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Characterization of benchmark soil series developed on basalt and limestone parent materials in Hyderabad-Karnataka region

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Abstract
A study was undertaken to characterize the benchmark soil series developed on Basalt (Raichur series) and Limestone (Kagalgomb series) parent materials in Hyderabad-Karnataka region. In Raichur series, the colour varied from dark grey (10YR 4/1) to very dark greyish brown (10YR 3/2) and in Kagalgomb series, very dark greyish brown (10YR 3/2) colour was observed. In Raichur series and Kagalgomb series, texture was clay, bulk density varied from 1.25 to 1.35 Mg m^{-3} and from 1.20 to 1.32 Mg m^{-3}, respectively. Water holding capacity of Raichur series ranged from 51.57 to 55.43 per cent whereas in Kagalgomb series it ranged from 49.57 to 55.46 per cent. The pH showed that moderately alkaline (7.8-8.4) in Raichur series and strongly alkaline (8.7 to 9.2) in Kagalgomb series. Organic carbon content in Raichur series ranged from 0.14 to 0.44 per cent and in Kagalgomb series ranged from 0.26 to 0.93 per cent. Available nitrogen (N) was low (167 to 189 kg ha^{-1}) in Raichur series and low to medium (246 to 448 kg ha^{-1}) in Kagalgomb series. Available phosphorus (P_2O_5) was low to high *i.e.* 8.90 to 81.75 kg ha^{-1} in Raichur series and 20.13 to 80.53 kg ha^{-1} in Kagalgomb series; the available potassium (K_2O) content ranged from 450 to 485 kg ha^{-1} in Raichur series and 395 to 671 kg ha^{-1} in Kagalgomb series. The DTPA extractable Fe, Cu and Mn were sufficient and Zn was deficient in both the Benchmark soil series.

Keywords: Benchmark soil series and Hyderabad-Karnataka region

Introduction
Soil is one of the most heterogeneous natural resources on the earth. Soil as the name itself expresses “Soul of Infinite Life”, supports all life-forms directly or indirectly. Development of soils takes many decades and sometimes centuries but can be destroyed in almost no time. It is not enough to describe soil as country’s greatest source of wealth, more than that it is country’s life.

Soil series is the lowest category in soil Taxonomy (Sehgal, 1992) [14]. It is considered as the most important category in the system as it is the fundamental unit of soil classification as well as the basic unit for most soil mapping projects. This is also regarded as the largest landscape unit about which all features and characteristics relevant to soil formation are distinguished.

A Benchmark Soil is one that is widely extensive, holds a key position in the soil classification system and is of special significance to farming, engineering or other uses. In simple terms Benchmark soils are those occurring in extensive areas so that their comprehensive characterization will contribute substantially to agricultural and other developments of the area. Information on benchmark soils and the results of experiments carried out on them can be extended to many of those soils closely related in classification and geography. Such soils can be used as standards for widespread application and are key to agro-technology transfer.

Benchmark soil concept helps to: (i) provide a base for research on soil and water management and crop responses to the inputs, (ii) design experiments to ascertain crop responses to variables which distinguish soil series or family and (iii) provide type locations for soil classification and further studies Murthy *et al.* (1982) [9]. So, assessment of present status of Benchmark soils and their quality helps in monitoring the soil and other resources in a sustainable manner.

In view of the above facts, an investigation was taken up to study the morphological and physico-chemical properties of the selected benchmark soil series in Hyderabad-Karnataka region.

Material and Methods

The Raichur series is a member of the very fine, montmorillonitic, *Isohyperthermic* family of *Pellusterts*. Raichur series soils have dark grey to very dark grey moderately alkaline clayey A horizon. The benchmark pedon of Raichur series is located in plot no 17 of Main Agricultural Research Station, UAS, Raichur, Karnataka and lies in 16° 12′ 12.251″ North latitude and 77° 19′ 32.829″ East longitude. Raichur series is extensively distributed in Raichur district.

The Kagalgomb series is a member of the very fine, montmorillonitic, *Isohyperthermic* family of *Chromusterts*. Kagalgomb soils have dark greyish brown to very dark greyish brown, strongly to very strongly alkaline clayey A horizon. The benchmark pedon of Kagalgomb series is located in Sirwal village, Shahapur Taluk, Yadgir District (earlier Gulbarga), Karnataka and lies in 16° 34′ 49.731″ North latitude and 76° 50′ 06.944″ East longitude. Kagalgomb series is extensively distributed in Yadgir district (earlier Gulbarga).

