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Characterization and Classification of Soils of Bharuch Taluka in Bharuch District of Gujarat

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Abstract: A detailed soil survey was undertaken at 1:10000 scale to describe, characterize, classify and evaluate the soils of Bharuch taluka, Bharuch district, Gujarat. Old and recent basaltic alluvial plains are the major landforms of the area. A total of 74 pedons, representing old (41 pedons) and recent (33 pedons) alluvial plains were studied. The soils were correlated and three soil series *viz*. Umraj, Derol and Singdot were identified. The Umraj belong to a very fine, smectitic Typic Haplusterts covers 30,839 ha (48.5 %) area, whereas Derol and Singdot a fine, smectitic Vertic Haplustepts and fine, mixed, Typic Haplustepts covers 20,604 ha (32.5 %) and 4,164 ha (6.6 %) area, respectively. The sand, silt and clay in the soils varied from 8 to 31, 24 to 49 and 23 to 67 per cent, respectively. The soils were very deep, neutral to slightly alkaline (pH 7.3 to 8.4) with low to medium in organic carbon content (0.14 to 0.58 %), low to high in calcium carbonate (1.9 to 16.5 %) with medium to high CEC [39.4 to 62.0 cmol (p^+) kg^{-1}] and high base saturation (67.4 to 92.0 %). Soils were assessed as highly to moderately suitable for major crops (cotton, pigeonpea, maize, sugarcane, wheat and chickpea).

Keywords: *Detailed soil survey, alluvial plain, soil classification, Vertisols, Inceptisols*

Introduction

Worldwide, the demand for food commodities is expected to increase by 75-100 per cent between 2010-2050 (Hosain *et al*. 2016). At the same time, modern intensive agriculture accounted a quantum increase in the crop production and ensures food security, has also resulted in the over exploitation and degradation of natural resources such as soil, air and water in India. The declining scenario in agricultural land and the growing food demand needs attention to optimized use of soil resources. Intensive and formidable land use needs a good level of knowledge of soil resources to design suitable soil management practices (Akpan-Idiok *et al*. 2016).

Timely and reliable information about soil resources is very essential with regard to their nature, spatial distribution, potential and constraints. The land resource inventory process provides an insight into the potentialities and constraints for efficient management of resources. It also offers to develop appropriate information on different landform distribution, cropping pattern and soil characteristics that can be used for management and proper utilization of land resources (Manchanda *et al*. 2002). Sharma *et al*. (2018) linked the village level land resource data with climate and socio-

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economic conditions for integrated village/block development programmes in Jamnagar district of Gujarat. The systematic soil survey provides an understanding of the nature and type of soil, its limitations, potential and suitability for different land uses (Prasad *et al.* 2009). Moreover, a necessity is always felt for taluka-wise database to take-up various agricultural developmental programmes. Therefore, detailed soil survey (1:10000 scale) of Bharuch taluka of Bharuch district, Gujarat was carried out to characterize and classify the soils for sustainable land use planning.

Materials and Methods

Bharuch taluka is located between 21°25'13" to 22°12'49" N latitude and 72°31'35" to 73°30'18" E longitude in Bharuch district, Gujarat (Fig. 1) and covers an area of 63,489 ha. It belongs to the Gujarat coastal plain physiographic region and west coast plain sub-physiographic region (Singh *et al*. 2016). It is located in Narmada river basin and mainly comprised of old and recent alluvial plains. The alluvium was derived from basaltic parent material of Amarkantak plateau, Anuppur district of Madhya Pradesh (Merh 1995). These plains are made up of a thick pile of unconsolidated sediments deposited by a combination of fluvial and aeolian agencies during the Quaternary period. The major geology is quaternary alluvium and topography is nearly level plains to very gently sloping in the north-east to south-west direction at an elevation upto 40 m above mean sea level (MSL).

