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Characterization and evaluation of soils of Kukadi Command (Minor-25) in Ahmednagar district of Maharashtra for land resource management

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Abstract: A detailed soil survey was undertaken to characterize and evaluate the land resources in Kukadi Command (Minor-25) in Ahmednagar district of Maharashtra. Two major landforms *viz.* pediments and piedmont plains were identified. Two slope classes *viz*. very gently sloping (1-3% slope) and gently sloping (3-8% slope) lands were identified. Ten soil series were tentatively identified and mapped as phases of soil series on 1:5000 scale. Soils of pediments and upper piedmonts (erosional surfaces) are very shallow to shallow in depth, loam to clayey in texture, have moderate to severe erosion and classified as *Lithic Ustorthents, Typic Ustorthents* and *Typic Haplustepts*. Soils of lower piedmonts (depositional surfaces) are moderately deep to very deep, fine-textured with shrink-swell potential, have slight to moderate erosion and classified as *Vertic Haplustepts* and *Typic Haplusterts*. Majority of the soils are calcareous in nature. The soils were grouped into IIws, IIIes, and IVes land capability sub-classes and 2d, 3st and 4st land irrigability sub-classes. The soil suitability analysis indicated that soils of pediments and upper piedmont plains are marginally to moderately suitable, whereas, soils of lower piedmont plains are moderately suitable for growing pearl millet, onion, groundnut, wheat and soybean. Suitability for sugarcane indicated that soils of pediments and upper piedmont plains are marginally to not suitable due to severe limitations of soil depth and slope, whereas, soils of lower piedmont plains are moderately suitable.

Key words: *Detailed soil survey, soil classification, land capability, land irrigability, crop suitability*

Introduction

Soil maps have become valuable tools for land resources management. Sustainable management of land resources is essential for food security, maintenance of environment and general well being of the people. Indiscriminate use of resources coupled with lack of management has, however, led to degradation echoing the concern of planners, researchers and farmers alike (Sharma 2006). Adequate knowledge about the properties and distribution of soils is key issue to support sustainable land management, which among others, includes fertility management, crop choice and possibilities for irrigation. Soil resource inventory through characterization of the resources provides an insight into the potentials and limitations of soils (Manchanda *et al.* 2002). The information generated through soil resource inventory is generally interpreted for various grouping of soils for land capability, land irrigability and suitability of soils for different crops through evaluation procedures which helps the administrators and managers for agriculture and related developmental activities on sustainable basis. Detailed soil spatial and attribute information is required for irrigation management. To improve the cropping intensity and irrigation water efficiency, understanding of the soil properties and their constraints is very important thereby increasing the gross area under irrigation and

the productivity per unit area per unit time. Keeping this in view, the present study was undertaken in Kukadi Command (Minor-25) in Ahmednagar district of Maharashtra to characterize and evaluate the soils for land resource management.

Materials and Methods

The study area (740.61 ha) is Kukadi Command (Minor-25) which is an experimental farm of Directorate of Water Management Research (ICAR), Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri located at Wadegaon village in Ahmednagar district of Maharashtra. The minor-25 has 27 outlets at head reach (27), mid reach (9) and tail end (8) with a design discharge of 625 liters/second. The gross cropped and culturable command area is 857 ha and 740 ha, respectively. Out of 740 ha culturable command area, 507 ha (68.5 per cent) was under irrigation, whereas, 233 ha (31.5 per cent) is under rainfed. The geology of the area is basalt. The major landforms identified in the area are pediments and piedmont plains. The piedmonts were further divided into upper and lower piedmont plains based on the elevation. The major slopes identified are very gently sloping (1-3%) and gently sloping (3-8%) lands. The climate of the area is semi-arid subtropical with well expressed seasons. The mean annual maximum and minimum temperatures are 31.9°C and 17.6°C, respectively. The average rainfall of the area is 750 mm. The area qualifies for '*Ustic*' and '*Hyperthermic*' soil moisture and soil temperature regimes, respectively. Commonly occurring tree species are *Azadirachta indica*, *Butea frondosa*, *Mangifera indica*, *Tamarindus indica*, *Acacia arabica*, *Zizipus jujube* interspersed with grasses like *Lantana camera*, *Cynodon dactylon*, *Arzemona Mexicana etc*. The total number of tube well in the study area are 37, out of which 31 wells are in operation irrigating an area of 62 ha prior to canal irrigation and the water quality, in general, is good for irrigation. Major crops grown in the area are pearl millet, sorghum, pigeonpea, onion, wheat, sugarcane and vegetables. During *kharif* season, pearl millet is predominant, whereas, during *rabi* season, sorghum, wheat and onion are predominant. Pearl millet-onion-groundnut is the common cropping sequence of the area.