A detailed high intensity soil survey of Raichur series (Fig.1) and Kagalgomb series (Fig.2) was conducted using Quick bird satellite imagery and cadastral map (1:8000 scales). Morphological characters like colour, structure, consistency and physico-chemical properties like bulk density, water holding capacity, pH, electrical conductivity, organic carbon, cation exchange capacity, etc. were studied for the profile samples.

Results and Discussion

Morphological properties (Table 1)

Slope plays an important role in the formation of soils, controls the process of erosion and alters the overall use of the land. Two slope classes were found in the study area. Very gentle slopes (1-3 %) occurred in Raichur series and nearly level slope (0-1 %) occurred dominantly in Kagalgomb series. The soils of the Raichur series were deep (100 to 150 cm) in depth and in Kagalgomb series soils were very deep (>150 cm) in depth. The depth of pedon was manifestation of topography. Similar observations were also made by Singh and Mishra (1996) [18].

Both Raichur series and Kagalgomb soils showed the hue of 10 YR throughout the profile and the dominant colour was dark grey (10YR 4/1) to very dark greyish brown (10YR 3/2) in Raichur series and very dark greyish brown (10YR 3/2) in Kagalgomb series this may be due to the clay humus complex and the dark matrix colour was due to presence of high organic matter content in the surface horizons. The results obtained in the present study are in agreement with the findings of Mahesh Kumar and Sharma (2014) [8].

In both the Benchmark soil series structure was predominantly moderate medium sub-angular blocky in the surface horizons and moderate medium angular blocky to strong medium angular blocky structure in the sub-soil horizon was noticed. Angular blocky structure in the sub-soil horizons was due to slickensides formation in these soils. These findings are in conformity with the findings of Sanjeev *et al.* (2005) [13].

Consistency varied from loose to very hard, friable to very firm, moderately sticky, moderately plastic to very sticky, very plastic in Raichur series soils. The surface horizons of Raichur series exhibited moderately sticky and moderately plastic, friable and loose in wet, moist and dry conditions, respectively. In Kagalgomb series consistence varied from slightly hard to very hard, friable to very firm, slightly sticky and slightly plastic to very sticky and very plastic in dry, moist and wet condition, respectively. Increase in stickiness and plasticity may be due to high clay content. Similar observations were made by Sharma *et al.* (2004) [16] in the soils of Neogal watershed in North-West Himalayas.

Physical properties

In Raichur series and Kagalgomb series (Table 2), the texture was clay throughout the profile and clay content showed the increasing trend through the soil depth. It could be attributed to several processes like illuviation of the finer fraction to the lower depth (Patil and Jagadishprasad, 2004) [10].

In Raichur series and Kagalgomb series pedons (Table 2), the bulk density varied from 1.25 to 1.35 Mg m^{-3} and 1.20 and 1.32 Mg m^{-3}, respectively. The bulk density increased with depth. The variation in bulk density was attributed to variation in organic matter; texture, compaction etc. (Sharma and Anil Kumar, 2003) [15] and reduction of organic carbon with depth. Similar findings were reported by Doddamani *et al.* (1994) [4] in vertisols of the upper Krishna command areas.

Water holding capacity of Raichur series and Kagalgomb series ranged from 51.57 to 55.43 per cent and 49.57 to 55.46 per cent, respectively (Table 2). These differences were due to the variation in clay and organic carbon content of the pedons. Similar results were reported by Singh *et al.* (1999) [17] in the soils of Ramganga catchment in Uttar Pradesh. The maximum water holding capacity followed same trend as of clay in soils (Mahesh Kumar and Sharma, 2014) [8].

Moisture retention capacity of Raichur series ranged from 21.59 to 34.61 per cent at 0.33 bars and from 14.53 to 26.13 per cent at 15 bars. Available water content ranged from 5.53 to 10.87 per cent (Table 2). Moisture retention capacity of Kagalgomb series ranged from 21.26 to 42.71 per cent at 0.33 bars and from 16.84 to 35.83 per cent at 15 bars. Available water content ranged from 4.43 to 9.19 per cent (Table 2). Higher moisture retention capacity may be attributed due to the higher clay content depth wise and also higher amount of organic carbon content in soil series. The results are in confirmation with the results of water retention characteristics of five swell shrink soils of Chandrapur district by Rajeev *et al.* (1998) [12].