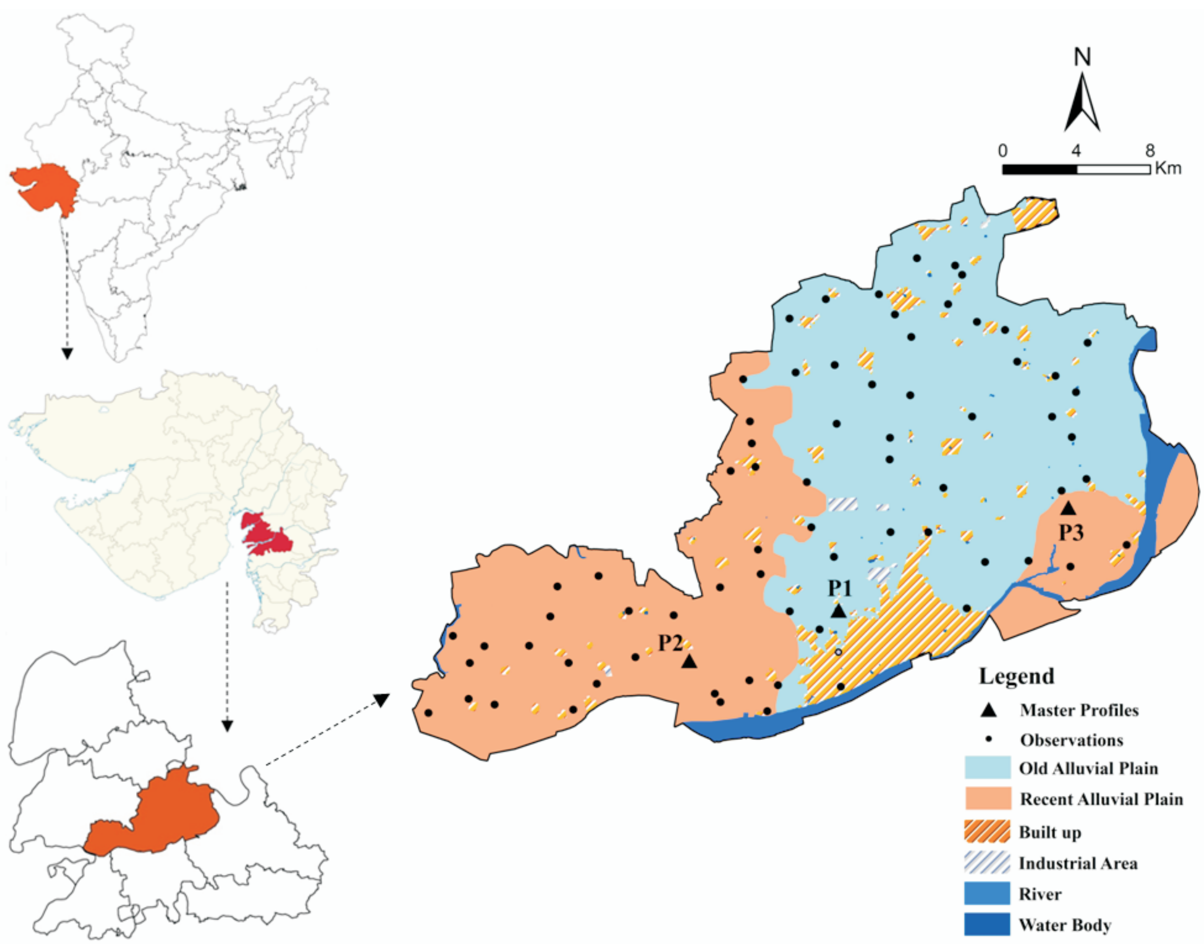

Fig. 1 Location and Landform map of Bharuch taluka with sampling sites

The area falls under agro-ecological sub-regions 5.2 *i.e.* hot semi-arid eco-region with medium and deep black soils (Velayutham *et al*. 1999) and characterised by ustic soil moisture regime and hyperthermic soil temperature regime. The climate of the taluka is semi-arid with hot and moist summers and dry winters. The mean annual temperature is 27.9°C with mean summer temperature of 31.1°C and mean winter temperature 23.3°C. May is the hottest month with 39.5°C mean daily maximum temperature and January is the coldest month with 12.7°C mean daily minimum temperature. The mean annual rainfall of the area is around 873 mm, received mainly during the southwest monsoon from June to September. Major crops grown in this area are pigeon pea (*Cajanus cajan*), maize (*Zea mays*), cotton (*Gossypium hirsutum*), sugarcane (*Saccharum officinarum*), wheat (*Triticum aestivum*) and green gram (*Vigna radiata*) with 90 to 120 days of length of growing period (LGP). The natural vegetation of the area comprised of *Azadirachta indica*, *Prosopis juliflora*, *Prosopis cineraria*, *Ziziphus mauritiana* and *Eucalyptus spp*.

Detailed soil survey was carried out at 1:10000 scale with the base map prepared using Indian Remote Sensing satellite data (IRS-P6 LISS IV), Digital Elevation Models (DEM) and Survey of India (SOI) Toposheets of 1:50000 scale. The delineation of land use land cover (LULC) was carried out by visual interpretation techniques. Slope, hill shade and contour (10 m) maps were prepared by using Cartosat-1 DEM (30 m) and landform map was generated by superimposing these maps. The landform, slope and LULC were overlaid over each other in Arc-GIS to generate landscape ecological units (LEUs) map.

