Agropedology 2005, 15 (1) 22-28

Soil survey interpretation of salt affected black soils of Jambusar taluka of Bharuch district of Gujarat State for suggested land use planning

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Abstract : The salt affected black soils showed inherent constraints in crop production due to their typical physical and chemical properties. Specific soil related constraints for crop production for these soils were identified and the soils were evaluated according to various interpretative systems using qualitative and quantitative approaches for sustainable land use planning. The land irrigability classification and over all scenario of the area suggested that low water requiring and deep-rooted crops with two supplemental irrigations in *kharif* and 2 to 3 irrigations in *rabi* season can be helpful in reducing surface salinity and prevents its further rise. According to soil-site suitability classification, the soils of pedon P_1 were highly suitable for sorghum and moderately suitable for cotton, pigeonpea and wheat with moisture and soil limitations and marginally suitable for rice due to climate, wetness and soil limitations. The soils of pedon P_2 were moderately suitable for cotton, sorghum, pigeonpea and wheat with different kinds and degrees of limitations. These soils showed the potential suitability as highly suitable for cotton, sorghum and pigeonpea with the improvement in the correctable limitations. The soils of pedon P_5 were marginally and/or not suitable for cotton, sorghum and pigeonpea cultivation due to soil salinity limitation but these soils can be put under woody species like *Salvadora persica* and *Prosopis juliflora* and forage grasses like *Dichanthium annulatum, Leptochloa fusca, Aeluropus lagopoides, Cynodon dactylon* and E*ragrostis* species *etc.* for optimum utilization of these lands and minimizing their further degradation.

Additional key words: Land evaluation, shrink-swell soils, salinity, sustainable land management, woody species, forage grass

Introduction

Land evaluation is the ranking of soil units on the basis of their capabilities (under given circumstances including level of management and socio-economic conditions) to provide highest returns per unit area and conserving natural resources for future use (Van Wanbeke and Rossiter 1987). The evaluation of land potential is a major tool in soil survey interpretation and natural resource management (Sims 1996; Sombroek and Heger 1996). Soil survey interpretation and land evaluation precede land use planning. Standard survey information can be interpreted for several purposes like suitability for agriculture through technical classification of soils, hydrological grouping, suitability for sewage disposal, trafficability, building construction etc.

The land characteristics which are measurable properties of physical environment that affect the land use and land quality (both external and internal) are considered in land evaluation. Mostly land evaluation is qualitative and is based on the expert judgment of soil surveyors and agronomists who interpret their field data to make them understandable to planners, engineers, extension workers and farmers. More recently, in-depth studies on specific soil related constraints, in particular soil fertility, available water and oxygen, soil workability and degradation hazards such as soil salinisation and soil erosion have all facilitated quantitative simulation of specific land use processes and opened the way for yield prediction, and so the ignorance of capability and suitability of the soils leads to the sub-optimal yield or complete failure of the crop. The salt affected Vertisols and associated soils have inherent constraints due to their typical physical and chemical characteristics which lower the crop productivity and therefore, the present study in Jambusar taluka of Bharuch district to find out the potentials and constraints of these salt affected black soils through soil survey interpretation and to suggest better management options for avoiding their further deterioration.

Materials and Methods

Study area

The study area, Jambusar taluka of Bharuch district of Gujarat, has the geographical coordinate 21°53' to 22°16' N latitude and 72°33' to 72°58' E longitude. The taluka is surrounded by Mahi River in North, Dhadar River in South, Gulf of Cambay on West and Vadodara district on East (Fig. 1) with total geographical area of 109700 ha, out of which the area under agriculture is 65244 ha , Uncultivable wasted land 6119ha, grassland 2758ha, other than agriculture 31753ha and current fallow 3826ha.

Geology and geographic units

The area has sedimentary deposits derived from basalt brought down by the Dhadar river and its tributary, recent alluvium of Mahi river and marine alluvium along the coastal line and landforms as alluvial plain of mid-land, flood plain of Mahi and Dhadar river and coastal low land.

Climate

The annual rainfall varies from 800 to 900 mm. The mean annual temperature is ranging from a minimum of 20.1°C to maximum of 31.4°C. Climate of this area falls under semiarid category. The average length of growing period is 120-150 days (Fig. 2). The water holding capacity of these soils is medium to high, which is ranging from 50 to 70 per cent.

