil structure and absence of argillic horizons suggests partial sodification in soils of the recent plains. On the other hands, sodic soils of active plains were at the initial stages of sodification as evidenced by lower values of pH (8.8 to 9.6) and ESP 23, equal ionic proportion of Cl^- and CO_3^- and abundance of amorphous lime with few and small lime nodules. The information on differential sodification stages in geomorphic surfaces appear to be useful in planning strategies for the reclamation of sodic soils in Uttar Pradesh.

Additional key words: *Sodification, distribution, management, remote sensing*

Introduction

Etah district lies between 26^0 45' to 28^0 02' N and 78^0 15' to 79^0 20' E covering 4.45 lakh ha with mean annual rainfall of 692 mm and mean annual air temperature of 25.7^{0}C. The topography of the district is governed by fluvial sediments comprising of Old Alluvial Plain (OAP), Recent Alluvial plain (RAP) and Active Alluvial Plain (AAP). The river Ganges and Kali nadi drain the area of the district. The water stagnation in the central and southwest parts of the district is common mainly due to seepage from canals, obstructed drainage due to transport network and other development activities. The weathering of aluminosilicate minerals under the prevailing alternate dry and wet conditions of the semi-arid climate provide a steady supply of alkali carbonates which accumulate in the lower topographic zones to form alkali soils. Using remote sensing techniques, survey was conducted to locate and characterize the sodic soils and assess their extent, formation and reclaimability under different geomorphic plains *viz,* old (OAP, recent (RAP) and active (AAP) alluvial plains.

Material and Methods

Based on land cover characteristics, area affected by salinity and sodicity, degree of sodicity and image chacactericstics, five mapping units (S1 to S5) were identified (Table 1). Sixty eight profiles (with many auger bores) representing different salinity/sodicity classes were studied for their site characteristics and morphology. A well distributed random cross-check auger sampling was also made to assess accuracy in terms of soil composition. The horizon-wise soil samples were analysed for salinity and sodicity using the standard procedures (Richards 1954). The morphological, site characteristics, physical and chemical characteristics and spatial distribution of salt affected soils are described elsewhere (Saxena *et al.* 2004).

Results and Discussion

Old alluvial plain

The OAP is characterised by flat to very gently sloping plains. A number of paleo-channels inter-connecting the oxbow lakes facilitate surface and subterranean flow of water. The landform is stabilized with marked soil development in the form of illuviation, structural development and calcification. The incidences of rising water table due to obstruction in natural drainage and seepage from canals in lower topographical situations have led to large-scale salinization and alkalization at placed like Jalesar, Awagarh, Sakit, Etah and Nidhauli kalan. At village Lakhimpur and adjoining places, surface accumulation of Na-silicate is very common and used for manufacturing glass in Firozabad town.

The soil matrix colour of salt affected soils (SAS) vary from grayish brown to dark grayish brown and dark yellowish brown in the hues of 10YR and 2.5Y. The well defined illuviation of clay and bases in the B horizon has markedly altered the soil colour to darker shades. The soil texture varies from loam, silt loam to clay loam. The presence of 20 to 40 cm thick lime-concretion layers occurring between 60 to 90 cm of soil is an important feature of sodic soils. The size and thickness of lime concretions increased with an increase in soil sodicity. The soil structure of the A horizon of pedons belonging to OS3 and OS4 classes were massive and platy and it was strong angular blocky and columnar in B horizons causing significant reduction in soil permeability. The process of illuviation associated with high ESP has imparted a well-developed natric horizon in these soils.

The soil belonging to OS3, OS4 and OS5 classes had high pH (9.5 to 10.5) and ESP (53 to 97). The soils of OS1 and OS2 classes have pH and ESP lower than 9.5 and 25 respectively. The salt efflorescence was maximum in the surface horizon and decreased with depth. The salt concentration in SAS was lower than the SAS of Haryana and Punjab. This observation is important in view of

Table 1. Image characteristics and nature of salt affected soils

Soil category	Percentage area affected	Land cover characteristics	Image characteristics/surrogate indicators
S1	<10	Normal crop stand of wheat and mustard; poor crop stand of pulses	Deep red and smooth textures; uniform crop textures; pinkish-light, grey-yellow and small parceling (poor crop stand)
S2	10-50	Cropped; occasionally barren	Red plus bluish gray tone; frequent but small patches of white in cultivated area, coarse texture.
S3	25-50	Barren land with salt grasses/*Acacia* vegetation	Light pinkish gray (grass/vegetation), white yellowish tone (barren and medium parceling)
S4	>75	Completely barren lands with 1 - 4 cm salt crust; occasional grasses	Yellowish white to chocolate colour
S5	>75	Completely barren with 3-8 cm salt encrustation	White tone with bluish streaks (oxbows and paleo-channels).

