*Agropedology, 2000, **10**, 152-162*

Characterization and classification of some salt-affected soils of Bhal Region of Gujarat

*A.K. Nayak, G. Gururaja Rao, Anil R.Chinchmalatpure and Ravender Singh**

Central Soil Salinity Research Institute, Regional Research Station, WALMI Campus, Anand 388 001, India

* Water Technology Centre for Eastern Region, Chandrasekharpura, Bhubaneshwar, India

Abstract

Characteristics and ionic composition of soils representing the recent and old flood plains of Bhal area of Gujarat were studied. Kharad soils (P1) are brown to dark brown in surface and reddish yellow in subsurface horizons, clay to clay loam in texture and show cracks upto 30 cm and classified as Vertic Haplustepts. Soils of Kalamsar (P2) are clay loam to sandy clay loam in texture, show more than 0.2 per cent organic carbon with decreasing trend from surface to subsurface and classified as Fluventic Haplustepts. Vachhnad soils (P4) are clayey in texture having well developed slickensides and classified as Typic Haplusterts. Soils of Saragwada (P3) show absence of diagnostic horizon and classified as Typic Ustorthents. All soils except Vachhnad soils are having both surface and subsurface salinity. Sodium and chloride are the dominant ions in the soils. The study indicates that in Pedon P1, rain water or water of low electrolyte concentration can be used alternatively with saline water for crop production and in pedons P2 and P3, only good quality water can be used for leaching the salts. Pedon P4 is non saline and hence no leaching is required.

Additional keywords : Alluvium, black soils, salinity, intrusion, leaching

Introduction

Salt affected soils are quite prevalent in Bhal region of Gujarat. Salinity in this area is due to (i) weathering of the mineral either in situ or elsewhere and subsequent transport and accumulations, (ii) inherent salinity, as this area remained under the sea for a long period and high saline water table has made the agricultural lands saline (Krishnan 1982) and (iii) lateral sea water intrusion in the lower aquifer. Presently, the crops viz. cotton, pigeon pea and sorghum are sown on upland and the low lying area are kept for rabi crops like wheat and gram on conserved moisture.

This area will shortly be irrigated by Narmada canal which will bring changes in the soil and water situations. In view of the above scenario, the present study was undertaken to generate a comprehensive database on the characteristics, classification and the degree of limitations with respect to constraints viz. soil salinity for crop production. The study would help in planning strategies for irrigation management for improving the agricultural productivity and to check further degradation of the soils.

Materials and methods

The study area lies between 21°45' to 22°55' N latitudes and 71°33' to 73°15' E longitudes covering the districts of Ahmedabad, Kheda and Bharuch (Fig. 1). Physiographically the area comprises of the recent and old flood plain with mudflat along tidal inlets. The area represents arid/semi-arid climate with mean annual rainfall varying from 600 to 900 mm occurring mainly during June to September and well expressed summer (March to June) and winter from November to February. The mean summer soil temperature is 31.1°C whereas mean winter soil temperature is 25.1°C representing hyperthermic soil temperature regime. The average potential evapotranspiration per year of the area is ranging from 1650 to 1980 mm. This area has the ustic soil moisture regime.

After thorough traversing, four representative pedons were studied at Kharad village (P1) in Bhadar watershed in Ahmedabad district, in Kalamsar village (P2) in MCl watershed (Kheda district), at Saragwada village (P3) in Sabarmati watershed in Ahmedabad district and at Vachhnad village (P4) in Dhadar watershed in Bharuch district. The morphological characteristics were described as per the Soil Survey Manual (Soil Survey Staff 1966). Standard methods were followed for determining $CaCO_3$, organic carbon, and CEC (Jackson 1967) and particle size analysis was carried out by International pipette method. The saturation extracts of the soils were prepared and analyzed for ECe, Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^{--}, CO_3^{--} and HCO_3^- (Richards 1954). Soils were classified as per Keys to Soil Taxonomy (Soil Survey Staff 1998).