A total of 74 geo-referenced pedons (Fig.1) were studied for morphological properties. After correlation protocol, three series has been identified. The horizon-wise soil samples from the representative soil series were collected, processed and analyzed for sand, silt and clay (Jackson 1979), saturated hydraulic conductivity (Klute 1965), calcium carbonate (Piper 1966), soil organic carbon (Walkley and Black 1934), pH, electrical conductivity, cation exchange capacity (CEC), exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) (Jackson 1973). On the basis of morphological, physical and chemical properties, soils were classified as per the Keys to Soil Taxonomy (Soil Survey Staff 2014). Soil map at phase level was delineated on 1: 10000 scale in ARC-GIS 10.5 software. The soil-site suitability was worked out for pigeonpea, cotton, maize, sugarcane, wheat and chick pea as per the methodology given in the FAO frame work on land evaluation (FAO 1976), modified by Sys *et al.* (1991) and Naidu *et al.* (2006).

Results and Discussion

Morphological Properties

Three soil series namely Umraj, Derol and Singdot were identified and mapped into five mapping units as phases of soil series. The morphological, physical and chemical characteristics of soils series are presented in table 1 to 3. The LEUs and representative pedons of soil maps are presented in fig. 2 and 3, respectively and soil mapping units are presented in table 4. Soils of Umraj series were very deep, moderately well drained and occur on nearly level to very gently sloping old alluvial plains. The soils were very dark grey (10YR3/1) in colour, clay in texture and had medium weak sub-angular to medium moderate angular blocky structure. These soils had 2-3 cm wide upto 30-40 cm and slickenside was observed at 40-48 cm depth. Derol soils were very deep and occur on nearly level to very gently sloping recent alluvial plains. These soils were moderately well drained, very dark greyish brown (10YR3/2) to dark yellowish brown (10YR4/4) in colour, silty clay in texture with medium weak sub-angular to medium moderate angular blocky structure. Singdot soils were very deep, calcareous, well drained, dark yellowish brown (10YR4/4) in colour, clay loam to loamy in texture with medium weak sub-angular blocky structure and occur on very gently sloping recent alluvial plains