Cadastral maps of the command area available at 1:5000 scale were collected from the Water Management Research Project, MPKV, Rahuri. A detailed soil survey was carried out using the base map. In all, 61 soil profiles covering the entire area were exposed and studied for morphological properties (Soil Survey Division Staff 2000) and classified as per Soil Taxonomy (Soil Survey Staff 2010). A total of 139 augur observations were taken for precise delineation of soil boundaries. Soil series were identified and mapped as phases of soil series. The soil phases considered were surface texture, slope and erosion. The soil legend code developed depicts the name of the soil series followed by texture, slope, erosion and stoniness (AIS&LUS 1971). Soil samples were collected from representative pedons and analyzed for different physical and chemical properties following standard procedures (Black 1965; Jackson 1967). The soils were grouped under different land capability subclasses (Klingebiel and Montgomery 1961) and land irrigability sub-classes (AIS&LUS 1971). The soil-site suitability for pearl millet, onion, groundnut, sugarcane, wheat and soybean was worked out as per the methodology given in the FAO frame work on land evaluation (FAO 1976) modified by Sys *et al.* (1991). The soil-site requirements as suggested by NBSS&LUP (1994) have been used for evaluating the suitability of different mapping units.

Results and Discussion

Characterization of soils

Five soil series (Kukadi-1, Kukadi-2, Kukadi-4, Kukadi-5, Kukadi-7) are tentatively identified on pediments. Soils of Kukadi-1 are very shallow, somewhat excessively drained, very dark brown (7.5YR 3/3 M), gravelly sandy clay loam with severe erosion and classified as loamy-skeletal, mixed, hyperthermic *Lithic Ustorthents*. Soils of Kukadi-2 are very shallow, somewhat excessively drained, very dark grayish brown (10YR 3/2 M), gravelly clay with severe erosion and classified as clayey-skeletal, mixed, hyperthermic (calcareous) *Lithic Ustorthents*. Soils of Kukadi-4 are shallow, well drained, very dark brown (7.5YR 2.5/3 M), clayey with

severe erosion and classified as clayey, mixed, hyperthermic (calcareous) *Typic Ustorthents*. Soils of Kukadi-5 are shallow, well drained, dark brown (10YR 3/3 M), clayey with severe erosion and classified as clayey, mixed, hyperthermic (calcareous) *Lithic Ustorthents*, whereas, soils of Kukadi-7 are shallow, well drained, dark brown (10YR 3/3 M), clayey with moderate erosion and classified as clayey, mixed, hyperthermic (calcareous) *Typic Haplustepts*. Three soils (Kukadi-3, Kukadi-6, Kukadi-8) are tentatively identified on upper piedmont plains. Soils of Kukadi-3 are shallow, somewhat excessively drained, dark brown (10YR 3/3 M), loamy, with severe erosion and classified as loamy-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*. Soils of Kukadi-6 are shallow, well drained, dark brown (10YR 3/3 M), gravelly clay with severe erosion and classified as clayey-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*. Soils of Kukadi-8 are shallow, well drained, dark brown (10YR 3/3 M), clayey with severe erosion and classified as clayey, mixed, hyperthermic (calcareous) *Typic Haplustepts*. Two soils (Kukadi-9, Kukadi-10) are tentatively identified on lower piedmont plains. Soils of Kukadi-9 are moderately deep, moderately well drained, fine with slight erosion and classified as fine, smectitic, hyperthermic (calcareous) *Vertic Haplustepts*. Soils of Kukadi-10 are very deep, moderately well drained, slightly eroded, fine with well developed slickensides and classified as fine, smectitic, hyperthermic (calcareous) *Typic Haplusterts*. The detailed soil map with phases of soil series is presented in figure 1 and the descriptive legend of soil map is presented in Table 1.

