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Characterization and Evaluation of Cotton-growing Soils of Ghatanji Tehsil, Yavatmal District, Maharashtra

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Abstract: The present investigation was carried out in the Ghatanji tehsil of Yavatmal district, Maharashtra to characterize and evaluate the soil suitability for the cotton crop. Soil resource inventory at 1:10,000 scale was undertaken to establish the soil-landform relationship. Five soil series were identified with the phases on nine landform units. These calcareous clayey soils were shallow to deep (33 to 140 cm) and had their colour in 10YR hue with value 3 to 4 and chroma 1 to 6. The soils were neutral to moderately alkaline with electrical conductivity ranging from 0.11 to 1.35 dSm^{-1} and had, very low to medium in organic carbon content (0.11 to 0.95%). The surface horizon of all the soils had medium sub-angular blocky structures but sub-surface horizons had medium to coarse and moderate to strong, sub-angular to angular blocky structure. The saturated hydraulic conductivity (SHC) of the soils varied from 0.0 to 6.52 cm $hr^{-1.}$. The available water content ranged from 4.60 per cent to 22.2 per cent in the surface horizon and increased with depth. The COLE value ranged from 0.09 to 0.21 cm. Calcium was the dominant cation on the exchange complex followed by magnesium, sodium and potassium. Taxonomically these soils were classified as Leptic Haplusterts, Sodic Haplusterts, Lithic Haplustepts and Typic Haplustepts at the subgroup level. Parametric land evaluation techniques (Sys & Riquier's) indicated marginally suitable to not suitable (Sys criteria) and good to poor (Riquier Index) for growing the cotton crop in Ghatanji tehsil of Yavatmal district.

Key words: *Soil characterization, classification, land evaluation, Sys and Riquier Index*

Introduction

Soil is a dynamic natural resource that determines the ultimate sustainability of any agricultural system. Water movement, water quality, land use, and vegetation productivity are all influenced by the soil (Schoonover and Crim 2015). The increasing population lead to hampering the sustainability of the ecosystem and its productivity. This leads to a systematic evaluation of soil resources concerning their use potential, which is very important for developing an effective land-use system for augmenting agricultural production on a sustainable basis (Pulakeshi *et al.* 2014).

Among the cotton-growing states, Maharashtra represents (38.06 lakh ha) almost half of the total acreage in India, followed by Gujarat (2.36 mha), Andhra Pradesh (2.14 mha), Northern Zone (1.56 mha), Madhya Pradesh (0.68 mha) and the rest in Karnataka, Tamil Nadu and other states. The production and productivity of Maharashtra was 89.0 lakh bales and 398 kg ha^{-1}, respectively (CCI 2016). Vidarbha is an important cotton-growing region in Maharashtra, where the area under cotton increases every year, *i.e.* 13.60 lakh ha with a production of 24 lakh bales with a productivity of 310 kg lint ha^{-1} (Anonymous 2018). Now a days, frequent crop failures are seen, and it is most prominently visible

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in Yavatmal district, and the cotton growers are facing a severe economic crisis resulting in an increasing suicide rate. This region is a hotspot for critical analysis of land use activity where the economic dependence of farmers is solely on cotton, and more than 50 per cent of the total net sown area has been under a single crop over the years and hence this study is targeted in the cotton-growing area of Ghatanji tehsil of Yavatmal district to know the soil-site suitability for cotton, so that suitable sites could be suggested.

Materials and Methods

Study area

The study was taken up in a Ghatanji tehsil of Yavatmal (19º 50' 27" to 20º 11' 44"N; 78º 05' 39" to 78º 28' 43"E), covering a total area of 969 sq. km at an elevation of 274 m above the mean sea level (MSL) (Fig. 1). The study area falls under North Deccan (Maharashtra) Plateau and is agro-climatically termed as hot moist to semi-arid eco-subregion. The climate of the area is sub-tropical, dry sub-humid with well-expressed summer (March-May), rainy season (June-October) and winter season (November-February). The mean maximum temperature varies from 33.1°C to 42.8°C in summer; mean daily minimum temperature is 14.7 °C to 17.9 °C in winter with a mean annual temperature of 27.6°C. The average annual rainfall of the district is 1093 mm and these area mostly under cotton, soybean, pigeon pea, sorghum, gram, wheat and vegetables.