Agricultural scenario

The area is under *rainfed* agriculture. Major crops cultivated in the area are cotton, pigeonpea, sorghum, pearlmillet and wheat (Table 1). The present source of irrigation water is tube-well and the area brought under Sardar Sarovar Canal Command. At present the groundwater depth is 10 to 12 m and water quality is saline.

Table 1. Present agriculture and crop productrity

Crop	Area (ha)	Productivity (q/ha)
Cotton	31,846	7-8
Pigeon pea	14,385	7.5 - 8
Rabi Sorghum	3,027	12-15
Pearl millet	3,161	10-12
Rice	649	8-10
Wheat	578	12-15
Sesame	1,637	5-7.5
Castor	486	8-10

Methodology

After thorough traversing, five pedons were exposed. The P_1, P_2, P_3, P_4 and P_5 were exposed at Ankhi, Bojidra, Panchpipla, Vedach and Tankari villages and studied for their morphological characteristics. The site characteristics for each pedon are given in Table 2. Horizon-wise soil samples were collected, ground and passed through 2mm sieve and used for laboratory analysis. Standard methods were followed for determining mechanical composition, calcium carbonate, organic carbon, cation exchange capacity and exchangeable sodium percentage (Jackson 1967). Saturation extract of the soils were prepared and analysed for electrical conductivity (Richards 1954). Soils were classified as per Keys to Soil Taxonomy (Soil Survey Staff 1998). These soils were evaluated according to various interpretative systems such as qualitative approaches like land capability classification (Klingebiel and Montgomery 1966), soil and land irrigability classification (AISLUS 1970) and fertility capability soil classification (Sanchez *et al.* 1982) and quantitative approaches like productivity potential (Riquier *et al.* 1970), Storie index rating (Storie 1976) and soil-site suitability classification (FAO 1976, and Sys 1985).