Table 2. Physical and chemical characteristics of salt affected soils (0-30 cm) of old alluvial plains

Characteristics		Mapping units				
		OS1	OS2	OS3	OS4	OS5
Depth (cm)		0-15	0-13	0-13	0-12	0-10
pH		8.5	9.4	10.1	10.0	9.7
ECe (dSm^{-1})		1.8	2.5	3.8	28.3	73.1
ESP		16.4	23	80	87	70
Ca^{2+}+Mg^{2+}(meL^{-1})		4.2	8.0	3.0	2.1	31.0
Na^+ (meL^{-1})		31.6	18.2	27.0	388.0	1030.0
K^+ (meL^{-1})		0.97	0.08	0.13	0.48	8.00
Cl^- (meL^{-1})		29.2	8.0	4.0	9.0	385.0
SO_4^{2-} (meL^{-1})		0.9	10.0	0	1.8	28.0
HCO_3^- (meL^{-1})		3.0	6.0	19.0	156.0	337.0
CO_3^{2-} (meL^{-1})		0.5	2.0	18.0	228.0	362.0
Clay (%)	A horizon	17.2	20.4	18.2	16.5	15.1
	B horizon	24.4	26.2	34.5	28.9	24.9

deflocculation effects of salts namely sodium and calcium carbonates/bicarbonates on soil particles and leaching of replaced Na during reclamation.

The relevant characteristics of the surface horizons of sodic soils of OAP are given in table 2. The surface horizons associated with high values of pHs, ECe and ESP are highly sodic. The impaired physical and chemical properties of these soils have led to their abandonment to farming and induced water and wind erosion. The continuous soil loss by erosion has gradually reduced the thickness of the A horizon. An inverse relationship has been observed between the thickness of A horizon and degree of soil pH and EC (Figure 1). Like sodic soils of Haryana and Punjab, sodic soils of Etah district have Na^+ as the dominant cations. Among anions CO_3^-+ HCO_3^- are more than Cl^- and SO_4^- (Bhargava 1988).

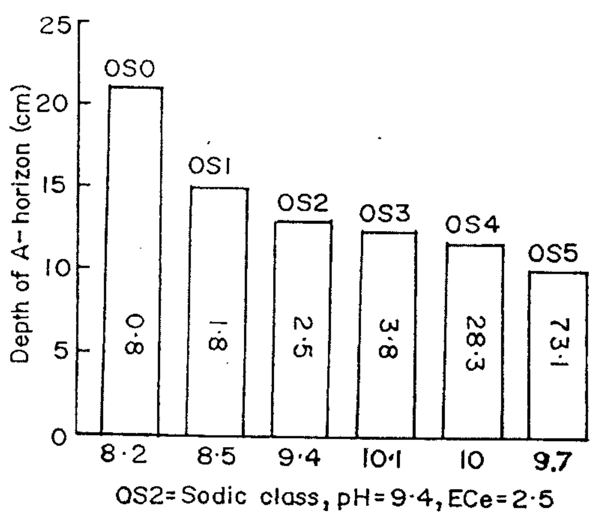

Fig. 1. Relationship between thickness of horizon, pH and EC

It is observed that sodium is in complete saturation with carbonate plus bicarbonates in OS3 and OS4 classes, thus making them stabilized and equilibrated sodic soils. The sodic soils of class OS2 appear to be in the process of sodification as there is still scope for increament of total soluble ions in the soil profile, more specifically CO_3^- +HCO_3^- ions to completely saturate and equilibrate with Na ions.