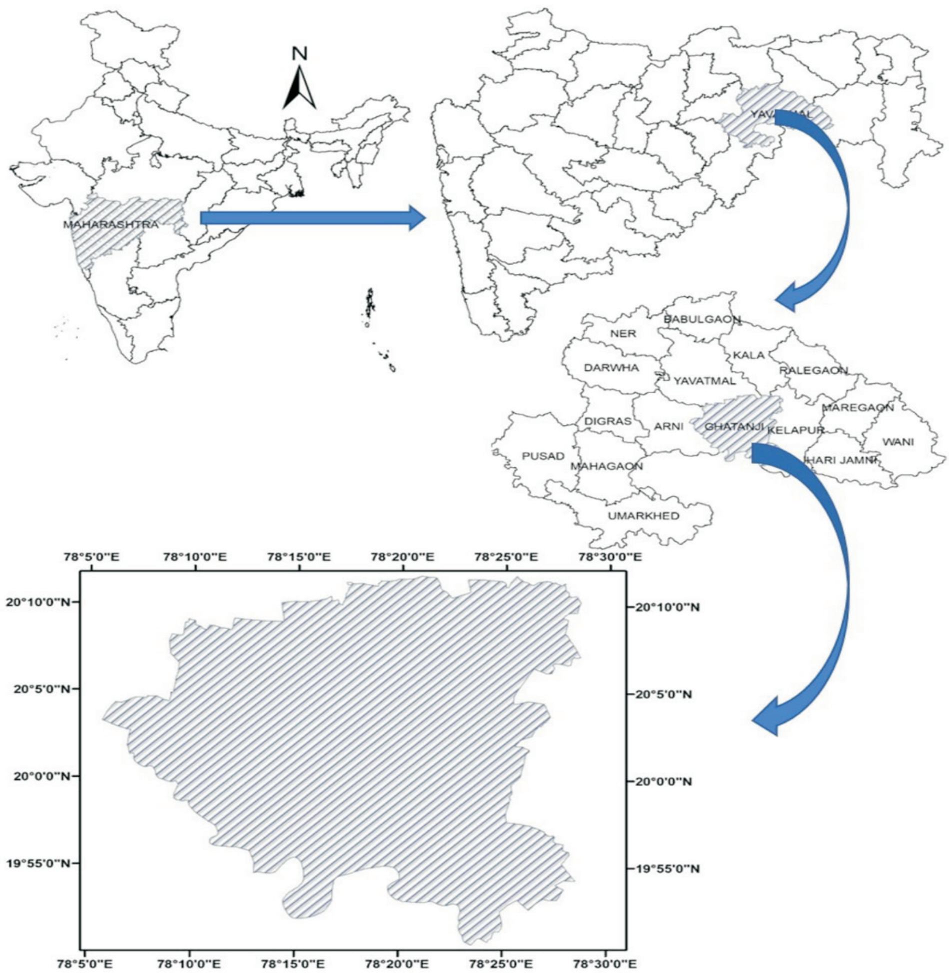

Fig.1. Study area showing the Ghatanji tehsil

The soil survey was carried out using a base map *i.e.,* land ecological units (LEU) as shown in fig. 2. The base map has nine landforms *viz*., hills and ridges, hillocks, plateau, undulating upland, pediment, escarpment, pediplain, alluvial and valley. Out of these nine landform units, cotton crops were cultivated in the five landform units, so representative pedons were studied in these landform units namely undulating upland, pediment, alluvial plain, pediplain and plateau. A total of eleven pedons were exposed and morphological characteristics were studied as per the Soil Survey Manual (Soil Survey Division Staff 2014). Horizon-wise soil samples were collected, air-dried and processed . Particle-size distribution (sand, silt and clay) was determined as per the international pipette method (Jackson 1979); water retention at 33 kPa and 1500 kPa as per procedure outlined by Klute (1986); saturated hydraulic conductivity (sHC) was determined by constant head methods as per the procedure of Klute and Dirksen (1986); coefficient of linear extensibility (COLE) was determined by linear extensibility (Schafer and Singer 1976). Chemical properties like pH and EC of the soil suspension (1:2 ratio) was determined by the procdures outlined by Jackson (1973); organic carbon