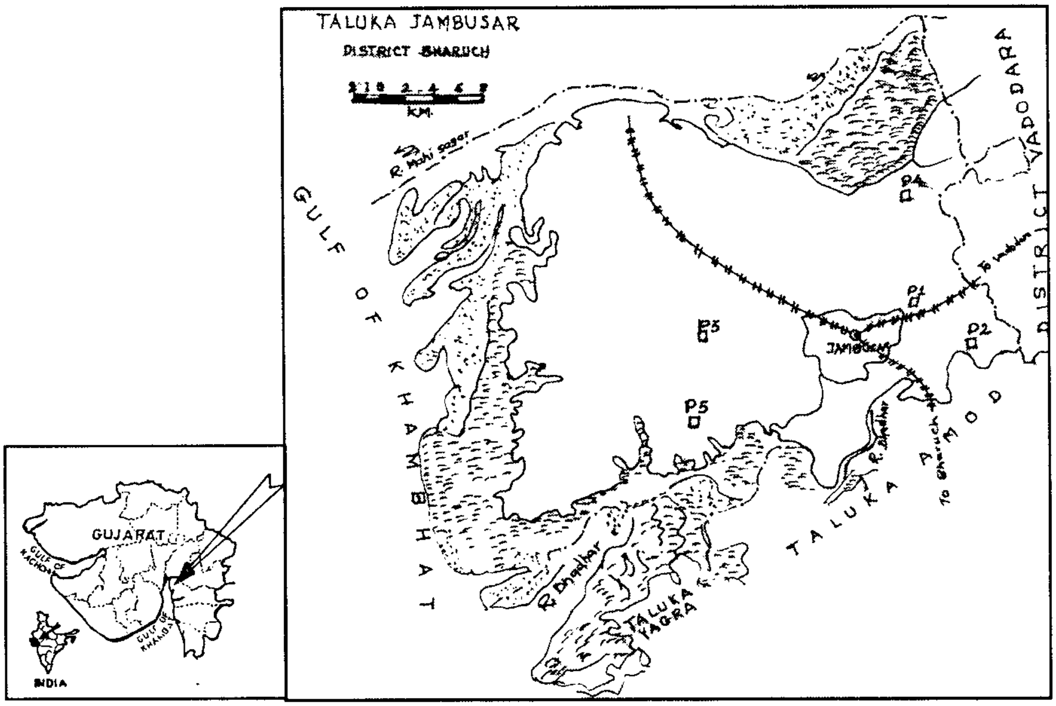

Fig. 1 Locat on of the study area

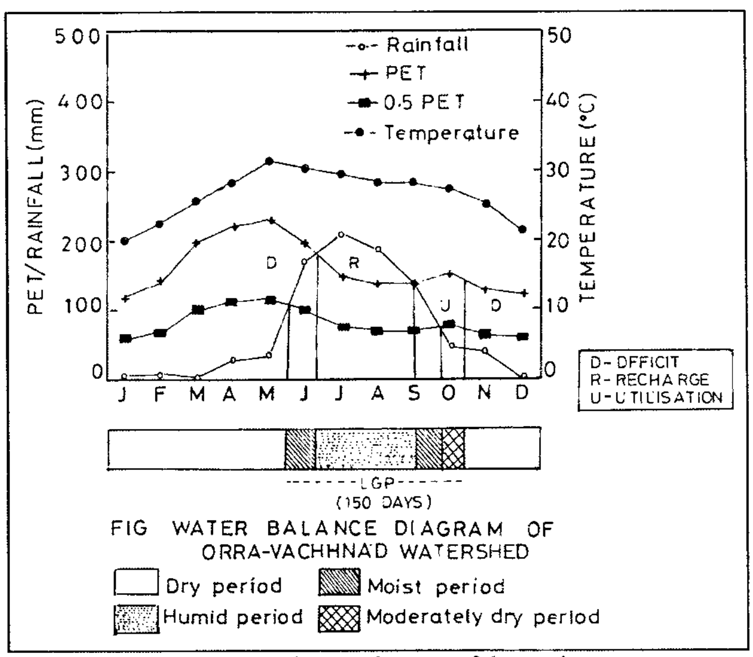

Fig. 2 Water Balance Diagram of the study area

Table 2. Site characteristics of pedons

Pedon	Physiography	Slope	Drainage	General features of soils in villages
P1	Mahisagar and Dhadar flood plain	1-3%	Well drained	Loamy to clay loam soils from recent alluvium
P2	Alluvial plain of midland	1-3 %	Imperfectly drained	Deep to very deep, clay, calcareous (alluvial) soil, deep and wide cracks during dry season, commonly known as black cotton soils
P3	Alluvial plain of midland	1-3%	Poorly drained	——do———
P4	Coastal low lands	1-3%	Imperfectly drained	Shallow to moderately deep, medium textured soils formed from river and marine alluvium
P5	Coastal low lands	0-1%	Poorly drained	Deep to very deep, clayey soils

Table 3. Physical and chemical properties of soils

Horizon	Depth (m)	Sand	Silt	Clay	pH	ECe (dSm^{-1})	OC	$CaCO_3$	CEC ($cmol\ kg^{-1}$)	ESP
		←——	(%)	——→			←—— (%)	——→		
Pedon 1 : Fluventic Haplustepts										
Ap	0-0.15	65.0	8.7	26.3	7.1	0.78	0.23	0.9	15.7	3.2
Bw1	0.15-0.35	41.3	22.1	36.6	6.9	0.76	0.20	2.1	23.0	5.6
Bw2	0.35-0.75	39.1	23.6	37.3	6.9	0.78	0.23	2.3	28.5	8.4
Bw3	0.75-1.17	40.8	29.4	29.8	7.2	0.78	0.17	1.7	29.0	8.3
C	1.17-1.48	66.5	6.9	26.6	7.1	0.80	0.03	1.9	27.0	8.1
Pedon 2 : Typic Haplusterts										
Ap	0-0.15	34.6	7.2	58.2	7.9	0.78	0.23	1.5	42.2	3.5
A12	0.15-0.58	47.5	5.0	47.5	8.3	0.80	0.21	1.5	41.1	4.4
Bss1	0.58-1.10	32.8	22.0	45.2	8.7	1.17	0.25	1.3	41.3	4.3
Bss2	1.10-1.40	37.4	16.6	45.9	8.8	1.25	0.29	1.7	40.3	5.9
BC	1.40-1.65	53.6	8.7	37.7	9.1	1.25	0.11	0.3	36.0	9.1
Pedon 3 : Udic Haplusterts										
Ap	0-0.19	16.3	38.6	45.1	9.3	1.33	0.24	2.3	31.0	9.1
A12	0.19-0.56	22.3	24.2	53.5	9.2	1.87	0.27	2.5	34.0	8.8
Bss1	0.56-0.75	15.6	23.2	61.2	9.1	3.12	0.29	2.3	36.4	9.6
Bss2	0.75-1.05	15.8	20.8	63.4	9.0	3.28	0.29	3.9	37.0	8.1
C	1.05-1.50	47.3	9.0	43.7	8.9	7.49	0.13	2.7	30.2	41.7
Pedon 4 : Typic Halaquepts										
A1	0-0.19	66.1	8.2	25.7	8.4	3.12	1.02	7.5	24.3	10.3
Bw1	0.19-0.35	78.3	5.1	16.6	9.0	3.50	0.84	7.8	13.0	9.5
Bw2	0.35-1.75	75.3	11.5	13.2	8.8	5.23	0.84	8.8	14.0	15.7
Csa	1.75-1.85	75.6	11.8	12.6	8.2	15.60	1.28	8.1	13.9	15.8
Pedon 5 : Typic Halaquepts										
A1	0-0.18	38.5	20.5	41.0	8.6	9.10	0.94	14.5	17.3	5.4
Bw1	0.18-0.55	23.3	38.6	38.1	8.1	11.34	1.76	15.1	28.7	7.3
Bw2	0.55-1.03	21.7	23.6	54.7	8.6	11.48	1.26	12.9	35.2	18.5
Csa	1.03-1.70	13.4	30.0	56.6	8.5	16.88	1.68	19.9	37.8	34.4