Recent alluvial plain

The RAP located between the old and active plain is comparatively younger than the OAP and older than the AAP. The RAP merges with the OAP with very gentle

Table 3. Physical and chemical characteristics of salt affected soils (0-30 cm) of recent alluvial plain

Characteristics		Mapping units				
		RS1	RS2	RS3	RS4	RS5
Depth (cm)		0-14	0-11	0-12	0-10	0-9
pHs		8.6	9.0	9.7	10.5	10.1
ECe (dSm^{-1})		0.9	2.4	1.4	6.4	29.4
ESP		8.0	11.0	27.0	63..0	44.0
$Ca^{+2}+Mg^{2+}$(meL^{-1})		4.0	7.0	4.0	5.0	9.0
Na^{+} (meL^{-1})		6.0	20.0	11.0	63.0	398.0
K^{+} (meL^{-1})		0.1	0.1	0.1	0.1	2.0
Cl^{-} (meL^{-1})		4.0	9.0	5.0	20.0	136.0
SO_4^{2-} (meL^{-1})		0	0	0	1.0	0
HCO_3^{-} (meL^{-1})		2.0	12.0	3.0	22.0	86.0
CO_3^{2-} (meL^{-1})		4.0	5.0	6.0	25.0	188.0
Clay (%)	A horizon	20.0	12.0	8.8	16.5	16.0
	B horizon	34.8	22.2	22.7	30.3	22.8

slopes but the demarcation between the RAP and AAP is well marked by high relief in the form of severely eroded terraces running parallel to Budhi Ganga along the towns of Soran, Ganjdudwara and Patiali. The spread of SAS in RAP is not as extensive as in case of OAP, but some specific topographical configurations at places like Sidhpura, Jaithra and Aliganj has given rise to large stretches of SAS.

Based on the severity and spatial extent, five classes of SAS were identified in the RAP. The surface colour of RS1 to RS5 classes vary from grayish brown to dark grayish brown and dark yellowish brown in the hues of 10YR and 2.5Y. The illuviation of clay in the B horizons have imparted darker colour to some parts of the soil matrix with chroma of 4 to 5 and value of 2 to 4. The soil texture is sandy loam and loam in the surface and loam, silt loam and clay loam in the lower layers. The soil structure is generally blocky but platy and massive structures are also observed in the surface horizons. The SAS are highly calcareous with abundance of amorphous lime in the sub-surface layers. However, presence of small and medium-sized lime concretions in the sub-surface layers of few profiles at villages Nagla beech and Jawahar Nagla indicate that formation of nodule (calcrete) is a recent phenomenon in these soils.

The soil pHs in SAS varied from 8.6 to 10.5. The surface layers of soil classes (RS1, RS2) are moderately sodic pH (8.6 to 9.1) but higher degree of sodification has occurred in the lower layers as evidenced by pHs values of 9.6 and 10.1. The whole profile of the soils of RS3, RS4 and RS5 classes are highly sodic with pHs ranging from 9.7 to 10.5 and ESP from 44 and 80.

Due to the recent origin, *in-situ* weathering has released lower amounts of salts in the soils of this zone. The topographical configuration and land drainage further prevented large-scale accumulation of salts in the zone. Except for soil class RS5, which had ECe value of 29.4 dSm^{-1}, the other soil class have lower salt concentration.

The some important characteristics of the surface horizons of sodic soils of RAP are given in table 3. These soils have relatively low salt content (ECe 0.9 to 29.4 dSm^{-1}). Amongst the cations, sodium is the dominant cation followed by calcium plus magnesium. Amongst anions, carbonates plus bicarbonates are the dominant one followed by chlorides but sulphates are absent or present

Table 4. Physical and chemical characteristics of surface horizon of salt affected soils of active alluvial plain

Characteristics		Mapping units				
		AS1	AS2	AS3	AS4	AS5
Depth (cm)						
Salt layer		0-0	0-0	0-6	0-7	0-5
Soil layer		0-17	0-17	6-29	7-24	5-20
pHs		8.8	8.8	9.0	10.3	9.6
ECe (dSm^{-1})		0.9	7.2	10.0	16.9	26.4
ESP		4.0	14.0	8.0	24.0	23.0
Ca^{2+}+Mg^{2+} (meL^{-1})		5.0	12.0	14.0	10.0	11.0
Na^{+} (meL^{-1})		5.0	75.0	100.0	196.0	385.0
K^{+} (meL^{-1})		0.4	0.8	1.0	0.7	7.2
Cl^{-} (meL^{-1})		6.0	78.0	106.0	110.0	302.0
SO_4^{2-} (meL^{-1})		0.0	17.0	6.0	10.0	13.0
HCO_3^{-} (meL^{-1})		4.0	2.0	3.0	42.0	37.0
CO_3^{2-} (meL^{-1})		0	0	0	57.0	42.0
Clay (%)	A horizon	12.5	25.7	18.7	10.6	15.6
	B horizon	15.6	17.3	20.4	18.8	14.0