Table 1. Morphological properties of soils

Horizon	Depth (cm)	Boundary[1] D T	Colour (Moist)	Texture	Structure[2] S G T	Consistency[3] D M W	Porosity[4] S Q	Roots[5] S Q	Reaction[6] (effervescence) e/es/ev	Nodules[7] (Ca) S Q	Other features[8]
Old alluvial plain : Pedon 1 Umraj series: ***Very- fine, smectitic, hyperthermic Typic Haplusterts*** (Lat.:21°43'44.04"N Long.:72°58'29.61"E)											
Ap	0-17	c s	10YR 3/1	Clay	m 1 sbk	h fr vs vp	f c	fm, cf	-	-	-
Bw	17-43	g s	10YR 3/1	Clay	m 2 abk	fr vs vp	vf m	ff	-	-	pf
Bss1	43-70	g s	10YR 3/1	Clay	m 2 abk	fi vs vp	vf m	ff	-	-	ss
Bss2	70-102	g s	10YR 3/1	Clay	m 2 abk	fi vs vp	vf m	vff	-	-	ss
Bss3	102-130	g s	10YR 3/1	Clay	m 2 abk	fi vs vp	vf m	-	-	-	ss
Bss4	130-155	-	10YR 3/1	Clay	m 2 abk	fi vs vp	vf m	-	-	-	ss
Recent alluvial plain : Pedon 2 Derol series: ***Fine, smectitic, hyperthermic Vertic Haplustepts*** (Lat.:21°42'17.74"N Long.:72°53'46.79"E)											
Ap	0-19	c s	10YR3/2	Silty clay	m 1 sbk	h fr s p	f c	ff, cf	-	-	-
Bw1	19-46	g s	10YR3/2	Silty clay	m 1 sbk	fr vs vp	f m	ff	-	-	-
Bw2	46-72	g s	10YR3/2	Silty clay	m 2 abk	fr vs vp	vf m	ff	-	-	pf
Bw3	72-100	g s	10YR3/2	Silty clay	m 2 abk	fr vs vp	vf m	-	e	-	pf
Bw4	100-150	-	10YR4/4	Silty clay	m 2 sbk	fr s p	vf m	-	-	-	-
Recent alluvial plain : Pedon 3 Singdot series: ***Fine-loamy, mixed, hyperthermic Typic Haplustepts*** (Lat.:21°46'41.54"N Long.:73°05'45.33"E)											
Ap	0-18	c s	10YR 4/4	Clay loam	m 1 sbk	sh vfr s p	f c	ff, cf	es	cf, fm	-
Bw1	18-48	g s	10YR 4/4	Clay loam	m 1 sbk	vfr s p	f c	ff, cf	es	cf, fm	-
Bw2	48-77	g s	10YR 4/4	Clay loam	m 1 sbk	vfr s p	f c	ff	ev	cf, fm	-
Bw3	77-110	g s	10YR 5/4	Loam	m 1 sbk	vfr s p	f c	-	ev	cf, fm	-
Bw4	110-150	-	10YR 5/4	Loam	m 1 sbk	vfr s p	f c	-	ev	cf, fm	-

1 D-Distinctness, a-abrupt, c-clear, g-gradual, d-diffuse, T- Topography, s-smooth, w-wavy, i-irregular, b-broken
2 S-Size, f-fine, m-medium, c-coarse, G-Grade, 0-structureless, 1-weak, 2-moderate, 3-strong, T-Type, gr-granular, cr-crumb, cmr-columnar, pr-prismatic, pl-platy, abk-angular blocky, sbk-subangular blocky, sg-single grain, m-massive
3 D-Dry, l-loose, s-soft, sh-slightly hard, h-hard, vh-very hard, M-Moist, vfr-very friable, fr-friable, fi-firm, vfi-very firm, W-Wet, as-slightly sticky, s-sticky, vs-very sticky, ps-slightly plastic, p-plastic, vp-very plastic
4,5,7 S-Size, vf-very fine, f-fine, m-medium, c-coarse, Q-Quantity, f-few, c-common, m-many
6 e-slightly effervescence, es-strong effervescence, ev-violent effervescence
8 pf-pressure faces, ss-slickensides

