Mapping of Salinity/Sodicity Levels for Improving Reclamation Strategy in Etah district

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Abstract: *The precise delineation of salt affected soils by using multispectral TM FCC and B/W Tm band 6 (10.4 to 12.5 μ m) made possible to develop the relationship between mapping unit and salinity/alkalinity levels. The salt affected soils are categorised into non saline-non alkali (S1); saline-alkali (S2); Alkali (S3), and sodic (S4, and S5) in Awagarh and Jalesar blocks of Etah district of Uttar Pradesh. Although in S1 soils, the salts are low but Na^+ dominate the exchange complex resulting moderate alkalinity hazards to crop plants. Slightly high values of Na^+(22 mel^{-1} and Cl^- (16 mel^{-1}) together with SO_4^{2-}(13.0 mel^{-1}) in S2 soils cause moderate alkalinity and moderate salinity hazards. An excess quantity of Na^+ (185 mel^{-1}) in the presence of $HCO3^-$ (211 mel^{-1}) SO_4^{2-} (167 mel^{-1})and Cl^- (144mel^{-1}) in S3 soils result into very strong salinity and severe alkalinity hazards but a slight different trend was observed in the soils of S5 unit where the Ionic concentration was dominated by Na^+ 1214, followed by SO_4^{2-} : 872, Cl^-:168, and CO_3^{2-} :164 mel^{-1}), present very severe salinity and severe alkalinity hazards. Thus mapping units vary in their ameolarative requirement. Huge input of chemical amendments in highly deteriorated S4 and S5 soils (in recent past) has not produced the desired results.* **(Key words :** *TM data, salinity/alkalinity)*

The soil salinity/alkalinity is becoming a major problem in irrigated agriculture in semiarid and arid climate. The dynamics of salt affected soils and soil water management techniques to mitigate its adverse affects are well understood. However, their problem are more elusive and consistent in identification and accurate mapping. Attempts have been made by several workers (Sharma *et al.*1988; Rao, *et al.* 1981; Dwivedi et al. 1992; Verma *et al*; 1994) to delineate the spatial extent of salt affected soils, but efforts to develop relationship between delineated unit and salinity/alkalinity levels are still lacking. Present study aims to achieve the indicated lapses and to suggest a changing concept in reclamation strategies.

MATERIAL AND MEHTODS

The study area is a part of Indo-Gangetic alluvial plain and lies between 26^0 45' and 27^0 N Lat., and 78^0 45' and 89^0 15' E Long. The climate is semi-arid subtropical with mean annual rainfall of 602 mm and mean annual air temperature of 25.7^0 C. The area is characterised by the presence of cut off channels, oxbows and old levees. Stagnation of water occurs every year due to the intermittent drainage net work. The problem of water stagnation is further aggravated due to flooding irrigation system. Unlined canals lie above the ground, has encouraged seepage losses resulting a high water table; a causative factor for salt formation. The area irrigated accounts to 78 per cent in Awagarh and 82 per cent in Jalesar block.

Salt affected and other degraded soils were mapped by visual image interpretation technique coupled with field studies. LANDSAT TM FCC 145-41 (1:50,000) of 9th March 1986 and IRS FCC of 20th March, 1991 was procured along with the diapositive of TM thermal band (10.4 to 12.5 μm). The diapositives were enlarged on Procom II to distinguish salt affected and droughty soils. The area was calculated using average value of class interval showing percent area covered by salts and rest of the area of the mapping unit is treated as vulnerable. Ground truth verification and soils studies in each mapping unit was undertaken during May, 1988. The soil samples collected were analysed for particles size distribution, pH, OC, $CaCO_3$, ECe, exchangeable cations and ESP using the standard procedures (Richards 1954). The soils were grouped into salinity/alkalinity classes as suggested by Richards (1954), Bhargava *et al.* (1976), and Sehgal *et al.* (1987). The gypsum requirement were worked out using graphical model developed by Abrol *et al.* (1990). Soils were classified as per Soil Survey Staff (1992).

RESULTS AND DISCUSSION

Image Interpretation : The interpretation of high resolution (30 meters), TM FCC of 1:50,000 scale facilitates in delineating more number of land units suffering from degradation hazards. They are (a) salt affected lands : S1: <10% area affected; S2: 10-30%; S3 30-50%; S4: 50-75%; S5: >75%, (b) waterlogged areas: W1 - slight; water stagnation in the soil profile < 6 months; W2 - moderate : water stagnation in the soil profile > 6 months; and (c) droughty areas : D1 - slight: AWC 50-100 mm; D2 - moderate: AWC is < 50 mm. The data of 1st November indicated the lands affected by salinity/alkalinity are in association with waterlogging. Most of the waterlogged units in November month appeared as salt affected in March data.