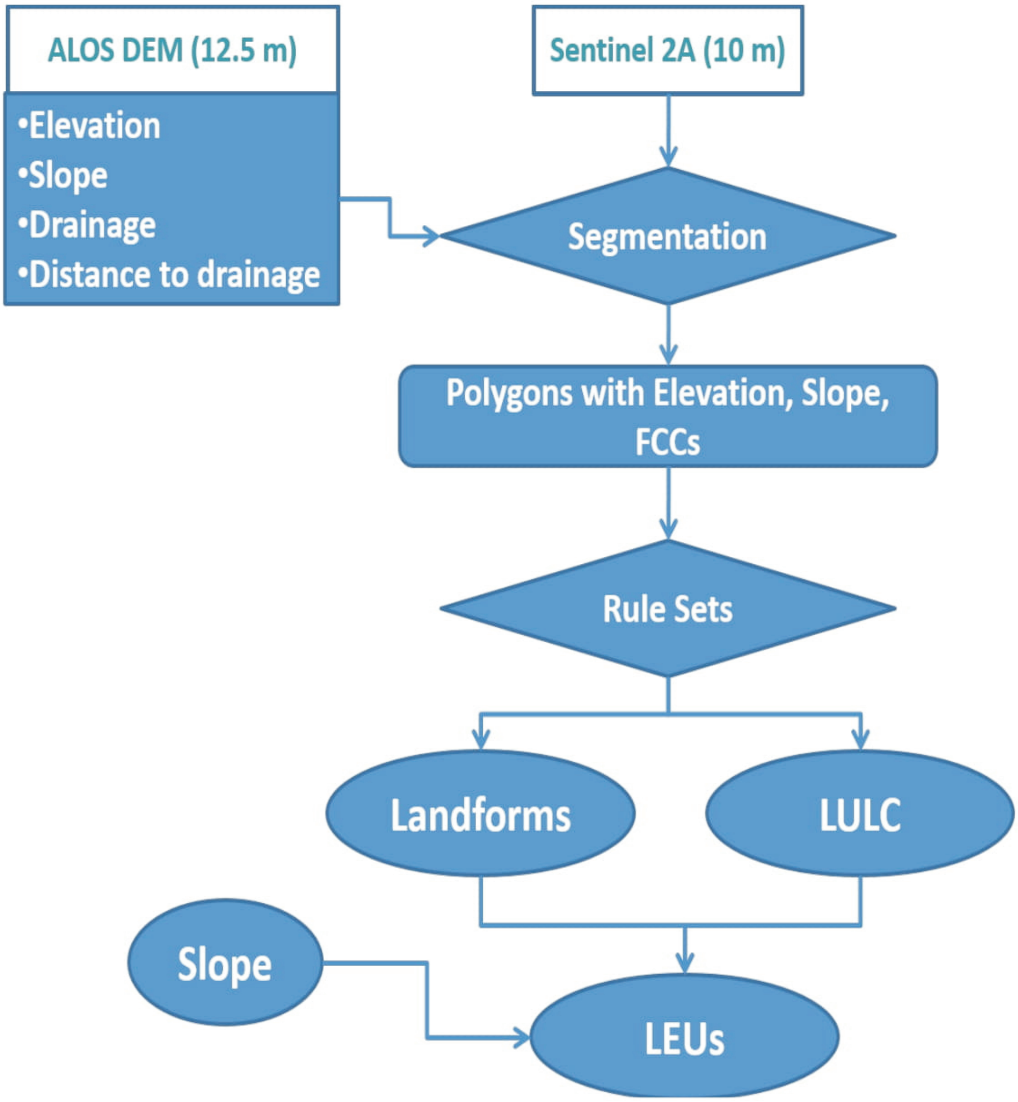

Fig. 2. Procedure followed in the developing the landform map-flowchart

(OC) of the soil was determined by wet-oxidation method (Walkley and Black 1934); calcium carbonate ($CaCO_3$) was assessed by rapid titration method (Piper 1966); exchangeable cations and cation exchange capacity of soils were determined using methods outlined by Schollenberger and Simon (1945); base saturation was determined by sum of cations method Jackson (1973). These soils were classified as per the USDA Soil Taxonomy (Soil Survey Staff 2014). These soils were evaluated for their suitability as per the criteria outlined by Sys *et al.* (1993). The productivity of the soils was computed and assessed by following the procedures described by Riquier e*t al.* 1970.

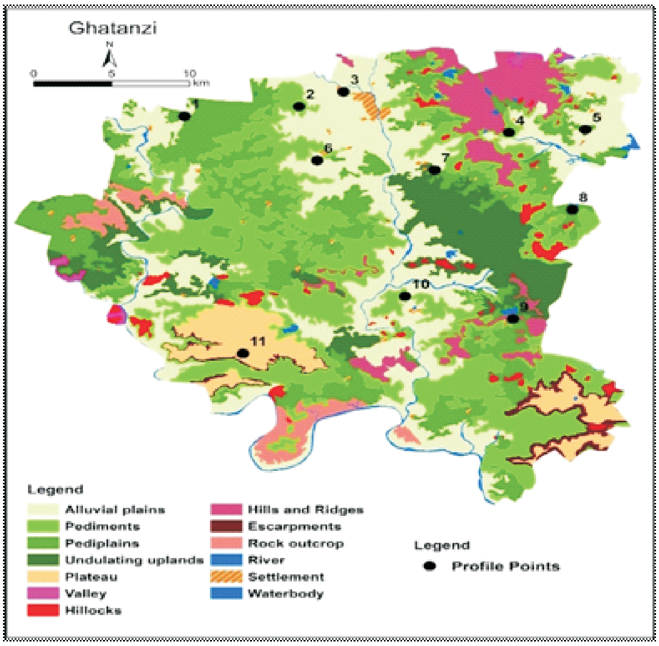

Fig. 3. Landform map with pedon location

Alluvial plain 25399.65 ha	Hillock 1806.45
Pediments 24496.35	Escarpment 1539.73
Undulating upland 9107.38	River 1394.16
Hills and ridges 6162.16	Settlement 698.02
Plateau 5027.32	Valley 411.96
Rock aut crop 2538.18	Water bodies 377.27
Total- 97200.23 ha	

Results and Discussion

Soil characteristics

The soils were very shallow to moderately deep (33-140 cm) and had their colour in hue 10YR, value 3 to 4, and chroma 1 to 6. This may be due to the reduction of iron under impeded drainage (Prasad *et al*. 1989) and the complexion and chelation of organic colloids on the surface of smectite (Singh *et al*. 1994). The texture of soils in all the pedons is clayey due to basaltic parent material (Murthy *et al.* 1982). The surface horizons of all soils had medium sub angular blocky structures. The sub-surface horizons had medium to coarse and moderate to strong subangular to the angular blocky structure. Some of the sub-soils horizons having pressure faces and slickensides were associated with coarse, strong, angular blocky structures. This may be attributed to the high shrink and swell phenomena of smectite clay present in these soils (Prasad *et al*. 1989). Violent to strong effervescence is observed throughout the profile in all the soils. This has been mainly due to the leaching of bicarbonates during the rainy season from the upper layers due to subsequent precipitation and prevailing semi-arid climatic conditions (Balpande *et al.* 1996).