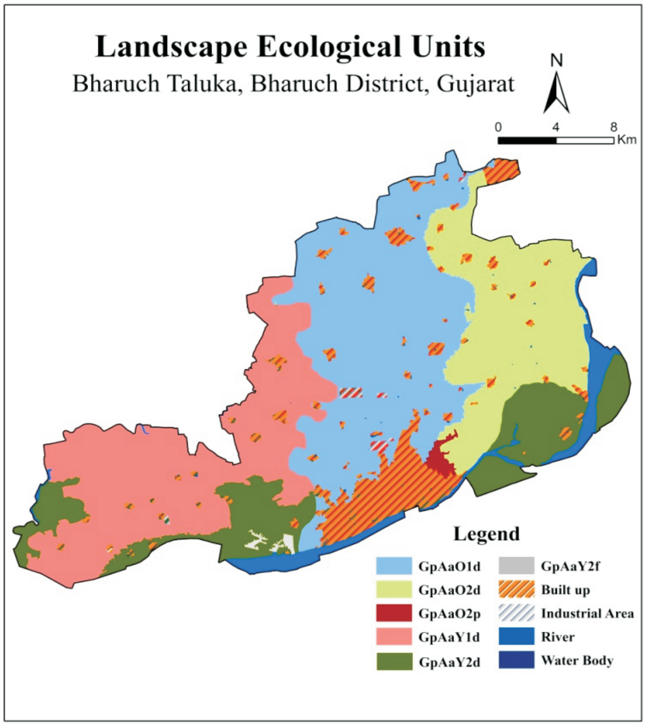

Fig. 2 Landscape ecological units map of Bharuch Taluka

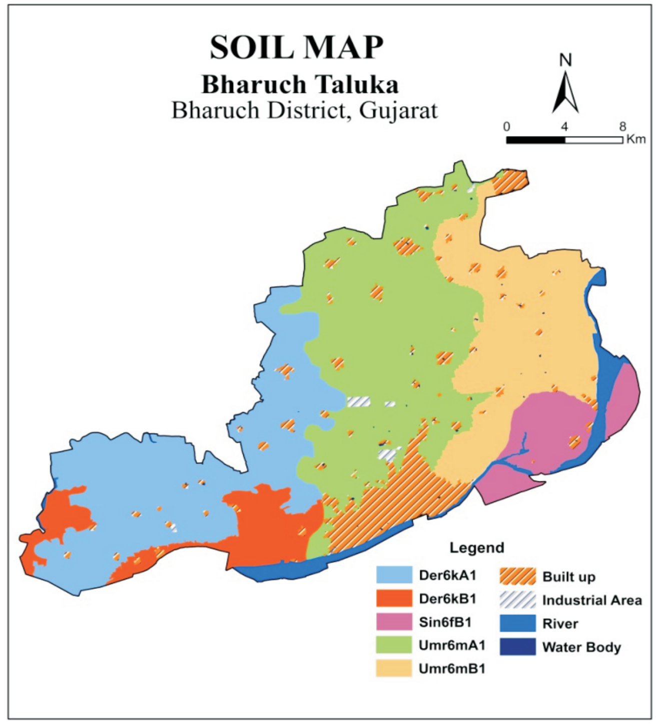

Fig. 3 Soil map of Bharuch taluka

Physical Properties

The data on particle size distribution (Table 2) indicated that the sand content of the soils varied from 10 to 31 per cent in the surface layer, whereas it varied from 7.8 to 27.7 per cent in the sub-surface layers. Silt content ranged from 24.2 to 49.3 per cent and

Table 2. Physical properties of soils

Horizon	Depth (cm)	Sand	Silt	Clay	sHC ($cm\ hr^{-1}$)
		<-------------	(%)	------------>	
Pedon 1 Umraj series: ***Very-fine, smectitic, hyperthermic Typic Haplusterts***					
Ap	0-17	10.0	25.8	64.2	0.10
Bw	17-43	7.8	26.9	65.3	0.09
Bss1	43-70	9.2	25.1	65.7	0.08
Bss2	70-102	8.5	24.9	66.6	0.07
Bss3	102-130	9.1	24.6	66.3	0.07
Bss4	130-155	8.6	24.2	67.2	0.06
Pedon 2 Derol series: ***Fine, smectitic, hyperthermic Vertic Haplustepts***					
Ap	0-19	16.2	41.5	42.3	0.16
Bw1	19-46	16.8	40.2	43.0	0.32
Bw2	46-72	15.5	40.7	43.8	0.62
Bw3	72-100	14.2	40.9	44.7	0.79
Bw4	100-150	14.3	40.7	45.0	0.77
Pedon 3 Singdot series: ***Fine-loamy, mixed, hyperthermic Typic Haplustepts***					
Ap	0-18	31.0	38.6	30.4	1.60
Bw1	18-48	23.7	41.2	35.1	1.29
Bw2	48-77	23.5	45.8	30.7	2.00
Bw3	77-110	27.4	49.3	23.3	1.82
Bw4	110-150	27.7	47.8	24.5	1.86