Locational features such as left out channels, oxbows, ponds and land use, though to some extent have helped in making distinction between saline/sodic and droughty soils but their appearance by dull white colour tone on FCC posed problem in their demarcation. However, greater precision in their demarcation was achieved by integration of thermal band (10.4-12.5 μm) with TMFCC (band 2,3,4) interpretation (Saxena *et al.* 1991).

The degree of soil salinity/alkalinity influences the land cover and land use pattern and in turn exhibits different tone, texture and pattern on the TM FCC. Sinanuwong, S. (1980) has also observed these variation in reflectance due to the presence of salt or through surrogate indicators of salt such as uneven growth of cultivated vegetation, the presence of bare spots and/or salt tolerant vegetations, and water retained by the soils. Variable ground detail registered in the form of tone texture and pattern on TM FCC such as uniform crop stand by deep red and smooth texture (S1), patchy crop stand by red + bluish grey tone (S2); barren lands with salt grass by light pinkish grey + yellowish white tone (S3); completely barren lands by yellowish white tone (S4) and completely barren lands with salt efflorescence (7-18cm) at surface by yellowish white tone with bluish streaks (S5) have enabled to distinguish the degree of soil salinity/alkalinity.

Soil Characteristics : Soil matrix colour of salt affected soils (SAS) of S1 to S5 varies from greyish brown to dark grayish brown and dark yellowish brown in the hues 10YR and 2.5 YR (Table 1). The texture varies from loamy sand to sandy loam in droughty soils. The SAS are highly calcareous and show progressive downward increase of lime or formation of kankar pan. Soils of S3, S4 and S5 showed strong to severe alkaline reaction with pH ranging from 9.5 to 10.5 where as S1 and S2 soils have moderate alkaline reaction. The ESP was found to vary from high to very high, (70 to 97) in S4 and S5 and moderately high, (20 to 53) in S3 soils. Salt efflorescence at the surface, and decreasing trend of ECe in the profile indicate excessive accumulation of salts in the surface horizons. The pedons S3 and S4 have coarse strong columnar structure in B horizon with massive or platty structure at the surface. The soils of S5 unit characterises by the presence of 7-18cm thick salt efflorescence at the surface which is about 2 per cent but it abruptly reduces in the underlying horizons (0.4 to 0.8%). Salt deposition in the micro low positions is much higher than the micro high and vice versa in case of alkalinity.

In general SAS are more deteriorated in the surface horizons and have CO_3^{2-} and HCO_3^- as dominant anions followed by Cl^- and SO_4^{2-} (Bhargava *et al.* 1988). However, the chemical estimation of studied soils have shown a little different trend (Table 2). The distribution of soluble cations and anions in the profile is illustrated in Fig. 1.