Table 1. Descriptive legend of soil mapping units, Kukadi command (Minor-25)

Mapping symbol	Mapping unit description	Area (ha)	Per cent of TGA
KlmC3st2	Kukadi-1, very shallow, gravelly sandy clay loam, gently sloping undulating upper slopes (3-8% slope), severe erosion, moderately stony	2.35	0.3
K2cB2st1	Kukadi-2, very shallow, gravelly clay, very gently sloping undulating upper slopes (1-3% slope), moderate erosion, slightly stony	21.35	2.9
K2cC3st2	Kukadi-3, very shallow, gravelly clay, gently sloping undulating upper slopes (3-8% slope), severe erosion, moderately stony	134.66	18.2
K3mB2st2	Kukadi-3, very shallow gravelly sandy clay loam, gently sloping undulating mid slopes (1-3% slope), moderate erosion, moderately stony	6.50	0.9
K3mC3st2	Kukadi-3, very shallow, gravelly sandy clay loam, gently sloping undulating mid slopes (3-8% slope), severe erosion, moderately stony	8.00	1.1
K4cB2st2	Kukadi-4, very shallow, clayey very gently sloping undulating upper slopes (1-3% slope), moderate erosion, moderately stony	8.70	1.2
K4cC3st2	Kukadi-4, very shallow, clayey, gently sloping undulating upper slopes (3-8% slope), severe erosion, moderately stony	18.65	2.5

K5cB2st1	Kukadi-5, very shallow, clayey, very gently sloping mid slopes (1-3% slope), moderate erosion, slightly stony	93.96	12.7
K5cC3st2	Kukadi-5, very shallow, clayey, very gently sloping mid slopes (3-8% slope), severe erosion, moderately stony	59.38	8.0
K6cB2st2	Kukadi-6, very shallow, clayey, very gently sloping mid slopes (1-3% slope), moderate erosion, moderately stony	57.10	7.7
K7cB2st1	Kukadi-7, shallow, clayey, very gently sloping mid slopes (1-3% slope), moderate erosion, slightly stony	10.43	1.4
K7cC3st1	Kukadi-7, shallow, clayey, very gently sloping mid slopes (1-3% slope), severe erosion, slightly stony	9.73	1.3
K8cB2st1	Kukadi-8, shallow, clayey, very gently sloping mid slopes (1-3% slope), moderate erosion, slightly stony	70.19	9.5
K9cB1	Kukadi-9, deep, clayey, very gently sloping foot slopes (1-3% slope), slight erosion	54.81	7.4
K9cB2	Kukadi-9, deep, clayey, very gently sloping foot slopes (1-3% slope), moderate erosion	74.21	10.0
K9cC3	Kukadi-9, deep, clayey, gently sloping foot slopes (3-8% slope), severe erosion	7.10	1.0
K10cB1	Kukadi-10, very deep, clayey, very gently sloping foot slopes (1-3% slope), slight erosion	101.31	13.7
K10cB2	Kukadi-10, very deep, clayey, very gently sloping foot slopes (1-3% slope), moderate erosion	2.18	0.3
		740.61	**100.0**