Results and Discussion

Soil characteristics

Analytical data showed that the soils of pedon P_1 had clay ranging from 26.3 to 37.3 per cent with cation exchange capacity from 15.7 to 29.0 cmol kg^{-1} (Table 4). The soils are neutral and EC ranged from 0.76 to 0.80 dS m^{-1}. The soils of pedon P_2 are neutral to alkaline with EC of 0.78 to 1.25 dS m^{-1} which increases with depth. The clay content ranged from 37.7 to 58.2 per cent. The soils of pedon P_3 are highly alkaline with pH varies from 8.9 to 9.3 and salinity from 1.3 to 7.5 dS m^{-1}. The soils of pedon P_4 had clay content ranging from 12.6 to 25.7 per cent. The soil salinity of these soils varies from 3.12 to 15.6 dS m^{-1} with pH 8.2 to 9.0. The soils of pedon P_5 are highly saline from 9.10 to 16.88 dS m^{-1}. These soils are highly calcareous (12.9 to 19.9 % $CaCO_3$).

Table 4. Interpretative Grouping for these soils

Soils	LCC	LIC	FCC	SIR	PP	Soil-site suitability (actual) with limitations				
						Cotton	Sorghum	Pigeonpea	Rice	Wheat
P1	I	2	Ldb	Excellent	64.6 (1)	S2ms	S1	S2ms	S3mws	S2m
P2	IIws	3	Cdvb	Fair	49.0 (2)	S2mw	S2w	S2mwn	S3m	S2mws
P3	IIIws	3	Cdvbs	Very poor	44.0 (2)	S3mwn	S3wn	S3wnm	S3mw	S3wms
P4	IVw	3	Ldbs	Very Poor	18.4 (3)	S3snm	S3sn	S3snm	S3msn	S3snm
P5	IVws	3	Cdvbs	Not Suitable	18.6 (4)	S3/N1n	S3/N1n	N1nm	S3mnw	S3wnm

Land capability classification

Land capability classification is broad grouping of soils based on their limitation. It serves as a guide to assess the suitability of land for cultivation, grazing and other uses. Land capability classes of these soils are presented in table 4. The clay texture with impeded drainage and soil salinity are the major limitations of P_3 and P_5 and therefore these soils are grouped into IIIws and IVws classes respectively. The other pedons were categorized in IIws (P_2) , IIIws (P_3) and I (P_1) classes.

Land irrigability classification

The land irrigability classes were 3 (land having severe limitation for irrigation) for soils of P_2, P_3 and P_5 because of low permeability and for soils of P_4 because of less available water holding capacity and depth to water table. The soils with high ESP coupled with higher amount of $CaCO_3$ are posing the constraints for irrigation. The stratigraphic advantage of this area indicates a sandyloam/ silty loam layer at about 1.5 to 2.0 m below the ground level which restricts the phenomenon of perched water table, generally not seen in the area. At present the interaction zone of transient salinity and secondary salinity lies between 4.5 to 7.0 m from the surface (Nayak *et al.* 2004). The interaction zone of salinity would shift to root zone salinity in the majority of the area and thereby increasing the salinity in the root zone leading to secondary salinisation if irrigation practice is followed in traditional ways. Yet there is scope for profitable irrigated agriculture through proper water management practice. While suggesting the sustainable land use plan, irrigation plays an important role in production and productivity of the land. Low water requiring and deep-rooted crops which can be grown with two supplemental irrigations in *kharif* and 2 to 3 irrigation in *rabi* season should find a favour. The key to irrigation management in this area lies not with reduction in the surface salinity but with the prevention of its further rise.