Na^+ is dominant cation in all the mapping units

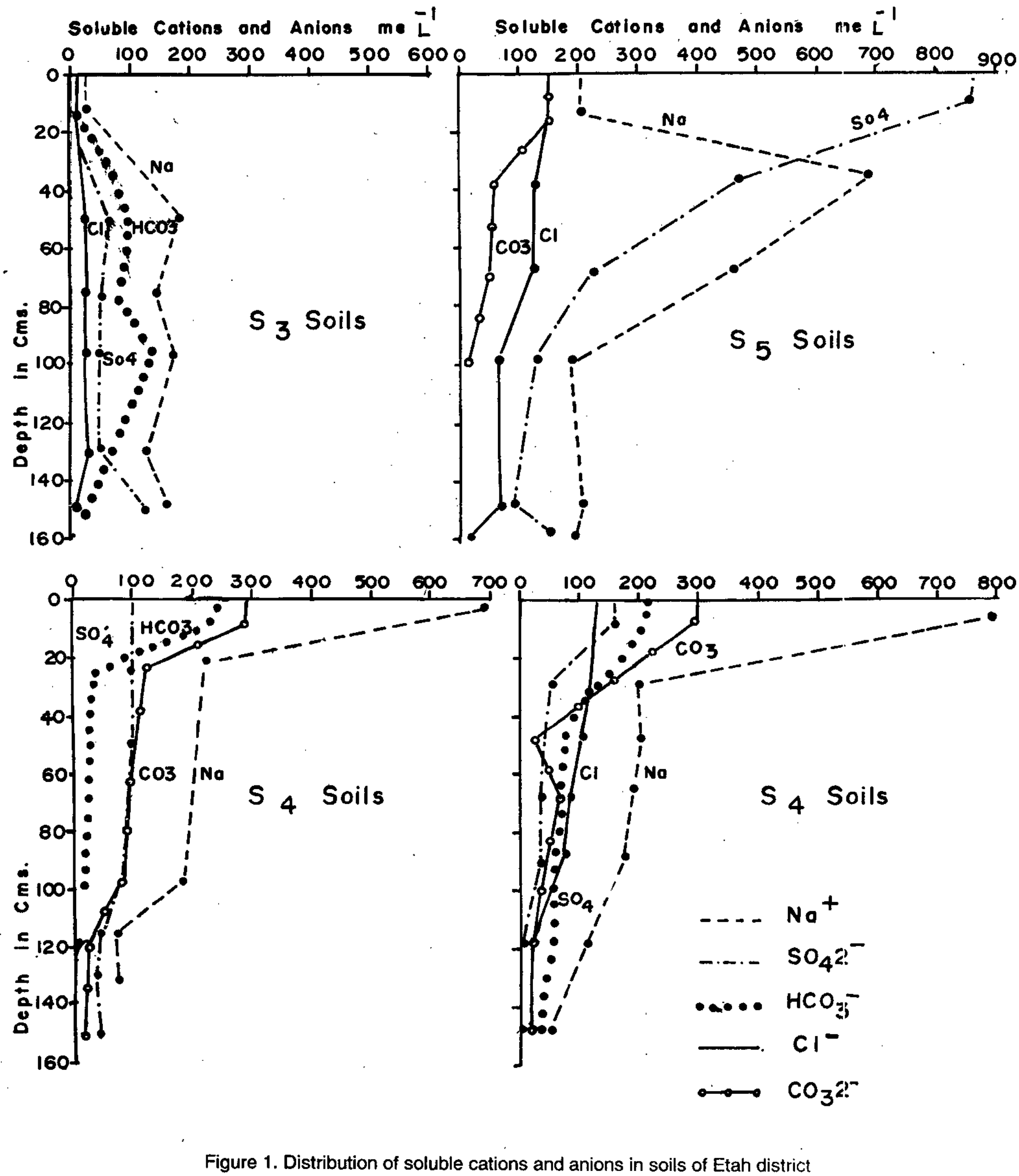

Figure 1. Distribution of soluble cations and anions in soils of Etah district

TABLE 1. Characteristics of soils of Awagarh and Jalesar blocks, Etah Dist.