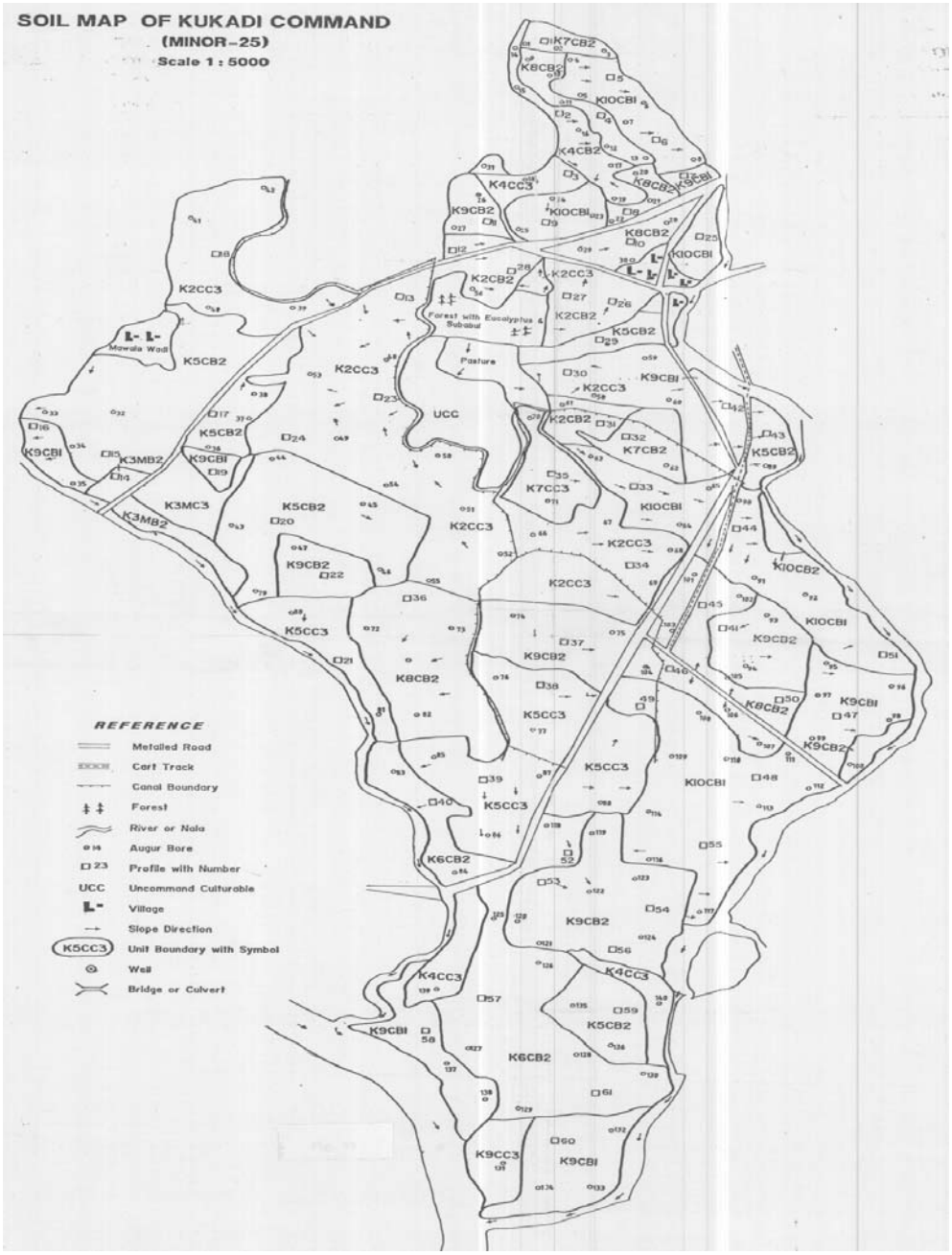

Fig. 1. Detailed soil map of Kukadi Command (Minor-25), Ahmednagar district

Physical and chemical properties of soils

The data (Table 2) indicate that the sand, silt and clay content varied from 15.8-57.3, 14.0-25.1 and 28.7-64.5 per cent, respectively. Higher clay content was observed in soils of Kukadi-9 and Kukadi-10 developed on lower piedmont plain compared to the soils developed on pediments and upper piedmonts. The higher clay content in soils of lower piedmont plain are associated with higher water retention at -33 and -1500 kPa. A significant and positive correlation was observed between clay and moisture retention at -33 kPa (r = 0.96**), clay and moisture retention at -1500 kPa (r = 0.87**) and clay and available water capacity (r = 0.89**). Jagdish-Prasad

et al. (2001) reported significant and positive correlation between clay and soil moisture retention at-33 kPa and -1500 kPa. The data (Table 3) related to chemical properties indicate that the soils of Kukadi-1 are neutral in reaction; soils of Kukadi-4, Kukadi-5, Kukadi-7, Kukadi-8, and Kukadi-10 are slightly alkaline, whereas, soils of Kukadi-2, Kukadi-3, Kukadi-6 and Kukadi-9 are moderately alkaline in reaction. The organic carbon (OC) content in these soils is low and ranged from 0.05 to 0.73 per cent. The cation exchange capacity ranged from 35.3 to 56.7 (cmol(p+)kg^{-1}) and calcium is the dominant exchangeable base followed by magnesium, sodium and potassium. Most of the soils in the study area are calcareous in nature.

Table 2. Physical properties of soils

Horizon	Depth (cm)	Sand 2-0.05 (mm) (%)	Silt 0.05-0.002 (mm) (%)	Clay <0.002 (mm) (%)	Coarse fragments	Water retention (%)		
						-33 kPa	-1500 kPa	AWC