Results and discussion

Morphological properties : The salient morphological features of the soils are given in table 1. The soil pedon showed the variation in soil characteristics which are in part inherited from or influenced by parent material, and in part, the result of the

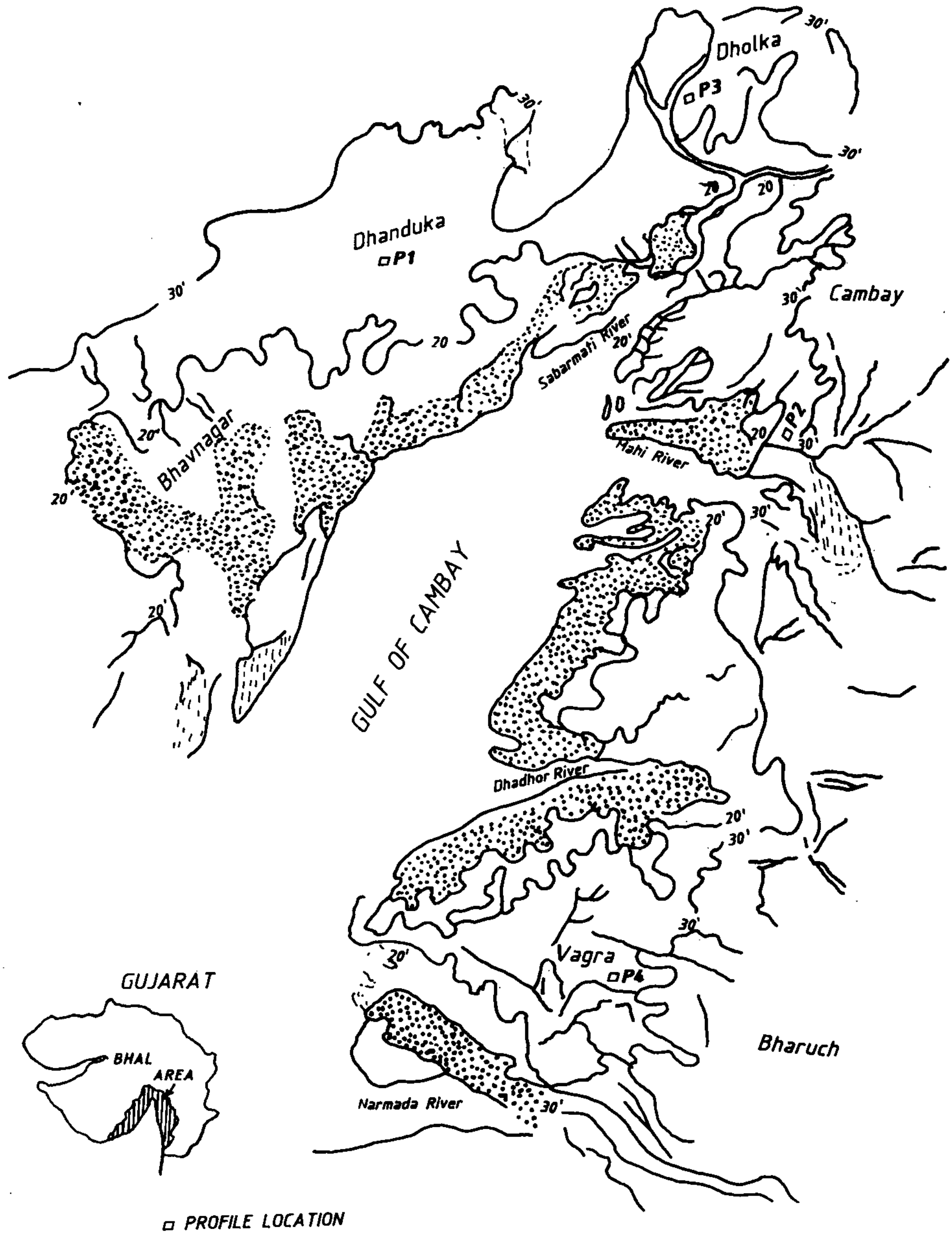

Fig. 1. Location of the study site in Bhal area (Gujarat State).

influence of other soil forming factors such as climate, soil biota, position on landscape and period of soil development. The soils of Bhadar watershed (Pedon 1) and MCI watershed (Pedon 2) have brown (7.5YR 4/4) to dark brown (7.5YR 3/2) colour. The surface horizon of pedon 2 exhibits yellowish brown (10YR 5/4) colour. The soils of Sabarmati watershed (P3) showed the colour ranging from light yellowish brown (10YR 6/4) to dark yellowish brown (10YR 3/4) whereas the soils of Dhadhar watershed are dark brown (10YR 4/3) to very dark brown (10YR 3/2). The variation in soil colour is due to nature and type of parent material. Though the parent material is alluvium for all the pedons except for pedon 3, where the soils are developed on marine sediments, the rivers have carried the sediments from the different area having different geology.