in traces. The soil class RS5 had relatively higher salt content (ECe 29.4 dSm^{-1}) in the surface horizon and significantly decreased with depth. In this case, a good amount of chlorides are also present in soil solution.

Active alluvial plain

The area between river Ganga and terraced plain of recent alluvium *i.e.* active alluvial plain is frequently inundated by the floods of river Ganges and its tributaries. The AAP is characterized by cutting and depostional fluvial featueres in the form of old channels, ox-bows, river meanders, sandbars and eroded levees. The farming activities are greatly affected by frequent flooding, siltation and waterlogging. The younger alluvium, typical of flood plain, comprising of coarser soil strata had poorly developed soil. The specific hydrological conditions have led to the accumulation and redistribution of salts at places like Bhaura, Labher, Yaqutganj and Kadarwadi *etc.*

The soil colour, texture and structure are greatly influenced by lithological discontinuities. The SAS are highly calacareous with presence of amorphous lime in the substratum. The distribution of clay in the soils of active alluvial plain showed irregular distribution with depth owing to discontinuity in parent materials. The clay content of surface horizons ranged from 12.5 to 25.7 per cent. Though the calcium carbonate is present in all the soils in amorphous form, but lime nodule fromation have started in the middle horizons of AS4. Based on the degree of sodicity and spatial distribution, the SAS in AAP has been mapped into five classes (AS1 to AS5). The pHs in the surface horizons of AS1 to AS3 soils ranged from 8.8 to 9.0 (Table 4) and slightly higher build up in the sub-surface horizons (9.1 to 9.5). The surface horizons of AS4 and AS5 have higher soils pHs ranging from 9.6 to 10.3 and decreased with depth to the tune of 9.1 to 9.4. The ESP values are lower than 14 in AS1 to AS3 but the surface horizons of AS4 and AS5 show ESP values ranging between 22 and 27. The ECe value in AS1 is less than 1.0 dSm^{-1} throughout the soil depth. In other four soil classes *i.e.* AS2 to AS5, ECe values ranged from 10.0 to 21.4 in the surface horizons and decreased with depth.

Table 5. Spatial distribution of salt affected soils in Etah district

Salt affected soils unit	Distribution of SAS in geomorphic sub-regions (ha)		
	Old alluvial plain	Recent alluvial plain	Active alluvial plain
S1	440.4	95.0	26.0
S2	3260.4	1134.2	560.8
S3	8275.9	2794.4	779.5
S4	26149.2	3066.2	492.5
S5	4914.6	504.2	243.7
Area of salt affected soils	43040.5	7594.0	2102.5
Area of geomorphic plain	1,82,137	1,80,413	82,550
Per cent area affected TGA (4,45,100 ha)	9.7	1.7	0.5
Percentage of geomorphic sub-region	23.6	4.2	2.5

Extent of sodicity in different geomorphic plains

The SAS of OAP have well developed angular blocky/columnar structure, argillic horizon, hard kankar pan and are associated with very high soil pH and ESP. The soils of RAP with cambic B horizons had segregation of lime in nodular from and medium to high ESP. The lime was mostly in amorphous form and the ESP was low. The SAS of AAP showed lithological discontinuity.