Kukadi-1: Loamy-skeletal, mixed, hyperthermic *Lithic Ustorthents*								
Ap	0-16	39.6	18.9	41.5	40	22.0	15.2	6.8
Kukadi-2: Clayey-skeletal, mixed, hyperthermic (calcareous) *Lithic Ustorthents*								
Ap	0-20	40.5	18.0	41.5	40.0	23.3	14.4	8.9
Kukadi-3: Loamy-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*								
Ap	0-18	52.2	15.2	32.6	40.0	19.0	14.2	4.8
AC	18-55	57.3	14.0	28.7	50.0	18.8	13.5	5.3
Kukadi-4 : Clayey, mixed, hyperthermic *Typic Ustorthents*								
Ap	0-13	30.2	21.3	48.5	10.0	26.8	16.7	10.1
AC	13-37	21.4	24.1	54.5	30.0	35.9	25.9	10.0
Kukadi-5: Clayey, mixed, hyperthermic (calcareous) *Typic Ustorthents*								
Ap	0-18	22.2	23.3	54.5	5.0	31.7	21.2	10.5
AC	18-40	20.4	23.0	56.6	25.0	34.4	22.7	11.7
Kukadi-6: Clayey-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*								
Ap	0-15	30.4	21.1	48.5	40.0	28.9	15.3	13.6
Kukadi-7: Clayey, mixed, hyperthermic *Typic Haplustepts*								
Ap	0-16	31.6	19.9	48.5	10.0	26.1	15.1	11.0
Bw	16-47	28.4	21.4	50.2	20.0	27.2	16.8	10.4
Kukadi-8: Clayey, mixed, hyperthermic (calcareous) *Typic Haplustepts*								
Ap	0-14	21.5	20.0	58.5	5.0	32.7	21.4	11.3
Bw	14-34	17.4	22.4	60.2	3.0	34.3	23.2	11.1
Kukadi-9: Fine, smectitic, hyperthermic (calcareous) *Vertic Haplustepts*								
Ap	0-19	26.0	23.5	50.5	5.0	32.4	21.4	11.0
Bw1	19-48	17.8	23.7	58.5	3.0	35.5	22.6	12.9
Bw2	48-79	17.4	23.0	59.6	3.0	36.7	23.5	13.2
Bw3	79-108	15.8	22.5	61.7	3.0	37.4	24.1	13.3
Bw4	108-135	20.8	22.0	57.2	3.0	34.2	22.1	12.1
Kukadi-10: Fine, smectitic, hyperthermic (calcareous) *Typic Haplusterts*								
Ap	0-18	18.8	25.1	56.1	39.12	11.38	0.40	0.79
Bw	18-50	20.0	22.5	57.5	40.17	11.02	0.28	0.41
Bss1	50-84	21.8	18.5	59.7	30.42	8.37	0.34	0.38
Bss2	84-122	20.4	15.1	64.5	30.00	4.49	0.35	0.29
Bss3	122-150	18.2	19.3	62.5	31.16	2.87	0.35	0.20