Depth (cm)	Colour	Silt	Clay (%)	Tex-ture	pH (1:2)	ECe (dsm^{-1})	$CaCO_3$ (%)	ESP (%)	Sali-* nity-class	Alka-* linity class
S1 - TYPIC USTOCHREPTS (NON SALINE-NON ALKALI) PAWAH										
0-11	10YR 5.5/3	38.3	17.3	l	8.3	0.90	1.4	1.9	VS	S
11-41	10YR 5/3	39.2	21.4	l	8.2	0.90	2.1	2.9	VS	S
41-71	10YR 5/3	41.2	22.7	l	8.5	1.31	8.5	3.7	VS	M
71-108	2.5YR 4/3	40.5	25.8	l	8.0	0.07	25.7	4.8	VS	S
S2 - AQUIC USTOCHREPTS (SALINE-ALKALI) LEHRA										
0-15	2.5Y 6/2	50.4	25.5	Sil	8.5	0.9	1.4	8.8	VS	M
15-40	2.5Y 6/2	55.5	30.0	Sicl	8.5	7.1	2.1	13.1	M	M
40-62	2.5Y 6/2	44.9	25.4	l	8.5	0.7	2.1	5.5	VS	M
62-90	2.5Y 6/2	31.4	27.0	cl	8.5	0.5	3.2	60.8	VS	S
90-110	2.5Y 6/2	29.7	28.0	cl	8.5	0.4	1.4	7.2	VS	M
110-140	2.5Y 6/2	26.6	27.7	cl	8.3	0.3	-	5.6	VS	S
S3 - TYPIC NATRUSTALFS (ALKALI) CHITRAPUR										
0-13	2.5Y 7/2	41.5	9.8	sl	8.2	2.0	1.4	4.0	VS	S
13-50	2.5Y 5/2	41.5	24.0	l	9.5	4.0	4.2	20.0	S	St
50-75	10YR 3/3	35.4	35.8	cl	9.8	4.7	2.9	53.0	M	St
75-96	10YR 3/3	42.2	32.2	cl	9.7	4.4	2.1	49.6	M	St
96-130	10YR 4/4	33.0	30.0	cl	9.7	4.3	2.9	48.0	M	St
130-150	10YR 5/4	31.4	25.0	l	9.5	3.6	3.6	39.8	s	St
S4- TYPIC NATRUSTALFS (SODIC) HASANGARH										
0-10	2.5Y 6.5/2	53.6	10.6	sil	10.0	17.4	3.6	86.8	VSt	Sv
10-30	2.5Y 6/2	56.0	12.4	l	10.5	12.9	2.5	94.0	St	Sv
30-50	2.5Y 4/4	52.3	27.6	cl	10.5	6.3	3.3	86.0	M	Sv
50-74	2.5Y 6/4	50.0	26.4	sil	10.3	4.8	16.8	71.0	M	Sv
74-90	2.5Y 6/4	54.0	24.3	sil	10.2	6.0	16.9	71.0	M	Sv
90-120	2.5Y 5/4	46.0	21.7	l	10.1	6.5	10.7	72.0	M	Sv
120-150	2.5Y 5/4	65.4	23.8	sil	-	6.7	19.6	60.0	M	-
S5- NATRIC CAMBORTHIDS (SODIC) HASANGARH										
0-18	2.5Y 7/2	46.9	13.1	l	10.5	62.9	2.1	58.3	VSv	Sv
18-40	10YR 5/4	47.0	26.9	cl	10.4	9.0	2.5	97.6	St	Sv
40-70	10YR 5/4	48.0	30.0	cl	10.5	5.8	2.5	97.0	M	Sv
70-102	10YR 5/4	51.4	32.7	sicl	10.3	4.9	3.2	84.6	M	Sv
102-150	2.5Y 4/4	59.3	30.0	sicl	10.3	2.7	12.1	80.3	S	Sv
150-160	2.5Y 4/4	48.6	29.8	cl	10.2	2.5	16.8	70.0	S	Sv

* Salinity/alkalinity hazards based on Sehgal *et al.* (1987)

Salinity Class			ECe	Alkalinity Class			pH(1:2)	ESP
Very slight	-	VS	0-2	Slight to negligible	-	S	7.3 - 8.3	<15
Slight	-	S	2-4	Moderate	-	M	8.3 - 9.0	15-30
Moderate	-	M	4-8	Strong	-	St	9.0 - 9.8	30-50
Strong	-	St	8-15	Severe	-	Sv	> 9.8	>50
Very strong	-	Vst	15-25					
Severe	-	Sv	25-50					
Vere Severe	-	VSv	> 50					

TABLE 2. Cations and anions in saturaion extract of the soils of Awagarh and Jalesar blocks, Etah district.

Characteristics	Mapping units				
	S1	S2	S3	S4	S5
Depth (cm)	0-11	0-15	13-50	0-10	0-18
pH	8.3	8.5	9.5	10.0	10.5
ECe (dsm^{-1})	0.9	7.1	4.0	17.4	62.9
ESP	1.9	8.8	20.0	86.6	58.3
Ca^{+}(mel^{-1})	3.2	5.9	4.0	1.0	2.6
Mg^{2+}(mel^{-1})	1.9	3.2	-	0.3	0.7
Na^{++}(mel^{-1})	10.7	21.7	185.0	823.0	213.7
K^{+}(mel^{-1})	0.4	0.5	0.5	4.0	0.6
Cl^{-}(mel^{-1})	12.5	16.3	30.0	144.0	167.5
SO_4^{2-}(mel^{-1})	1.7	2.0	79.5	167.3	871.8
HCO_3^{-}(mel^{-1})	2.0	13.0	80.0	211.0	13.7
CO_3^{2-} (mel^{-1})	-	-	-	306.0	164.0

showing an increasing trend from S1 to S4 categories. In the soils of S4 unit, the CO_3^{2-} is a dominant anion and is associating with moderately well drained micro high position of the landscape. The SO_4^{2-} and Cl^- are dominant anions followed by CO_3^{2-} in S5 soils which might have deposited at the surface in the form of salt efflorescence due to fluctuating water table in the micro low topographic conditions. Anions, in general, are low in S3 category but the concentration of HCO_3^- and SO_4^{2-} is observed below 75cm depth which show potentiality of soil for further degradation. The soluble anions is low in S2 soils even much less in the S1 soils but heir high values of ESP still require separate treatment for reclamation.