Kagalgomb soils showed lower infiltration rate than Raichur soils (Table 3). The basic infiltration rate of Kagalgomb soils is 0.9 cm hr^{-1} whereas in Raichur soils it is 1.7 cm hr^{-1}. Lower infiltration rate of the Kagalgomb soils could be attributed to its higher initial moisture content and slow permeability of the soils. Higher infiltration rate of Raichur soils may be due to the higher non-capillary pores of the soils. The results were in accordance with the findings of Doddamani *et al.* (1994) [4].

Chemical properties (Table 4)

In Raichur series and Kagalgomb series, the pH ranged from 7.8 to 8.4 (moderately alkaline) and 8.7 to 9.2 (strongly alkaline). The relatively high pH of the soils was ascribed to the high degree of base saturation (Mahesh Kumar and Sharma, 2014) [8]. High pH in Kagalgomb series is due to their calcareous nature and high exchangeable sodium content (Yeresheemi *et al.,* 1998) [21].

Electrical conductivity was high in Raichur series ranging from 0.3 to 0.7 dS m^{-1} which indicates that Raichur series soils are non-saline. In Kagalgomb series, the EC values of the pedons ranged from 0.1 to 0.3 dS m^{-1}. The upper solum was relatively low in salts than in the lower solum. This might be due to leaching of salts from the soil surface to lower depths due to irrigation and their accumulation in lower depths. Kagalgomb series soils were low in EC; this may be

due to highly alkaline nature of soils. Similar findings were reported by Patil and Sonar (1994) [11].
Organic carbon content in Raichur series ranged from 0.14 to 0.44 per cent, which in general accumulated in surface layers. Organic carbon content in Kagalgomb series ranged from 0.26 to 0.93 per cent. The organic carbon content of surface horizons was greater than the sub surface horizons due to high amount of litter and crop residues at the surface. Organic carbon content of the soils follows decreasing trend with depth in all the pedons. Similar findings were reported by Sanjeev *et al.* (2005) [13].
In Kagalgomb series, free $CaCO_3$ values were comparatively higher than Raichur series. Free $CaCO_3$ content of Raichur series ranged from 1.62 to 4.75 per cent whereas in Kagalgomb series it ranged from 8.5 to 18.0 per cent. The per cent calcium carbonate in soils increased with depth in Kagalgomb series (Subbaiah and Manickam, 1992) [19].

Fertility characteristics (Table 4)
The soils of Raichur series were low in available nitrogen content (167 to 189 kg ha^{-1}) and low to medium (246 to 448 kg ha^{-1}) in Kagalgomb series. Nitrogen content showed indefinite pattern with the depth. The availability of nitrogen in all the soils was higher in surface horizons due to organic matter content (Khan *et al.,* 1997) [6]. The low levels may be ascribed to several factors such as lower organic carbon, resulting from sub-optimal plant growth, high pH and high $CaCO_3$ content in the soil series under investigation, favouring higher ammonia volatilization losses. Similar finding was recorded by Yeresheemi *et al.* (1998) [21] in salt affected Vertisols of upper Krishna command area of Karnataka.
The available phosphorus content ranged from low to high in both Raichur series (8.90 to 81.75 kg ha^{-1}) and Kagalgomb series (20.13 to 80.53 kg ha^{-1}). The highest available phosphorous content (85.81 kg ha^{-1}) in surface soils of Raichur series may be due to relatively higher organic carbon content and lower fixation of phosphorus at near neutral soil pH. Similar results were reported by Ashok *et al.* (2001) [2]. Lower amounts of available phosphorus could be related to higher P-fixation capacities of soils derived from granite-gneiss and limestone resulting mainly due to their calcareous nature, particularly because silt and clay sized carbonate fractions, with increased specific surface, constitute nearly 60 per cent of the total carbonates in the calcareous soils of the Raichur and Kagalgomb series. (Yeresheemi *et al.,* 1998) [21].
The available potassium content in soils of Raichur series ranged from 450 to 485 kg ha^{-1} which is rated high and in Kagalgomb series, the available potassium content ranged from 395 to 671 kg ha^{-1} and it indicates that in majority of the Kagalgomb soils available potassium content is high. Available potassium content followed irregular trend with depth and relatively higher levels of available K could be attributed to predominance of K-rich micaceous minerals in arid region soils and their dissolution under salt-affected conditions. The results are in conformity with the values obtained by Yeresheemi *et al.* (1998) [21].
The available sulphur in Raichur series was ranged from 11.33 to 26.06 mg kg^{-1}. The data revealed that the available sulphur content in majority of Raichur series was medium to high category and in Kagalgomb series, its ranged from 8.73 to 55.90 mg kg^{-1} which comes under low to high category. The available sulphur followed irregular pattern with depth. Similar observation noticed by Arora *et al.* (1988) [1] and Balanagoudar (1989) [3]. The higher values of total sulphur in black soils may be due to gypsiferous nature of these calcareous black soils. Similar findings were reported by Venkatesh and Satyanarayana (1999) [20] in vertisols of Dharwad.
In Raichur series and Kagalgomb series, the DTPA extractable Fe, Cu and Mn were sufficient throughout the profile depth. The DTPA extractable Zn was found deficient which indicates Zinc content was below the critical level. It could be attributed to the high pH and calcareous nature of soil. Relatively higher availability of Fe, Mn and Cu could be ascribed to origin of these soils from granite-gneiss and limestone; similar results were reported by Yeresheemi *et al.* (1998) [21]. There was no definite trend for the distribution of these micronutrients with respect to depth.