Table 3. Chemical properties of soils

Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	O.C. (%)	$CaCO_3$ (%)	Exchangeable bases				CEC
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
						($cmol(p+)kg^{-1}$)				
	Kukadi-1: Loamy-skeletal, mixed, hyperthermic *Lithic Ustorthents*									
Ap	0-16	7.8	0.13	0.23	2.27	25.87	7.16	0.29	0.34	37.4
	Kukadi-2: Clayey-skeletal, mixed, hyperthermic (calcareous) *Lithic Ustorthents*									
Ap	0-20	8.6	0.09	0.23	18.42	36.12	2.12	0.27	0.19	39.1
	Kukadi-3: Loamy-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*									
Ap	0-18	8.7	0.13	0.28	12.60	31.50	4.10	0.72	0.07	36.1
AC	18-55	8.8	0.16	0.09	13.28	30.91	4.87	0.75	0.07	35.3
	Kukadi-4 : Clayey, mixed, hyperthermic *Typic Ustorthents*									
Ap	0-13	8.2	0.11	0.38	2.09	28.75	13.87	0.25	0.20	45.3
AC	13-37	8.2	0.09	0.32	2.49	36.12	8.87	0.38	0.15	52.0
	Kukadi-5: Clayey, mixed, hyperthermic (calcareous) *Typic Ustorthents*									
Ap	0-18	8.5	0.15	0.60	15.01	2.88	8.90	2.12	0.48	50.9
AC	18-40	8.4	0.17	0.56	19.42	2.50	9.36	2.04	0.42	51.2
	Kukadi-6: Clayey-skeletal, mixed, hyperthermic (calcareous) *Typic Ustorthents*									
Ap	0-15	8.6	0.17	0.61	23.42	32.00	3.79	0.77	0.69	39.0
	Kukadi-7: Clayey, mixed, hyperthermic *Typic Haplustepts*									
Ap	0-16	8.2	0.23	0.52	4.02	30.37	9.96	0.27	0.34	43.4
Bw	16-47	8.4	0.11	0.47	3.64	36.25	8.12	0.15	0.16	47.2
	Kukadi-8: Clayey, mixed, hyperthermic (calcareous) *Typic Haplustepts*									
Ap	0-14	8.3	0.33	0.54	7.36	43.98	6.75	0.97	0.47	54.2
Bw	14-34	8.5	0.16	0.50	9.22	46.23	5.54	0.95	0.27	56.7
	Kukadi-9: Fine, smectitic, hyperthermic (calcareous) *Vertic Haplustepts*									
Ap	0-19	8.8	0.16	0.73	9.22	35.12	6.62	1.25	0.40	46.6
Bw1	19-48	8.7	0.26	0.73	9.40	36.72	9.32	2.07	0.35	49.4
Bw2	48-79	8.7	0.33	0.71	9.56	37.00	10.62	3.54	0.35	51.3
Bw3	79-108	8.9	0.31	0.61	9.40	39.75	11.47	4.20	0.43	55.2
Bw4	108-135	8.9	0.33	0.56	12.26	36.75	12.37	4.26	0.39	54.3
	Kukadi-10: Fine, smectitic, hyperthermic (calcareous) *Typic Haplusterts*									
Ap	0-18	8.3	0.24	0.66	4.91	2.84	18.20	2.96	0.59	54.3
Bw	18-50	8.5	0.16	0.41	7.79	2.88	12.94	2.22	0.46	54.9
Bss1	50-84	8.5	0.18	0.19	14.8	3.98	7.52	1.08	0.44	40.2
Bss2	84-122	8.5	0.16	0.05	13.1	4.36	3.94	0.96	0.40	39.1
Bss3	122-150	8.6	0.13	0.05	10.2	4.50	2.14	0.40	0.38	35.4