Soil Taxonomy : The morphology, and physical and chemical characteristics of S5 soils suggest that the soil moisture control section may remain dry for longer duration. The plants may also not be in position to grow when salt is around 2 per cent in a plough layer. During field traversing an encrustation of salt varying from 10-18 cm was observed on the surface in S5 unit. Despite the presence of clay enriched B horizons but the very fine stratification and lack of clay skins (10X) preclude its placing in Alfisol order. Based on these considerations the pedon S5 has been classified as Aridisols. Since the requirement of 2 per cent salt and product of its thickness in centimeters and salt percentage by weight of 60 is not fulfilled. The pedon is classified Camborthids. It also meet all the other requirement of Typic except the SAR, and hence qualify for Natric Camborthids (Yermic-Cambisols).

The ECe is low (2.0 to 4.7 dsm^{-1}), pH is high (9.8) in the soils of S3 unit. But both pH (10.5) and ECe (17.4 dSm^{-1}) values are high for S4 units indicating very high concentration of sodium ions. High sodium saturation causes peptization releasing clay which moves down, fills the voids and forms the cutans (Murphy *et al.* 1982). The presence of coarse strong columnar structure, appreciable increase in fine clay and regular decrease of sand on clay free basis between 50 to 96 cm (S3) and 30 to 90 cm (S4) and are other supportive evidences to quality for Typic Natrustalfs (Hapilic/Calcic-Slolnetz).

The soils of S2 and S1 units under Typic Ustochrepts (Eutric/Calcaric-Cambisols) are with or without saline phase. Aquic phase was associated with W2 unit. Droughty soils were key out as Typic Ustipsamments and Typic Uslochrepths. The land degradation units S1W1 and S2W2 are saturated with water for longer time and have slightly high sodium concentration and do not show high salt appearance on the surface. They have been classified as Aeric Halaquepts (Gleyic/Stagnic-Solonetz) and Typic Naturastalfs.

Soil Salinity/Alkalinity Hazards : Data on field and laboratory observations show the varying extent of problem in mapped soils. Further correlation of extent of problem with degree of salinity and/or sodicity enabled to group the mapped soils into five categories as under.

Category	Mapping unit affected (%)	Extent of salinity and alkalinity
S1	<10	Very slight salinity, moderate alkalinity
S2	10-30	Moderate salinity, and moderate alkalinity
S3	30-50	Slight to moderate salinity strong alkalinity
S4	50-75	Very strong salinity severe alkalinity
S5	>75	Very severe salinity and severe alkalinity

TABLE 3. Salt affected and associated degraded soils (ha) in Awagarh and Jalesar bolcks Etah District, Uttar Pradesh.

Mapping units	Awagarh	Jalesar	Total
Soils with salinity/alkalinity hazard	5097 (17.7)	1097 (3.7)	6194 (137)
S1 limited extensive (< 10%)	112 (0.4)	25 (0.08)	137
S2 moderate extensive (10-30%)	290 (1.0)	230 (0.9)	520
S3 Extensive (30-50%)	936 (3.2)	183 (0.1)	1119
S4 Very extensive (50-75%)	1645 (5.7)	144 (0.5)	1789
S5 Extremely extensive (>75%)	2114 (7.4)	515 (1.7)	2629
Soils likely to be affected with salinity/alkalinity	5974 (20.8)	1828 (6.0)	7802
Soils with salinity/alkalinity associated with waterlogging	338 (0.7)	75 (0.2)	413
S1W1 Limited	200 (0.7)	40 (0.1)	240
S2W2 Moderate	138 (0.5)	35 (0.1)	173
Soils with waterlogging hazards	611	11	622
W1 Slight	311 (1.1)	-	311
W2 Moderate	300 (1.0)	11 (0.04)	311
Droughty soils	1009 (3.5)	9661 (32.2)	10670
D1 Slight	486 (1.7)	6913 (23.1)	7399
D2 Moderate	523 (1.8)	2748 (9.1)	3271
Total degraded land	13029 (45.3)	12672 (42.3)	25701
Non-problematic land	15661 (54.7)	17300 (57.7)	32961
Total area of blocks	28690 (100)	29972 (100)	58662

Figures in parantheses indicate % of the total block area.