decreased with depth except in Singdot series. The clay content of the soils varied from 30.4 to 64.2 per cent in the surface horizons whereas it varied from 23.3 to 67.2 per cent in the sub-surface horizons. The total clay content increased with depth in Umraj and Derol series, whereas it was irregularly distributed in Singdot series. The increase in clay content in pedons with soil depth indicated illuviation of clay from surface to sub-surface horizons of Derol soils (Bhattacharyya *et al*. 1998). Saturated hydraulic conductivity was very slow (<0.1 cm hr^{-1}) in soils of Umraj series, slow to moderately slow (0.16-0.79 cm hr^{-1}) in Derol series and moderately slow (1.29-2.0 cm hr^{-1}) in Singdot series (Table 2). It might be due to variability in particle size distribution, exchangeable sodium percentage, pH and organic matter.

Chemical Characteristics

In general, the surface soils were neutral to slightly alkaline in reaction with pH ranging from 7.3 to 8.3. The sub-surface soils were slightly alkaline (pH 7.6-8.4) in nature (Table 3). The electrical conductivity ranged from 0.10 to 1.07 dS m^{-1}. The organic carbon content was low and ranged from 0.14 to 0.43 per cent except in Ap horizon of Umraj soils (0.58 %). The calcium carbonate ($CaCO_3$) content ranged from 1.9 to 16.5 per cent and it increased with depth in all the soils, which may be due to calcification under alkaline soil environment (Srivastava *et al.* 2002) and highest $CaCO_3$ was found in Singdot soils (9.2- 16.5 %). The cation exchange capacity (CEC) and base saturation per cent (BSP) ranged from 39.4 to 62 cmol (p^+) kg^{-1} and from 67.4 to 92 per cent, respectively (Table 3). Ca^{2+} and Mg^{2+} were the dominant cations followed by Na^+ and K^+. The ratio between Ca and Mg (Ca:Mg) varied from 1.3 to 6.1 and narrower Ca:Mg ratio was due to the chemical composition and nature of parent materials from which soils had been derived. The exchangeable sodium percentage (ESP) and exchangeable magnesium percentage (EMP) ranged from 0.5 to 13.3 per cent and 11.3 to 30.4 per cent, respectively (Table 3). The continued removal of Ca^{2+} as $CaCO_3$ in the prevailing semi-arid climate may adversely cause development of sub-soil sodicity that may affect the use and management of these soils in future (Chinchmalatpure *et al*. 2008). Derol soils had high ESP in surface layer due to accumulation of sodium salt by frequent irrigations and subsequent evapotranspiration coupled with heavy application of fertilizers. High EMP in the soils indicates the presence of Mg-rich minerals such as palygorskite and dolerite, which are found in the marine and alluvial deposited soils of Gujarat coastal plains (Vasu *et al*. 2018).

Soil Classification

Umraj soils with slickensides close enough to intersect, cracks (2-3 cm wide upto 30-40 cm deep) and more than 30 per cent clay in all the horizons, were classified as Vertisols. These soils were placed under Typic Haplusterts at subgroup level on the basis of Ustic soil moisture regime (SMR) and absence of lithic contact within 50 cm depth from the surface. These soils were very deep, clay in texture (67.2 per cent) and thus classified under very-fine family textural class.