The particle-size distribution indicated that the clay content varied from 44.3 to 71.9 per cent in the surface horizon, and in sub-surface horizon it ranged from 45.3 to 79.3 per cent. This might be due to the illuviation or translocation of clay from the surface to the sub-surface horizon. The silt and sand content varied from 6.2 to 35.9 per cent and 6.40 to 43.3 per cent, respectively. The variation in soil separates may be due to soil developed on different physiographic units and its parent material (Murthy *et al.* 1994). The data (Table 2) reveals that saturated hydraulic conductivity of the soils varied from 0.0 to 6.52 cm hr^{-1}. The saturated hydraulic conductivity of the soils of series 3 is 0.00 cm hr^{-1} due to high content of sodium in the sub-surface horizon. It is generally noticed that it is low in the sub-surface horizons than that in the surface owing to the compaction of soil material at lower horizons. This decreasing trend of saturated hydraulic conductivity with depth was also reported by (Bharambe *et al.* 1999; Kadu *et al.* 2003).

Table 1. Morphological properties of the soils

Series	Depth (cm)	Boundary	Matrix Colour	Texture	Coarse fragments (%)	Structure	Consistence	Pores	Roots	Efferve scence	Nod ules	Other features
Series 1 (Pandurna Bk) : Very fine, smectitic, hyperthermic Leptic Haplusterts												
Ap	0-14	-	10 YR 3/2	c	5	m2sbk	sh fi vsvp	-	-	ev	vf f c	-
Bw	14-35	-	10 YR 3/1	c	-	m2abk	sh fi vsvp	-	-	ev	vf f c	-
Bss	35-60	-	10 YR 3/1	c	-	m2abk	shvsvp	-	-	ev	-	-
Cr	60	Weathered material										
Series 2 (Pandurna) : Clayey, smectite, Typic Haplustepts												
Ap	0-15	-	10 YR 3/6	c	-	m 2 sbk	sh fi vsvp	-	-	-	-	-
Bw	15-35	-	10 YR 3/4	c	-	m 2 sbk	sh fi vsvp	-	-	-	-	-
Cr	35-60	Weathered material										
Series 3 (Ghantanji) : Very fine, smectitic, hyperthermic Sodic Haplusterts												
Ap	0-14	g s	10 YR 3/2	c	10	m2sbk	-	-	-	-	vf f c	-
Bw	14-28	g s	10 YR 3/2	c	-	m2abk	-	-	-	-	fm c	pf
Bss1	28-45	g s	10 YR 3/2	c	-	m2abk	-	-	-	-	fm c	ss
Bss2	45-72	g s	10 YR 3/4	c	-	m2abk	-	-	-	-	fm c	ss
Bss3	72-115	g s	10 YR 3/6	c	-	m2abk	-	-	-	-	fc c	ss
Cr	115-140	g s	10 YR 3/6	c	-	m2abk	-	-	-	-	-	-
Series 4 (Jamb) : Clayey, smectitic, hyperthermicTypic Haplustepts												
Ap	0-16	c s	10 YR 3/2	c	-	m2sbk	h frvsvp	vf m	m m	ev	m m	-
Bw	16-37	c s	10 YR 3/2	c	-	m3sbk	fi vsvp	vf m	f m	ev	f m	-
BC	37-57	a s	10 YR 4/2	c	-	m2sbk	frvsvp	f m	-	ev	fm c	-
R	57	Hard basalt rock										
Series 5 (Patapangra) : Clayey, mixed, hyperthermic Lithic Haplustepts												
Ap	0-13	c s	10 YR 3/2	c	5-10	m2sbk	vhvfrvsvp	vf m	f f	es	-	-
Bw	13-33	c s	10 YR 3/1	c	5-10	c3sbk	vhvfivsvp	vf m	-	es	-	-
R	33	Hard basaltic boulders										