Table 1. Morphological characteristics of soils

Horizon	Depth (cm)	Colour	Texture	Structure	Consistence	Effervescence	Roots	Special features
				P1 (Kharad)				
Ap	0–20	7.5YR 4/4	cl	m2 sbk	sh fi sp	ev	f f	many, medium lime nodules, open crack (1 cm wide)
Bw1	20–35	7.5YR 4/4	c	m2 abk	h fi sp	ev	f f	many, medium, lime nodules, open crack (1 cm wide)
Bw2	35–55	7.5YR 4/4	c	m2 abk	h vfi svp	ev	vf f	many, medium lime nodules
Bw3	55–80	7.5YR 3/2	c	m3 abk	vh vfi svp	ev	vf f	lime nodules
C	80–145	7.5YR 7/8 & 7.5YR 7/2	c	c3 abk	vh vfi vsvp	ev	–	many, coarse lime nodules
				P2 (Kalamsar)				
Ap	0–20	10YR 5/4	cl	m2 sbk	sh fr ssps	–	f/m c	–
A2	20–40	7.5YR 3/4	scl	m2 sbk	h fr ssps	–	f/m c	–
Bw1	40–70	7.5YR 3/2	scl	m2 sbk	vh fr ssps	e	f f	–
Bw2	70–105	7.5YR 3/3	scl	m2 sbk	h fr sp	e	f f	–
C	105–150	10YR 4/4	scl	m1 sbk	– fr ssps	es	–	–

				P3 (Saragwada)				
Ap	0–15	10YR 6/4	cl	f1 sbk	sh fr s0p0	es	f m	–
A2	15–35	10YR 6/4	cl	f1 sbk	h fr s0p0	es	f m	–
A3	35–80	10YR 3/4	cl	m	h fr s0p0	es	–	–
C	80–150	10YR 3/4	cl	m	h fr s0p0	ev	–	–
				P4 (Vachhnad)				
Ap	0–16	10YR 4/3	c	m2 sbk	h fi sp	–	c m	pot hole, gilgai, cracks of 2 to 3 cm wide
Bss1	16–42	10YR 4/3	c	m2 sbk	vh fi sp	e	m f	pressure faces, few $CaCO_3$ nodules, wide cracks
Bss2	42–85	10YR 3/3	c	m2 abk	vh vfi vsps	e	f f	slickensides, cracks, few $CaCO_3$ nodules
Bss3	85–150	10YR 3/2	c	m3 abk	vh vfi vsps	es	-- --	slickensides, many lime nodules
BC	150–185	10YR 3/2	c	m3 abk	vh vfi vsps	ev	-- --	slickensides, abundant $CaCO_3$ nodules

These soils are deep to very deep and the texture is varying from clay to clay loam in all pedons except in pedon 3, which is sandy clay loam in texture, may be due to the deposition of marine sediments. The soils are having subangular blocky structure (P2 & P3) in all horizons and angular blocky structure in subsurface horizons of pedons 1 and pedon 4. The soils (P1 & P4) showed the cracks of 1-2 cm wide and 50-60 cm deep and few to many $CaCO_3$ nodules throughout the profile. The pedon 4 showed the well developed slickensides in the Bss2 and Bss3 horizons.

Soil characteristics : The characteristics of soils (Table 2) of the different watersheds showed that the soils are slightly to moderately alkaline in nature (pH 7.5 to 8.2). These soils are saline with the ECe ranging from 1 to 132 dS m^{-1}. The ECe of soils varied from 6.4 to 12.0 (P1); 49.0 to 70.0 (P2); 96.0 to 132.0 (P3) and 0.98 to 1.4 dS m^{-1} (P4). The highest value of ECe is (132 dS m^{-1}) observed in surface horizon of the pedon 3, due to frequent tidal inundation which leaves behind the salt with soil materials, hence concentration of soluble salts are more. The salt content is decreasing with depth of profile in all pedons except in P4 where it is increasing with depth. The soils (P4) are nonsaline in nature at present but are potentially saline because the area has saline groundwater. There is no significant variations in the bio-climatic condition among these regions and the potential evapotranspiration is ranging from 1650 to 1975 mm per year. There is a wide temporal and spatial variations in the depth and quality of groundwater among the watersheds (Table 3). The high ground water table in Kharad (P1) and Saragwada (P3) may be due to the intrusion of sea water whereas the low groundwater table at Kalamsar (P2) and Vachhnad (P4) is due to accelerated exploitation of the water for crop production. There is variation in clay content of soils of different watersheds. The per cent clay content is more in soils of Dhadar watershed (P4), followed by P1, P3 and P2. The textural composition of soils, variation in depth and quality of ground water and proximity to the sea coast may be attributed to variation in the soil salinity in the different watersheds. The $CaCO_3$ content of soils of Bhadar watershed (P1) is ranging from 17.5 to 19.0 per cent, that of P2, P3, P4 are ranging from 1.0 to 8.5 per cent. The $CaCO_3$ is increasing with depth in all soil profiles indicating the poor drainage condition.