Land capability and land irrigability

The soils are grouped under IIws, IIIes and IVes land capability sub-classes (Table 4). The lands under IIws have few limitations for cultivation with minor soil problems due to fine texture. The soils are nearly level to level and very gently sloping lands, moderately well drained, high clay content with slow to moderately slow permeability. The lands under IIIes have moderate limitations of soil depth, slope and erosion, whereas, the lands under IVes are fairly good cultivable lands with severe limitations for cultivation with respect to soil depth and erosion. The soils are grouped under 2d, 3st and 4st land irrigability sub-classes (Table 4). Lands under 2d have moderate limitations for sustained use under irrigation. These are nearly level to gently sloping lands. Due to high clay content and pH, these soils have problems of permeability and drainage. Lands under 3st have severe limitations with respect to soil and topography. The main constraint is shallow depth. The lands under 4st are marginally suitable for sustained use under irrigation with severe limitations of soil depth and slope. Land leveling operations also may not work in these units as the soils are shallow and expose the parent material and bed rock below that.

Table 4. Land capability, land irrigability and soil-site suitability for different crops

Soil series	Land capability sub-class	Land irrigability sub-class	Soil-site suitability rating					
			Pearl millet	Onion	Ground-nut	Sugar-cane	Wheat	Soy-bean
Kukadi-1	IVes	4st	S3	S3	S3	N2	S3	S3
Kukadi-2	IVes	4st	S3	S3	S3	N2	S3	S3
Kukadi-3	IVes	4st	S3	S3	S2	N2	S3	S3
Kukadi-4	IVes	4st	S2	S2	S3	N2	S3	S3
Kukadi-5	IVes	4st	S2	S3	S3	S3	S3	S3
Kukadi-6	IIIes	4st	S3	S3	S3	N2	S3	S3
Kukadi-7	IIIes	3st	S2	S2	S2	S3	S2	S3
Kukadi-8	IIIes	3st	S2	S2	S3	S3	S2	S2
Kukadi-9	IIws	2d	S2	S2	S2	S2	S2	S2
Kukadi-10	IIws	2d	S2	S2	S2	S2	S2	S2

Suitability of soils for crops

The suitability of soils for pearl millet, onion, groundnut, sugarcane, wheat and soybean is presented in Table 4. The data indicates that soils of Kukadi-1, Kukadi-2, Kukadi-3 and Kukadi-6 are marginally suitable for pearl millet cultivation due to severe limitations of slope, soil depth, pH and OC; soils of Kukadi-4, Kukadi-5, Kukadi-7 and Kukadi-8 are moderately suitable due to moderate limitations of soil depth, pH and OC, whereas, soils of Kukadi-9 and Kukadi-10 have moderate limitations of pH and OC. Suitability for onion indicates that soils of Kukadi-1, Kukadi-2, Kukadi-3, Kukadi-5 and Kukadi-6 are marginally suitable due to severe limitations of slope, soil depth, pH and OC, soils of Kukadi-4, Kukadi-7 and Kukadi-8 are moderately suitable due to moderate limitations of soil depth, pH and OC, whereas, soils of Kukadi-9 and Kukadi-10 have moderate limitations of soil pH and OC. The suitability of soils for groundnut indicates that soils of Kukadi-1, Kukadi-2, Kukadi-4, Kukadi-5, Kukadi-6 and Kukadi-8 are marginally suitable due to severe limitations of slope, soil depth, pH and OC; soils of Kukadi-3 and Kukadi-7 are moderately suitable due to moderate limitations of soil