Table 2. Physico-chemical characteristics of soils

Series	Depth (cm)	Particle Size distribution			sHC (cm h^{-1})	AWC (%)	COLE (cm)	pH (1:2)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Extractable Bases cmol (p^+) kg^{-1}					CEC cmol (p^+) kg^{-1}	Base Saturation (%)	ESP (%)
		Sand (%)	Silt (%)	Clay (%)								Ca^{++}	Mg^{++}	Na^+	K^+	Sum			
Series 1 (Pandurna Bk) : Very fine, smectitic, hyperthermic Leptic Haplusterts																			
Ap	0-14	16.2	11.9	71.9	2.71	14.5	0.21	8.07	0.44	0.95	9.12	56.8	6.80	0.43	1.48	65.5	81.4	80.5	0.52
Bw	14-35	13.9	14.3	71.8	2.73	11.8	0.20	8.28	0.16	0.76	10.9	63.6	5.60	0.47	0.44	70.1	77.7	90.2	0.60
Bss	35-60	14.7	14.8	70.5	4.06	12.1	0.20	8.37	0.16	0.64	13.1	66.0	5.20	0.47	0.42	72.1	84.4	85.4	0.55
Series 2 (Pandurna) : Clayey, smectite, Typic Haplustepts																			
Ap	0-15	27.0	28.7	44.3	1.50	12.1	0.12	7.03	0.19	0.95	6.20	40.0	13.6	0.26	1.33	55.2	69.1	79.8	0.37
Bw	15-35	43.3	6.2	50.5	2.61	12.0	0.09	7.04	0.11	0.42	7.27	42.8	22.8	0.78	0.50	66.9	88.3	75.8	0.88
Series 3 (Ghantanji) :Very fine, smectitic, hyperthermic Sodic Haplusterts																			
Ap	0-14	8.10	20.0	71.9	0.88	13.7	0.10	8.20	0.22	0.70	8.98	52.0	4.40	1.04	1.43	58.9	66.1	89.1	1.57
Bw	14-28	8.80	12.0	79.2	1.02	17.4	0.17	8.58	0.24	0.48	8.05	44.0	15.6	2.43	0.82	62.9	76.0	82.7	3.19
Bss1	28-45	8.60	13.9	77.5	0.17	16.2	0.15	8.85	0.44	0.34	8.91	38.8	18.0	7.83	0.61	65.2	74.1	88.0	10.5
Bss2	45-72	10.2	10.5	79.3	0.00	16.8	0.13	8.86	0.87	0.25	9.55	40.0	9.20	14.1	0.72	64.0	58.1	110	24.2
Bss3	72-115	11.0	15.6	73.4	0.00	13.6	0.18	8.87	1.11	0.20	10.8	26.4	25.2	17.2	0.92	69.7	73.8	94.5	23.3
Cr	115-140	10.1	23.1	66.8	0.00	12.0	0.09	8.86	1.35	0.11	11.1	24.8	23.6	18.3	0.92	67.6	68.1	99.3	26.8
Series 4 (Jamb) : Clayey, smectitic, hyperthermic Typic Haplustepts																			
Ap	0-16	24.5	29.0	46.5	1.28	11.5	0.14	7.89	0.18	0.22	7.62	45.2	10.4	0.47	0.38	56.5	52.2	108	0.90
Bw	16-37	17.2	35.9	46.9	2.53	13.2	0.19	8.24	0.14	0.39	10.8	50.8	14.0	0.42	0.30	65.5	63.5	103	0.66
BC	37-57	29.7	25.0	45.3	6.52	4.60	0.11	8.25	0.15	0.39	23.2	46.8	10.8	0.30	0.30	58.2	45.7	127	0.65
Series 5 (Patapangra) : Clayey,smectitic, hyperthermic Lithic Haplustepts																			
Ap	0-13	7.50	26.2	66.3	1.87	22.2	0.15	7.1,8	0.42	0.59	11.8	47.2	17.6	0.17	0.95	65.9	61.7	107	0.27
Bw	13-33	6.40	33.4	60.2	1.10	12.7	0.16	7.50	0.17	0.59	9.69	48.4	8.40	0.17	0.69	57.7	56.1	103	0.30

Available water content ranged from 4.60 per cent to 22.2 per cent on the surface horizon, and it increased with depth. This trend can be attributed to high amounts of 2:1 type smectitic clay, which has a large surface area and shrink-swell properties. A linear relationship between clay content and moisture retention was also reported (Nikam *et al.* 2006; Balpande *et al.* 2007). The value of COLE ranged from 0.09 to 0.21 cm, indicating shrink-swell activities in these soils due to the predominance of smectitic clay (Balpande *et al.* 1996).