Derol and Singdot soils have cambic (Bw) sub-surface diagnostic horizon and were classified as Inceptisols. Both soils were grouped under Ustepts at sub-order level due to 'Ustic SMR and Haplustepts at the great group level because these pedons did not show either duripan or calcic horizon and base saturation was more than 60 per cent at a depth between 25 to 75 cm from the surface. Derol soils were placed under Vertic Haplustepts due to shrink-

Table 3. Chemical characteristics of soils

Horizon	Depth (cm)	pH	EC (dS m^{-1})	OC (%)	$CaCO_3$ (%)	CEC	Exchangeable bases Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	BS (%)	Ca: Mg	ESP (%)	EMP (%)
						<-----	-----cmol (p^{+}) kg^{-1}	-----	-----	----->				
Pedon 1 Umraj series: ***Very-fine, smectitic, hyperthermic Typic Haplusterts***														
Ap	0-17	7.3	0.66	0.58	2.2	57.9	23.6	17.6	6.0	0.5	82.4	1.3	10.3	30.4
Bw	17-43	7.8	0.45	0.43	2.8	62.0	25.2	16.8	5.9	0.5	78.2	1.5	9.6	27.0
Bss1	43-70	7.7	0.70	0.40	3.1	58.7	25.4	14.6	7.8	0.6	82.5	1.7	13.3	24.8
Bss2	70-102	7.7	0.68	0.32	2.5	57.0	25.6	16.0	6.1	0.6	84.7	1.6	10.8	28.0
Bss3	102-130	7.6	0.89	0.29	3.1	59.5	27.6	14.8	6.3	0.6	82.8	1.9	10.6	24.8
Bss4	130-155	7.6	0.92	0.22	4.1	62.0	28.0	15.6	5.8	0.7	80.8	1.8	9.4	25.1
Pedon 2 Derol series: ***Fine, smectitic, hyperthermic Vertic Haplustepts***														
Ap	0-19	8.3	1.07	0.40	1.9	46.2	15.2	10.4	5.1	0.4	67.4	1.5	11.1	22.5
Bw1	19-46	7.6	0.10	0.37	2.5	49.5	27.2	9.6	0.3	0.6	76.0	2.8	0.6	19.3
Bw2	46-72	7.8	0.17	0.30	2.8	46.2	32.4	9.2	0.3	0.5	91.8	3.5	0.7	19.9
Bw3	72-100	8.2	0.58	0.24	6.0	49.5	32.0	9.4	0.4	0.5	85.4	3.4	0.8	18.9
Bw4	100-150	7.8	0.14	0.25	2.8	50.3	28.4	9.8	0.6	0.3	77.8	2.9	1.2	19.4
Pedon 3 Singdot series: ***Fine-loamy, mixed, hyperthermic Typic Haplustepts***														
Ap	0-18	8.1	0.15	0.35	9.2	39.4	29.6	4.8	0.2	0.6	89.4	6.1	0.6	12.1
Bw1	18-48	8.2	0.16	0.27	10.4	41.9	30.4	7.6	0.2	0.3	92.0	4.0	0.5	18.1
Bw2	48-77	8.3	0.14	0.24	15.7	49.5	31.6	5.6	0.3	0.3	76.4	5.6	0.6	11.3
Bw3	77-110	8.3	0.19	0.20	16.1	40.2	31.2	5.2	0.3	0.3	91.9	6.0	0.7	12.9
Bw4	110-150	8.4	0.15	0.14	16.5	44.4	30.8	5.6	0.3	0.3	83.3	5.5	0.7	12.6