depth, pH and OC, whereas, soils of Kukadi-9 and Kukadi-10 moderate limitations of pH and OC. The suitability of soils for growing sugarcane indicates that soils of soils of Kukadi-1, Kukadi-2, Kukadi-3, Kukadi-4 and Kukadi-6 not suitable due to very severe limitations of slope, soil depth, pH and OC; soils of Kukadi-5, Kukadi-7 and Kukadi-8 are marginally suitable due to severe limitations of soil depth, pH and OC and soils of Kukadi-9 and Kukadi-10 are moderately suitable due to moderate limitations of pH and OC. The suitability of wheat indicates that soils of Kukadi-1, Kukadi-2, Kukadi-3, Kukadi-4, Kukadi-5 and Kukadi-6 are marginally suitable due to severe limitations of depth, slope, pH, OC, soils of Kukadi-7 and Kukadi-8 are moderately suitable with moderate limitations of soil depth, pH and OC whereas, soils of Kukadi-9 and Kukadi-10 have moderate limitations of OC and pH. The suitability of soils for soybean indicates that soils of Kukadi-1, Kukadi-2, Kukadi-3, Kukadi-4, Kukadi-5, Kukadi-6 and Kukadi-7 are marginally suitable with severe limitations of soil depth, slope, pH and OC; soils of Kukadi-8 are moderately suitable with moderate limitations of soil depth, pH and OC whereas, soils of Kukadi-9 and Kukadi-10 have moderate limitations of soil pH and OC.

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References

AIS&LUS (All India Soil and Land Use Survey) (1971). Soil Survey Manual (Revised Edition), IARI, New Delhi. 121p.

Black, C.A. (1965). Methods of Soil Analysis, Part 1&2. (American Society of Agronomy, Madison, Wisconsin, USA).

FAO (1976). Framework for Land Evaluation. Soils Bulletin No. 32. (Food and Agriculture Organization : Rome).

Jackson, M.L. (1967). Soil chemical analysis. (Prentice Hall India Pvt. Ltd., New Delhi).

Jagdish-Prasad, Nagaraju, M.S.S., Srivastava, R., Ray, S.K. and Chandran, P. (2001). Characteristics and Classification of Some Orange Growing Soils in Nagpur District of Maharashtra. *Journal of the Indian Society of Soil Science* **49**: 735-739.

Klingebiel, A.A. and Montgomery, P.H. (1961). Land capability classification. Agric. Handbook 210 (USDA. Soil Conservation Service, Washington, D.C).

Manchanda, M.L., Kudrat, M. and Tiwari, A.K. (2002). Soil survey and mapping using remote sensing. *Tropical Ecology* **43:** 61-74.

NBSS&LUP (1994). Soil-site suitability criteria for different crops. In: Proceedings of National meet on Soil-site suitability criteria for different crops. 31p.

Sharma, P.D. (2006) Soil Science Research - Vision 2025. *Indian Society of Soil Science News Letter* **20,** p. 1.

Soil Survey Division Staff (2000). Soil Survey Manual Handbook 18. (USDA Washington, D.C).

Soil Survey Staff (2010). Keys to Soil Taxonomy, 11th Edition. (USDA Natural Resources Conservation Service, Washington, D.C).

Sys, C.E., Van Ranst and J. Debayeve (1991). Land Evaluation, Part I and II. Re-edited volumes of Publication No. 7. (General Administration of Cooperation and Development, Brussels, Belgium).

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