Spatial extent of SAS in different geomorphic plains

The actual areal extent of classes namely S1, S2 and S3 was worked out by reducing the polygon area of classes S1, S2 and S3 by < 10%, 10-25% and 25-50% respectively as mentioned in mapping legend (Saxena *et al.* 2004). In case of SAS classes S4 and S5, total polygon area was taken as actual area (Table 5). The polygon-wise area of classes S1 and S2 was 39567.6 ha (OS1: 8808.6, OS2: 18631.1, RS1:1919.8, RS2: 6481.7, AS1:521.4, AS2:3205 ha) but after respective corrections, the actual area was computed to 5516.9 ha (OS1:440.4, OS2: 3260.4; RS1: 95.0, RS2: 1134.2; AS1: 26.1, AS2: 560.8 ha). Similarly the actual area under SAS classes *i.e.* OS3, RS3 and AA3 was calculated to 11,849.5 ha by reducing the respective polygon area by 25 to 50% as mentioned above. In case of SAS classes OS4, RS4, AS4, OS5 and AS5, total polygon area was considered as actual area.

The data (Table 5) indicates that a total of 52,737 ha (11.9 % of district) is covered by SAS in Etah district. The problem of sodicity is more severe in the soils of old alluvial plains where it occupies nearly 9.7 per cent area. The sodicity problem in the recent and active alluvial plains is less and cover only 1.7 and 0.5 per cent area respectively.

Reclaimability of sodic soils in different geomorphic plains

Amongst three plains, the soil of old alluvial plain are severely affected by sodicity that occupy middle and lower parts of the gently sloping plain. These sois have high pHs (10.0 to10.6) and clay is completely saturated with exchangeable Na (ESP 80 and more). The soils are highly calcareous and bulk of the lime has already been precipitated in the form of lime concretions. Due to high degree of sodification, these soils are not under cultivation. The soil solutions, low in electrolyte concentration, but dominant in CO_3^- plus HCO_3^- ions have enhanced the saturation of exchange complex of soil with Na. The dissolution of applied gypsum will provide soluble Ca for Na replacement and also sufficient electrolytes to the irrigation water to prevent clay dispersion. This will improve the permeability of soil and facilitate removal of replaced Na. In pockets, with good quality ground water, vertical drainage through shallow tube-wells can also prove effective. The dissolution of

$CaCO_3$ by the CO_2 produced by growing plants will further supply needed Ca and electrolyte concentration to accomplish reclamation. The major difference in the sodicity hazards between soils of OAP and RAP is that the former showed the proportionate occurrence of sodium and carbonate plus bicarbonate whereas the later showed wide variation. The higher precipitation of $CaCO_3$ in OAP may facilitate easy and low cost reclamation with lower doses of gypsum. As indicated by the moderate values of pH and ESP, the sodic soils of AAP are undergoing the initial phases of sodication process. The soil solution dominates in NaCl rather that Na_2CO_3 and $NaHCO_3$. The $CaCO_3$ present in amourphous form than concretions showed contrasting features in sodic soils occurring in OAP and RAP.

References

Bhargava, G. P. and Abrol, I. P. (1978). Characterisation of some typical salt affected soils of Uttar Pradesh. Report No. 6, CSSRI Karnal, India.

Bhargava, G. P. (1988). Occurrence of salt affected soils in a toposequence in north western part of Indo-Gangetic alluvial plain. *Journal of the Indian Society of Soil Science* **36,** 303-307.

Bhargava, G. P., Pal, D. K., Kapoor, B. S. and Goswami, S. C. (1981). Characteristics and genesis of some sodic soils in the Indo_Gangetic alluvial plain of Haryana and Uttar Pradesh. *Journal of the Indian Society of Soil Science* **19,** 61-70.

Oster, J. D. and Shainberg, I. (2001). Soil response to sodicity and salinity: Challenges and Opportunity. *Australian journal of Soil Research* **39,** 1219-1224.

Richards, L. A. (Ed) (1954). 'Diagnosis and improvement of Saline and Alkali Soils'. Handbook No. 60 *USDA,* Washington, D. C.

Saxena, R.K., Verma, K.S. and Barthwal, A.K. (1991). Assessment of land degradation hazards in Etah district, Uttar Pradesh using Landsat data. Photonirvachak: *Journal of Indian Society of Remote Sensing* **19**, 83-84.

Saxena, R.K., Sharma, R.C., Verma, K.S., Pal D.K. and Mondal, A.K. (2004). Salt affected soils in Etah district, Uttar Pradesh. NBSS & CSSRI Publ. No. 108.

Sharma, R. C., Saxena, R. K. and Verma, K.S. (2000). Reconnaissance mapping and management of salt affected soils using satellite images. *International Journal of Remote Sensing* **21**, 3209-3218.