Table 4. Brief description and extent of soil series

Soil series	Mapping unit No.	Mapping unit symbol*	LEU**	Description	Area (ha)	Area (%)
Umraj	1	Umr6mA1	GpAaO1d	Very deep, moderatel y well drained, very dark grey, clay soils on level to nearly level old alluvial plains with clay surface and slight erosion	19072	30.0
	2	Umr6mB1	GpAaO2d & GpAaO2p	Very deep, moderately well drained, very dark grey, clay soils on very gently sloping old alluvial plains with clay surface and slight erosion	11767	18.5
Derol	3	Der6kA1	GpAaY1d	Very deep, moderately well drained, very dark greyish brown to dark yellowish brown, silty clay soils on level to nearly level recent alluvial plains with silty clay surface and slight erosion	16066	25.3
	4	Der6kB1	GpAaY2d & GpAaY2f	Very deep, moderately well drained, very dark greyish brown to dark yellowish brown, silty clay soils on very gently sloping recent alluvial plains with silty clay surface and slight erosion	4538	7.2
Singdot	5	Sin6fB1	GpAaY2d	Very deep, well drained, dark yellowish brown, clay loam to loam soils on very gently sloping recent alluvial plains with clay loamy surface and slight erosion	4164	6.6
				Total	55607	87.6
				Built up, Industrial area	7882	12.4
				Grand Total	63489	100.0

*Umr- Umraj, Der- Derol, Sin- Singdot, 6-very deep soil, m- clay, k-silty clay, f- clay loam, A-slope 0-1%, B-slope1-3%, 1-slight erosion.
** G-Gujarat coastal plain, p-West coast plain, AaO- Old alluvial plains, AaY- Recent alluvial plains, 1- slope 0-1%,
2- slope1-3%, d- double crop, p-plantation, f- forest.

swell properties and presence of pressure faces between 46 to 100 cm depth and having 42 to 45 per cent clay content. Derol soils were very deep, silty clay in texture with 42-45 per cent clay content and thus qualify for having fine family textural class. Singdot soils did not have lithic contact within 50 cm depth therefore, grouped under Typic Haplustepts. These soils were also very deep, clay loam to loam in texture with clay content up to 35 per cent and classified as fine-loamy, textural family class.

Soil Suitability for Crops

According to suitability assessment criteria proposed by Sys *et al*. (1991) and Naidu *et al*. (2006), soil site suitability of all the mapping units was assessed for major crops grown in the area. The majority of soils were assessed as highly suitable (S1) to moderately suitable (S2) for the major crops (Table 5). Out of the five mapping units, four units (1 to 4) comprised of 51,443 ha area was highly suitable for cotton cultivation and moderately suitable for other major crops (pigeon pea, maize, sugarcane, wheat and chick pea). LGP, drainage and texture of these soils are the major constraint for cultivation of pigeon pea and maize. For sugarcane and chick pea cultivation, major limitations are mean temperature, rainfall, drainage and texture of these soils. The mapping unit no. 5 (4,164 ha) was highly suitable (S1) for pigeon pea, maize, sugarcane and chickpea whereas moderately suitable (S2) for cotton and wheat crops. Major limitations that decide the suitability of these soils for cotton and wheat cultivation are LGP, drainage and texture of the soils. The cultivation of these crops as per their suitability of soils can support the sustainable crop production without any adverse impact in soils of Bharuch taluka.

Table 5. Soil Suitability for major crops

Mapping unit no.	Cotton	Pigeon pea	Maize	Sugarcane	Wheat	Chick pea
1	S1	S2	S2	S2	S2	S2
2	S1	S2	S2	S2	S2	S2
3	S1	S2	S2	S2	S2	S2
4	S1	S2	S2	S2	S2	S2
5	S2	S1	S1	S1	S2	S1

Summary

Based on soil survey, three soil series were identified in Bharuch taluka of district Bharuch, Gujarat. Vertisols occupy 48.5 % and Inceptisols 39.1 %. Soils were mostly clay to silty clay in texture, neutral to slightly alkaline in reaction, low to medium organic carbon content and medium to high in cation exchange capacity [39.4- 62.0 cmol (p+) kg^{-1}] with high base saturation (67.4-92.0 %). Soils were highly suitable cotton and moderately suitable for pigeonpea, maize, sugarcane, wheat and chickpea. Major limitations that decide the suitability of these soils are rainfall, mean temperature, LGP, drainage and texture of the soils. Hence, proper soil and water conservation measures as well as good agronomic practices may be adopted to enhance productivity.

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