Cation exchange capacity varied from 18.6 to 45.2 being highest in pedon 4. The ESP of Kharad soils (P1) ranged from 20.0 to 23.0 and SAR from 16.5 to 27.8. The saturation extract showed preponderance of Cl^- and SO_4^{--} ions, with low concentration of $CO_3^{--}$and $HCO3^{--}$ (Table 4) which facilitate the development of sodicity with neutral pH in pedon P1 (Rengasamy and Olsson 1991). Leaching of electrolytes from these soils either by rain water or by the use of irrigation water (low electrolyte concentration) below threshold limit may induce swelling and dispersion of soils. At a given ESP, the decrease in the electrolyte concentration increases the soil dispersion, but at the highest level of electrolyte concentration, the soil disperses slightly regardless of the magnitude of ESP (Valasco Molina *et al.* 1971). Several other workers (Oster and Schroer 1979; Shainberg et al. 1981) have reported that when water of low salt concentration (<3 meq l–1) is applied, the susceptibility to clay dispersion and resultant decrease in hydraulic conductivity increased drastically. Hence, the soils of Pedon P1 (Kharad) can be subjected to leaching by rain water or water with low electrolyte concentration till the threshold limit is reached after which the saline ground water can be used for irrigation.

Table 2. Physical and chemical properties of soil

Horizon	Depth (cm)	ECe dSm^{-1}	pH (1:2)	$CaCO_3$ %	OC $g\ kg^{-1}$	Particle size distribution (in <2 mm soil (%))			ESP	CEC cmol (p+) kg^{-1}
						Sand	Silt	Clay		
P1 (Kharad)										
Ap	0–20	12.0	7.5	17.5	0.5	34.0	25.2	40.8	22.5	27.8
Bw1	20–35	11.6	7.7	17.5	0.7	34.3	23.8	41.9	22.8	27.9
Bw2	35–55	8.6	7.7	18.0	0.5	34.4	22.8	42.8	23.0	28.0
Bw3	55–80	6.8	7.5	18.5	0.1	31.6	23.7	44.7	22.5	28.3
C	80–145	6.4	7.8	19.0	0.1	31.2	23.3	45.5	20.0	28.5
P2 (Kalamsar)										
Ap	0–20	70.0	7.7	0.5	4.0	46.0	22.3	31.7	2.6	18.6
A2	20–40	50.0	7.9	0.8	4.5	43.1	25.5	31.4	2.9	19.2
Bw1	40–70	54.0	7.6	1.2	3.0	31.7	25.8	32.5	3.4	19.6
Bw2	70–105	56.0	7.8	1.4	2.0	39.4	26.2	34.4	3.9	20.3
C	105–150	49.0	7.7	3.0	2.2	37.5	27.5	35.0	4.2	19.9
P3 (Saragwad)										
Ap	0–15	132.0	7.9	7.5	3.0	48.0	20.0	32.0	9.5	19.0
A2	15–35	86.0	8.0	8.0	3.5	43.6	23.9	32.5	10.3	19.6
A3	35–80	80.0	8.1	8.0	2.0	42.5	23.5	34.0	12.0	20.2
C	80–150	76.0	8.2	8.5	1.0	40.4	24.6	35.0	14.5	22.1
P4 (Vachhnad)										
Ap	0–16	1.17	7.4	0.8	3.2	29.2	26.3	44.5	2.0	40.0
Bss1	16–42	0.98	7.4	1.3	2.4	14.7	24.1	51.2	2.1	42.0
Bss2	42–85	1.00	7.6	1.9	1.9	16.6	30.6	53.8	2.7	45.0
Bss3	85–150	1.20	7.8	4.0	–	14.8	30.1	55.1	3.1	45.2
BC	150–185	1.40	8.0	7.3	–	13.6	38.6	47.8	3.7	41.0