Present and potential productivity ratings

Productivity rating refers to the actual land capability for crop production under given pedo-climatic conditions. The present productivity ratings were poor for P_4 and P_5, good for P_2 and P_3 and excellent for P_1. The major limitations (along with others) for poor rating of P_5 were soil salinity and accumulation of calcium carbonate and in case of P_4 were soil texture, soil salinity and calcium carbonate content. The improvement in the soil productivity of these soils could be made by adding the organic manure (Gupta *et al.* 1986), managing soil salinity, availability of soil moisture and putting these soils under salt tolerant low water requiring crops.

Storie index rating

The soils of P_1 were qualified for excellent P_2, for fair P_3 and P_4 for very poor classes. The soils P_5 were qualified as unsuitable for cultivation because of drainage and soil salinity problems.

Fertility capability classification

The soils were evaluated for fertility capability class with modifier, and its interpretation are presented in table 4. All the soils have the modifiers like ustic soil moisture regime (d) indicating moisture deficiency during dry season unless soil is irrigated and calcareous nature (b) indicating the possibility of potential deficiency of micronutrients. The other modifiers for P_3 and P_5 were clay textured top soils with shrink and swell properties, tillage is difficult when too dry and too wet (v) and presence of soluble salts (s) which requires special management for salt sensitive crops or the use of salt tolerant species/cultivars.

Soil-site suitability classification

The suitability of these soils was evaluated for the crops like cotton, sorghum, pigeonpea, rice and wheat. The soil-site suitability classification (Table 4) showed that the soils of P_1 were highly suitable for sorghum and moderately suitable for cotton, pigeonpea and wheat with moisture and soil limitations and marginally suitable for rice due to climate, wetness and soil limitations. The soils of P_2 were moderately suitable for cotton, sorghum, pigeonpea and wheat with different kinds and degrees of limitations. These soils showed the potential suitability as highly suitable for cotton, sorghum and pigeonpea with the improvement in the correctable limitations by adopting the optimum level of management (Chinchmalatpure *et al.* 2001). The soils of P_5 are marginally and/or not suitable for cotton, sorghum and pigeon pea cultivation due to soil salinity limitation.

Land use planning

Soil survey interpretation (Table 4) showed that soils of P_1 and P_2 were rated best for agricultural use. The soils of P_4 and P_5 due to severe soil salinity limitation and fertility constraints were rated as marginally suitable/ unsuitable for agriculture. The soils of P_3 can be brought under better cultivation by overcoming the limitation of wetness and soil salinity. Careful soil management techniques and conservation measures / practices coupled with selection of salt tolerant species could help in increasing the productivity of the land.

The sustainable land use planning addresses the present and potential land utilization patterns under agricultural and non-agricultural sectors. It attempts to strike a balance between agricultural and non-agricultural sectors as per the potential of land and demand of the growing population in an area. Looking into the hydro-geological situations of the area, the arable crops like cotton, pigeonpea and sorghum in *kharif* season and dill (*Anethum geaveolens* L.), wheat, mustard and safflower in *rabi* season have tremendous scope for cultivation in slight to moderately salt affected black soils. Poor land with high soil salinity having low agricultural potential can be put under woody species like *Salvadora persica, Prosopis juliflora etc.* As the degradation process has been at work since very long time, the reclamation and rejuvenation process shall also take sometime to put the operating processes in reverse gear. But once these soils have been covered with green canopy of *Salvadora* or forage grasses like *Dichanthium annulatum, Leptochloa fusca, Aeluropus lagopoides, Cynodon dactylon* and E*ragrostis* species *etc*, which are suitable to grow on these salt affected soils, surface accumulation of salt minimizes. Ecological equilibrium is restored as a large number of birds survive on berries of *Salvadora*. The pods of *Prosopis* have a high nutritive value (Patel and Shekhat 1987) and good fuel wood from *Prosopis* can be obtained. These trees and forage grasses can be a biological source of land reclamation and can play a very vital role in rejuvenation of these sick soils.

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Received December 2003; Accepted January 2005