Soil Properties and Management Requirement : The SAS of Jalesar and Awagarh blocks were classified into saline-alkali : pH <8.5, ECe > 4 dsm^{-1}, ESP >15), alkali : (pH > 8.5, ECe< 4 dSm^{-1}, ESP > 15) and sodic (pH 8.5, ECe > 4.0 dsm^{-1}, ESP > 15) classes. The concentration Na^+ 10.7 mel^{-1} cl^- (12.5 mel^{-1}) in S1 soils is low (Table 3) with slightly high values of pH:8.3 and ECe: 0.9 dsm^{-1}, characterise the soils into non saline and non alkali class. The soils offer moderate alkalinity hazards to crop plants as such these require approximately 1 tonne ha^{-1} gypsum to grow a normal crop (Abrol *et al.* 1990). Soils are suited to most of the climatically adopted crops.

The values of pH:8.5 and ECe : 7.1 dSm^{-1}, qualify S2 soils for saline alkali class. Sodium : 21.7 mel^{-1} as dominant cation; cl^- : 16.3 mel^{-1} and SO_4^{2-} 13.0 mel^{-1} as dominant anions offer moderate alkalinity and moderate salinity hazards to crop plants and require 3 tonnes ha^{-1} gypsum for amelioration of these soils. As ESP of S2 soils fall within 10-15 range, the crops suited are safflower, mash, pears, lentil, pigeonpea, urid and beans (Singh *et al.* 1981).

An excess quantity of exchangeable Na^+: 185 mel^{-1} in association of HCO_3^-: 80 mel^{-1} and SO_4^{2-} 79.5 mel^{-1}in the soils of S3 unit presents strong alkalinity and moderate salinity hazards to crops. The soils come under alkali class and gypsum requirement is 11 tonnes ha^{-1}. The ESP of the soils fall with in 30-50 range thus the suitable crops are raya, wheat and sunflower (Chhabra *et al.* 1979; Singh *et al.* 1979).

The values of S4 soils for pH : 10.7 (very high) ECe : 17.4 dsm^{-1} (high), ESP : 94.0; similarly the values are very high for pH : (10.5), very high for ECe : 62.9 dsm^{-1}, very high for ESP : 97.6 of S5 soils. Ionic concentration in S4 soils is dominated by Na^+ : 823 mel^{-1} followed by CO_3^{2-} : 306, HCO_3^-: 211, SO_4^{2-}: 167 and Cl^{-1} : 144.0 where in case of S5 soils, the ionic concentration is dominated by Na^+ : 214 followed by SO_4^{2-}: 872 , Cl^{-1} : 68.5 CO_3^{2-} : 164 mel^{-1}. These soils come under sodic class and the gypsum requirement exceeds beyond 15 tonnes ha^{-1}. As such in beginning growing of crops is impossible, they are well suited to adopted grasses and trees. Grasses like *Diplachne fusca* (kemal grass), *Chloris gauana* (Rhodes grass), and *Brachiaria mutica*, (Para grass) have been reported as highly tolerant