Soils were neutral to moderately alkaline (pH 7.03 to 8.87) and pH increased down the profile.The electrical conductivity of soil varied from 0.11 to 1.35 dSm^{-1}. The organic carbon content of the soils varied from 0.11 to 0.95 per cent. The soils of series 4 showed an increasing trend with depth may be due to soil inversion. All the soils were calcareous, and the $CaCO_3$ content varied from 6.20 to 23.2 per cent. The distribution of calcium carbonate in soil profile invariably showed an increasing pattern with soil depth, which indicated leaching down of calcium and subsequent precipitation at lower depth may be due to high pH level (Pal *et al.* 2000; Challa *et al.* 2000). There was dominance of calcium and magnesium content on the exchange complex in all the pedons (Table 2). The cation exchange capacity in all the pedons ranged from 45.7 to 88.3 $cmol(p^+)\ kg^{-1}$ (Table 2). The higher CEC in some horizons might be due to higher smectitic clay mineralogy. The base saturation in soils ranged from 75.8 to 127 %, which is more than 100 % due to the presence of Ca-zeolites (Pal *et al.* 2006). Low exchangeable sodium percentage (<5) was observed in all the soils except the soil series of 3 (Ghatanji), where the ESP increases down the profile. This increased exchangeable sodium content makes soils impermeable the saturated hydraulic conductivity will become zero (Murthy *et al*. 1982; Nimkar *et al*. 1992).

Soil classification

The soils were grouped into different taxonomical classes based on morphological, physical and chemical characteristics (Table 3). The soils of series 1 and 3 were moderately deep to deep, black in colour,

Table 3. Soil series description and its taxonomic classification

Series	Pedon location	Series description	Taxonomic classification
1	Pedon 1 (Pandurna Bk)	Moderately shallow, dark grayish brown, clay, moderately calcareous, moderately well drained, slightly eroded on land, very gently sloping	Very-fine, smectitic, hyperthermic Leptic Haplusterts
2	Pedon 2 (Pandurna)	Shallow, dark yellowish brown, clay, moderately calcareous, imperfectly drained, moderately eroded on, gently sloping land	Clayey, smectitic Typic Haplustepts
3	Pedon 3 (Ghatanji)	Deep, very dark grayish brown, clay, moderately calcareous, moderately well drained, slightly eroded on, very gently sloping land	Very-fine, smectitic, hyperthermic Sodic Haplusterts
4	Pedon 4 (Jamb)	Moderately Shallow, very dark grayish brown, clay, slightly deep calcareous, well drained, severely eroded on, gently sloping land	Clayey, smectitic, hyperthermic Typic Haplustepts
5	Pedon 5 (Patapangra)	Shallow, very dark grayish brown, clay, moderately calcareous, well drained, slightly eroded on, very gently sloping land	Clayey, mixed, hyperthermic Lithic Haplustepts

clayey (>30% clay), and characterized by deep, wide cracks when dry that open and periodically, shrink-swell properties, gilgai microrelief and very well developed slickensides close enough to intersect underlain by cambic horizon qualify for order Vertisols. The occurrence of the paralithic contact within the 100 cm soil depth in soil of series 1 meets the requirement for the subgroup Leptic Haplusterts while the other soil having exchangeable sodium percentage >15% within 100 cm soil depth compels to put as Sodic Haplusterts at subgroup level with fine textural class. The soils having ochric epipedon underlain by cambic sub-surface horizon with its upper surface boundary within 100 cm of the mineral soil surface and it's lower boundary at a depth of 25 cm or more below the mineral soil surface have been classified in the order Inceptisols. Because of the prevailing ustic moisture regime in the study area, these soils are classified in the suborder Ustepts and qualify for Haplustepts great group. The Haplustepts great group is further divided into two subgroups on the basis of lithic contact *viz.* Lithic Haplustepts and Typic Haplustepts as per Soil Survey Staff (1998). The soils of series 2 and 4 meets the requirement of subgroup Typic and is classified as Typic Haplustepts, whereas due to the presence of lithic contact within the first 50 cm soil depth in series 5, which is classified as Lithic Haplustepts.