Cation exchange capacity varied from 18.6 to 45.2 being highest in pedon 4. The ESP of Kharad soils (P1) ranged from 20.0 to 23.0 and SAR from 16.5 to 27.8. The saturation extract showed preponderance of Cl^- and SO_4^{--} ions, with low concentration of $CO_3^{--}$and HCO_3^{-} $^-$(Table 4) which facilitate the development of sodicity with neutral pH in pedon P1 (Rengasamy and Olsson 1991). Leaching of electrolytes from these soils either by rain water or by the use of irrigation water (low electrolyte concentration) below threshold limit may induce swelling and dispersion of soils. At a given ESP, the decrease in the electrolyte concentration increases the soil dispersion, but at the highest level of electrolyte concentration, the soil disperses slightly regardless of the magnitude of ESP (Valasco Molina *et al.* 1971). Several other workers (Oster and Schroer 1979; Shainberg et al. 1981) have reported that when water of low salt concentration (<3 meq l−1) is applied, the susceptibility to clay dispersion and resultant decrease in hydraulic conductivity increased drastically. Hence, the soils of Pedon P1 (Kharad) can be subjected to leaching by rain water or water with low electrolyte concentration till the threshold limit is reached after which the saline ground water can be used for irrigation.

In Kalamsar (P2) and Saragwada soils (P3), ESP ranges from 2.6 to 4.2 and 9.5 to 14.5, whereas SAR from 47.4 to 60.5 and 55.0 to 84.4, respectively. The salts (predominantly sodium chloride) accumulate in the soil profile during the dry summer season, showing high SAR and high electrical conductivity. During monsoon salts are leached out by the rain water and ECe and SAR of the soils are decreased making it possible for cultivation. Singh (1996) reported that 0.60 m water is required to reduce 76, 87 and 89 per cent of salt, respectively from surface layers of clay (Vertic Haplustepts), loam (Typic Haplustepts) and sandy loam (Fluventic Haplustepts) soils of Bhal region. Though these soils (P2 and P3) are showing high SAR and low ESP, it may not be classified as sodic soils. However, the high SAR during summer months may cause the soil dispersion and ultimately deteriorate the soil structural stability. Although ESP and SAR levels generally have excellent relationship with structural stability when sodium levels are artificially adjusted to single soil sample (Kazman *et al.* 1983), this does not provide a rational for favouring relative indices of sodicity over absolute indices of sodicity (Cook and Mullar 1997).

Table 3. Groundwater characteristics of the study area

Name of the study area	No. of sample	Depth of groundwater (m)		EC dS m^{-1}	pH
		Pre-monsoon	Post-monsoon		
Kharad	4	12.0	9.0	6.5	8.3
Kalamsar	4	47.0	42.0	1.0	8.1
Saragwada	3	13.5	9.0	5.5	8.4
Vachhnad	5	19.5	17.2	5.3	8.2

Table 4. Ionic composition of saturation extract of soils in meq l^{-1}

Horizon	Depth (cm)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--} + HCO_3^{-}	$SO4^{--}$	Cl^{-}	SAR
				P1 (Kharad)					
Ap	0-20	23.0	5.5	91.4	0.2	5.5	9.5	105.0	27.8
Bw1	20-35	22.4	5.7	88.0	0.1	5.0	9.0	102.0	27.4
Bw2	35-55	14.8	4.2	67.0	0.1	4.9	8.1	73.0	23.7
Bw3	55-80	13.1	3.9	51.0	0.1	2.9	6.1	59.0	20.3
C	80-145	14.9	4.0	45.0	0.1	3.9	9.1	51.0	16.5
				P2 (Kalamsar)					
Ap	0-20	93.0	105.0	508.0	3.8	7.5	15.0	680.0	50.3
A2	20-40	58.0	64.0	375.4	3.1	6.5	48.0	445.0	47.4
Bw1	40-70	47.0	60.0	433.0	3.1	7.0	40.0	493.0	58.8
Bw2	70-105	48.0	66.0	446.4	2.1	5.5	47.0	508.0	58.3
C	105-150	37.0	50.0	402.0	1.5	3.5	55.0	432.0	60.5
				P3 (Saragwad)					
Ap	0-15	117.0	177.0	1026.0	1.8	5.0	17.0	1300.0	84.4
A2	15-35	76.0	170.0	613.0	1.0	4.5	20.0	835.0	55.0
A3	35-80	59.0	146.0	655.0	0.8	4.0	30.0	856.0	76.2
C	80-150	54.0	104.0	604.0	1.0	3.0	47.0	710.0	67.5
				P4 (Vachhnad)					
Ap	0-16	3.0	2.4	6.1	0.1	2.5	2.2	7.0	3.7
Bss1	16-42	2.6	2.2	5.2	0.1	2.1	1.0	6.7	3.4
Bss2	42-85	2.6	1.9	5.3	0.1	2.2	1.0	6.8	3.5
Bss3	85-150	3.8	1.9	6.2	0.05	3.0	1.8	7.1	3.7
BC	150-185	3.9	2.8	7.3	0.05	3.4	2.7	7.9	4.0