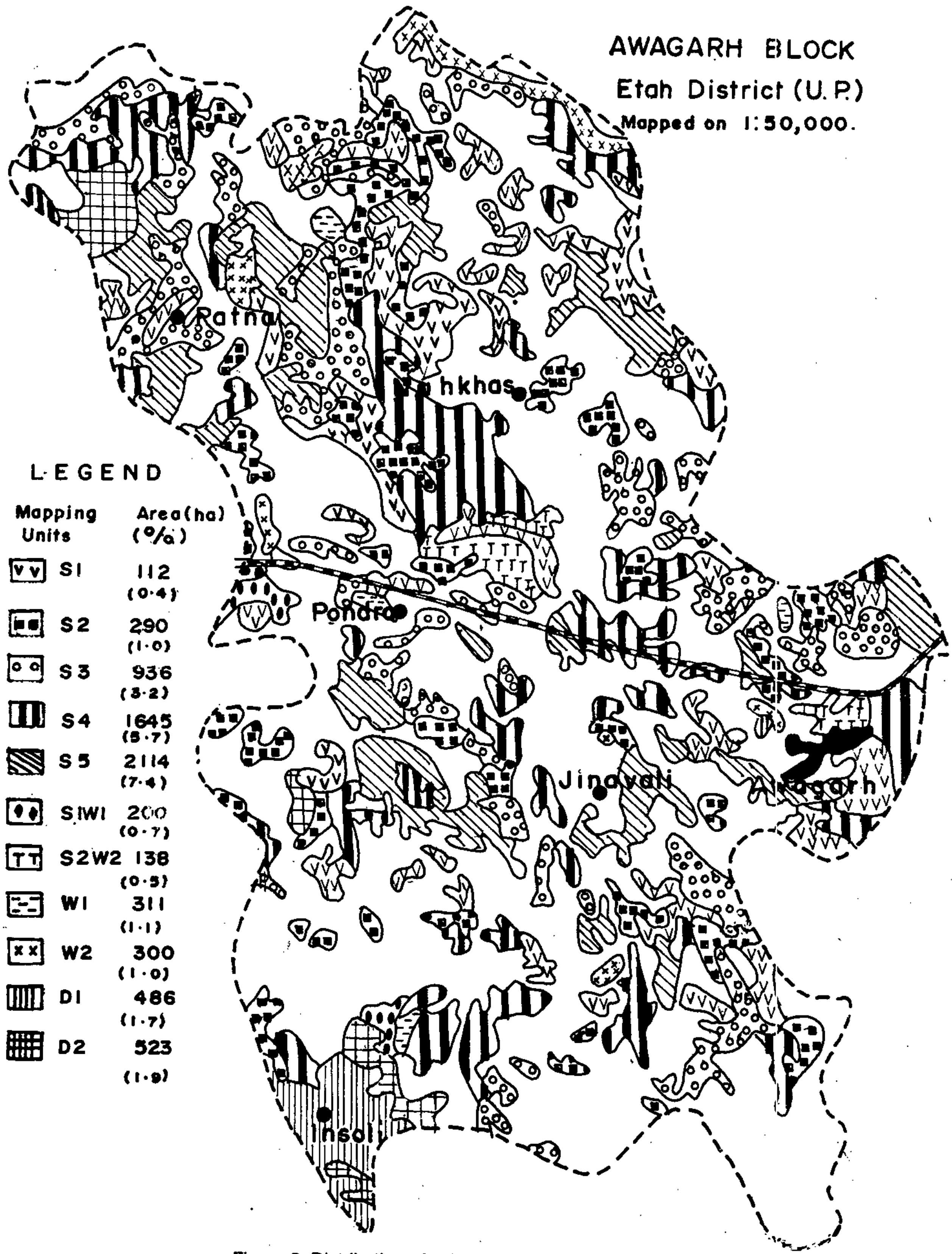

Figure 2. Distribution of salt affected and associated degraded soils

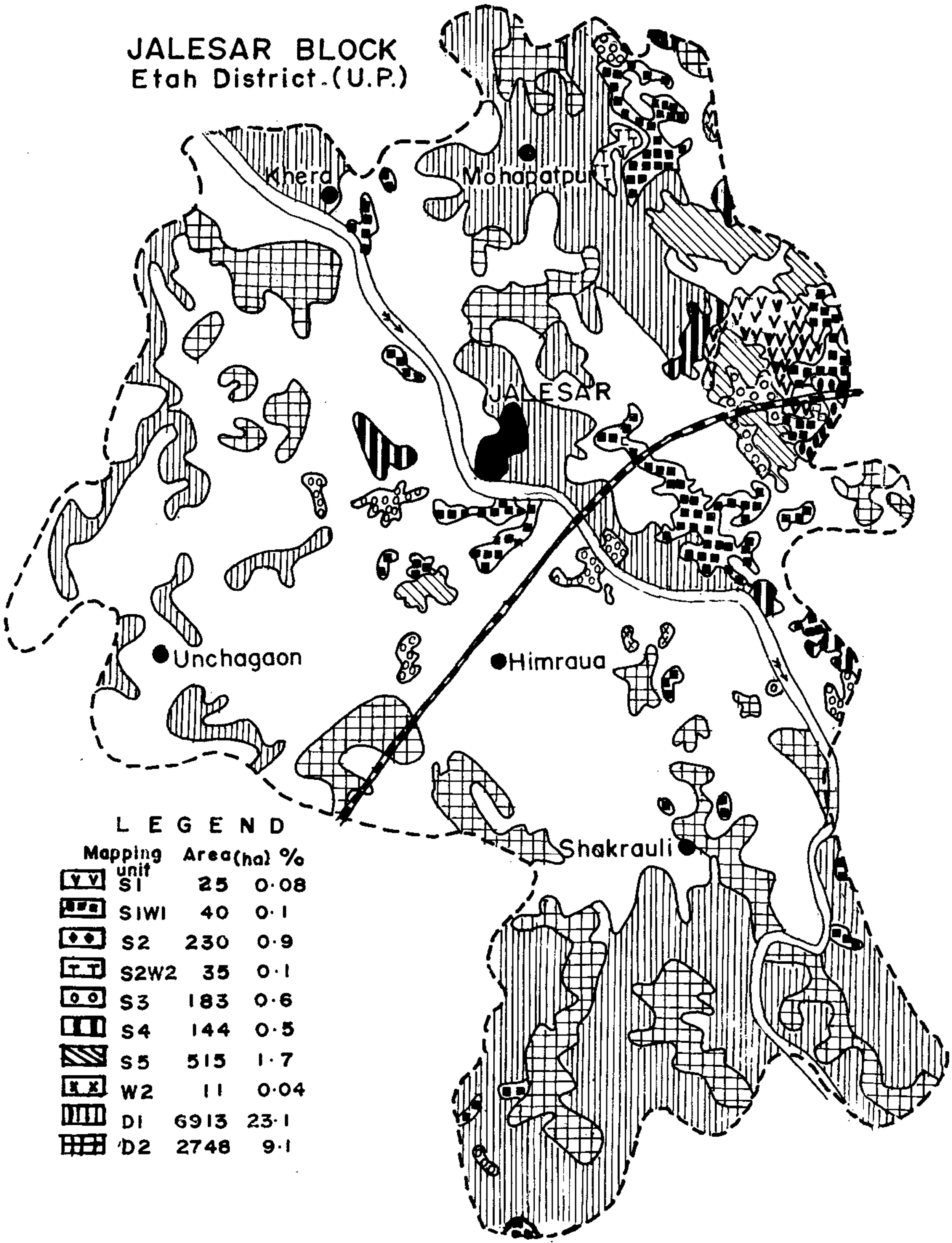

Figure 3. Distribution of Salt affected and associated degraded soils

to alkali environments (Kumar & Abrol 1986).

Extent of Salt affected Soils : The droughty, salt affected and water logged soils accounts for 10,670 ha, 6,832 ha and 622 ha, respectively. It is observed that 32 per cent of Jalesar block is suffering from droughtiness in comparison of 3.5 per cent of Awagarh block. Salinity/alkalinity is the dominant problem of Awagarh block which accounts 19 per cent of the area. Another 7,327 ha lands shown as vulnerable are likely to be affected by this problem if proper control measures are not adopted (Table 3, Fig. 2 & 3).

Gypsum Requirement : It is seen from the Gypsum requirement for individual mapping units as well as for the whole blocks (Table 4) that much less quantity of gypsum is needed to reclaim the soils of the S1, S2, S3 and vulnerable class. The S4 and S5 soils require more than 15 tonnes gypsum per hectare.

TABLE 4. Gypsum requirement of Awagarh and Jalesar Blocks

Salinity/ Alkalinity		GR (t ha^{-1})	AWAGARH BLOCK		JALESAR BLOCKS	
			Area (ha)	GR (tons)	Area (ha)	GR (tons)
S1	D	1	112	112	25	25
	V	1	2111	2119	475	4750
S2	D	3	290	871	236	689
	V	1	1162	1162	918	918
S3	D	11	936	10300	183	2015
	V	1	1405	1404	275	275
S4	D	15	1645	24675	144	2166
	V	1	987	987	87	87
S2	D	15	2114	3171	515	7718
	V	1	302	302	74	74
S1W1		1	200	200	40	40
S2W2		3	138	414	35	105
Total			11409	737032	7500	19085.8

D = Degraded, V = Vulnerable; GR = Gypsum requirement

Priority Areas for Reclamation : It may not be out of place to mention that the existing trend of concentrating reclamation measures on highly deteriorated S4 and S5 soils, have not yielded desired results. Since the S4 and S5 soils have very high concentration of carbonate and bicarbonate of sodium, require long term and high input treatment. It is proposed that the priority of the reclamation project may be diverted from S4 and S5 to S2 and S3 soils with suitable provision of drainage net work on S1, S1W1, S2W2 and vulnerable soils.

It can be concluded that the salinity/alkalinity levels can be distinguished with the help of latest tool of remote sensing and the delineated mapping unit has got its direct bearing in making recommendation for its reclamation. Chemical characterisation of the soils made possible to work out the ameolarative requirement of the chemical amendments. A revised concept for priorities the reclamation of SAS (as suggested) will improve the economic condition of the farmer through better return from the land needing less chemical amendment.

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