Table 4. Degree of limitation and suitability of soils of different soil series for growing cotton

Characteristics	Series 1	Series 2	Series 3	Series 4	Series 5
Mean temperature in growing season (^oC)	1	1	1	1	1
Mean max. temp. in growing season (^oC)	2	2	2	2	2
Mean min. temp. in growing season (^oC)	1	1	1	1	1
Mean RH in growing season (%)	1	1	1	1	1
Total rainfall (mm)	2	2	2	2	2
Rainfall in growing season (mm)	1	1	1	1	1
Length of growing period (Days)	2	2	1	2	2
AWC (mm/m)	2	3	2	3	3
Soil drainage (Class)	1	2	1	1	1
Texture (Class)	1	1	1	1	1
pH (1:2.5)	3	1	3	3	2
CEC (C mol (p^+)/kg)	1	1	1	2	1
BS (%)	1	2	1	1	1
$CaCO_3$ in root zone (%)	2	1	1	2	2
OC (%)	2	1	3	4	3
Effective soil depth (cm)	3	3	1	3	3
Stoniness (%)	1	1	1	1	4
Coarse fragments (Vol %)	1	1	2	1	2
Salinity EC saturation extract (dS/m)	1	1	1	1	1
Slope (%)	2	4	2	4	2
Soil Suitability (Rating)	**S3**	**N**	**S3**	**N**	**N**

Suitability and evaluation of cotton crop

As per Sys *et al.* (1993) criteria, the soils of series 1 and 3 are marginally suitable to not suitable due to the marginal limitation of pH, $CaCO_3$, organic carbon and soil depth and severe limitation of organic carbon, stoniness, coarse fragments and slope (soils of series 2,4 and 5) as depicted in table 4.

Riquier's productivity index of all the five soil series were shown in table 5. Soil of series 1 and 3 are good owing to some limitation of soil texture, moisture and soil depth. The soils of series 2 and 5 are poor in land productivity index due to soil moisture limitation and effective soil depth. Soils of series 4 is classified under average land productivity index with average soil moisture limitation, soil depth and texture. Cotton is grown extensively in these land where the land productivity index is average/poor, which may be the main reason for crop failure in these regions (Karthikeyan *et al.* 2019). Comparing the Sys and Riquier indices (Riquier *et al.* 1970) results are one class ahead of the Sys suitability indices (Karthikeyan *et al.* 2013).

Table 5. Productivity index for cotton crop (Rating class with assigned values), Productivity classes and Index of Potentiality

Profile No	H	D	P	T	N	O	A	M	PI	P class	P'
Series 1	70	90	80	80	100	90	100	100	36.3	Good	II
Series 2	60	80	50	80	100	90	100	100	17.3	Poor	IV
Series 3	80	90	100	80	100	90	100	100	51.8	Good	II
Series 4	60	100	50	80	100	90	100	100	21.6	Average	III
Series 5	50	100	50	80	100	90	100	100	18.0	Poor	IV

PI - Productivity Index

P - Classes of Productivity

P'- Index of Potentiality

Productivity Index- (PI) = H * D * P *T * N or S* O* A* M

H - Soil moisture content

D– Drainage

P- Effective depth of soil

T - Texture and structure of the root zone

N - Average nutrient content of A horizon

S - Soluble salt content

O - Organic matter in A1 horizon

A - Mineral exchange capacity

M - Reserves of weatherable minerals in B horizon

Conclusion

The soils of Ghatanji tehsil were characterized and classified. Based on the soil characteristics, these soils were classified as Leptic Haplusterts, Sodic Haplusterts, Lithic Haplustepts and Typic Haplustepts at the subgroup level. Based on the soil site suitability and productivity indices of the soils of five soil series were grouped under marginally suitable to not suitable and good to poor in productivity indices for the cotton crop.

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