Soil classification : Soils of Kharad and Kalamsar are classified as Inceptisols and meet the requirements of the cambic B horizon and having the ustic moisture regime and so classified at greatgroup level as Haplustepts. The soils of Kharad are clay in texture and having clay content more than 30 per cent and show cracks up to a depth of 30 cm and so keyed out at subgroup level as Vertic Haplustepts. Soils of Kalamsar show more than 0.2 per cent organic carbon up to a depth of 125 cm and also regular decrease in organic carbon content from a depth of 25 cm to a depth of 125 cm. Therefore, they are classified as Fluventic Haplustepts at subgroup level. Soils of Saragwada are classified as Typic Ustorthents due to the absence of diagnostic horizon. Soil of Vachhnad are fine textured, marked by wide and deep cracks and slickensides close enough to intersect showing no lithic or paralithic contact within 50 cm from the surface so these soils have been classified as Typic Haplusterts.

In all the watersheds studied, the soil and water conditions are quite fragile in nature. Hence proper irrigation management need to be developed to sustain the productivity of the soil. In the area of high ground water table, low water requiring arable crops can be cultivated with limited use of water using micro irrigation methods like drip and sprinkler. In Pedon P1, rain water or water of low electrolyte concentration can be used alternatively with saline water for crop production. Whereas in pedons P2 and P3, only good quality water can be used for leaching the salts and subsequent crop production.

Acknowledgements

The authors are grateful to Gujarat State Land Development Corporation, Gandhinagar for providing financial assistance for conducting the study.

References

Cook G.D., and Muller, W.J. (1997). Is exchangeable sodium content a better index of soil sodicity than ESP? : A reassessment of published data. *Soil Science* **162,** 343-349.

Jackson, M.L. (1967). 'Soil Chemical Analysis' (Prentice Hall of India Pvt. Ltd. : New Delhi).

Kazman, Z., Shainberg, I., and Gal, M. (1983). Effect of low level of exchangeable sodium and applied phospho-gypsum on infiltration rate of various soils. *Soil Science* **155,** 15-22.

Krishnan, M.S. (1982). 'Geology of India and Burma', 6th Edition, (CBS Publication and Distributors : Delhi, India).

Oster, J.D., and Schroer, F.W. (1979). Infiltration as influenced by water quality. *Soil Science Society of America Journal* **43,** 444-448.

Rengasamy, P., and Olsson, K.A. (1991). Sodicity and soil structure. *Australian Journal of Soil Research* **29,** 935-952.

Richards, L.A. (Ed.) (1954). 'Diagnosis and improvement of saline alkali soils'. USDA Agriculture Handbook No. **60,** (United States Government Printing Office : Washington, DC.)160p.

Shainberg, I., Rhodes, J.D., and Prather, R.J. (1981). Effect low electrolyte concentration on clay dispersion and hydraulic conductivity of a sodic soil. *Soil Science Society of America Journal* **45,** 273-277.

Singh, Ravender (1996). Leaching behaviour of some Inceptisols. *Journal of the Indian Society of Soil Science* **44,** 621-625.

Soil Survey Staff (1966). Soil Survey Manual, United States Department of Agriculture, Handbook No. **18** (Oxford and IBH Publication Co. Ltd. : New Delhi).

Soil Survey Staff (1998). Keys to Soil Taxonomy, 8th Edition, (SCS, USDA : Washington, D.C.).

Velasco-Molina, Hugo Alega, Swoboda, Allen R., and Godfrey, Curtis L. (1971). Dispersion of soils of different mineralogy in relation to sodium absorption ratio and electrolyte concentration. *Soil Science* **5,** 282-287.

(Received : October, 1999; Accepted : November, 2000)