Exchangeable cations (Table 5)
The exchangeable calcium was the dominant cation in both the series and exchangeable Ca ranged from 33.93 to 38.51 cmol (p^+) kg^{-1} in Raichur series and 25.41 to 48.48 cmol (p^+) kg^{-1} in Kagalgomb series. The exchangeable bases in both the series were in order of Ca^{+2}> Mg^{+2}> Na^+> K^+ on the exchange complex (Table 5). The low value of exchangeable monovalent compared to divalent was due to preferential leaching of monovalent than divalent. These findings are in accordance with Gundlur (1991) [5].
CEC of the Raichur series ranged from 60.57 to 65.42 cmol (p^+) kg^{-1} and in Kagalgomb series ranged from 61.94 to 65.79 cmol (p^+) kg^{-1} (Table 5). This is due to accumulation of clay especially due to presence of smectic group of clay minerals (Landey *et al.,* 1982) [7]. Per cent Base saturation by sum of basic cations was low in Raichur series compared to Kagalgomb series, because of better leaching in Raichur series with low amount of bases in its parent material in contrast to Kagalgomb series.
The ESP of both Raichur series and Kagalgomb series were ranged from 3.43 to 6.91 per cent and 5.40 to 20.71 per cent, respectively (Table 5) and there was a general increase in ESP values down the profile depths which indicated initiation of the process of sodiumization in a downward direction (Yeresheemi *et al.,* 1998) [21].

Table 1: Morphological features of Benchmark soil series

Pedon no.	Horizon	Depth (cm)	Colour		Structure	Consistency			Slope (%)	Erosion	Drainage
			Dry	Moist		Dry	Moist	Wet			
Raichur series (RCHmB1g_0)											
P1	Ap	0-19	10YR 4/1	10YR 3/2	2m sbk	L	fr	ms mp	1-3	Slight	Moderately well
P1	Bw	19-55	10YR 3/1	10YR 3/1	2m sbk	H	fi	vs vp			
P1	Bss1	55-88	10YR 3/1	10YR 3/1	3m abk	H	fi	vs vp			
P1	Bss2	88-120	10YR 3/2	10YR 3/1	3m abk	H	fi	vs vp			
P1	Bss3	120-148	10YR 3/2	10YR 3/1	2m abk	Vh	Vfi	vs vp			
Kagalgomb series (KGBmA1g_0)											
P2	Ap	0-30	10YR 4/2	10YR 3/2	2m sbk	Sh	fr	ss sp	0-1	Slight	Moderately well

P2	Bw	30-60	10YR 3/2	10YR 3/2	2m sbk	H	fi	ss sp			
P2	Bss1	60-91	10YR 3/2	10YR 3/2	3m abk	H	fi	vs vp			
P2	Bss2	91-121	10YR 3/2	10YR 3/2	3m abk	H	fi	vs vp			
P2	Bss3	121-142	10YR 3/2	10YR 3/2	3m abk	H	fi	vs vp			
P2	Bss4	142-178	10YR 3/2	10YR 3/2	3m abk	Vh	Vfi	vs vp			

Note: Sh – slightly hard, H - hard, L - loose, vh - very hard, fr – friable, fi - firm, ss – slightly sticky, sp – slightly plastic, vs – very sticky, vp - very plastic, ms - moderately sticky, mp - moderately plastic, m – medium, f - fine, sbk – sub angular blocky, abk - angular blocky.

Table 2: Physical properties of Benchmark soil series

Pedon no.	Horizon	Depth (cm)	Coarse sand	Fine sand	Total sand	Silt	Clay	Soil Textural class	BD (Mg m^{-3})	Porosity	MWHC	SMC (%)		
			% of fine earth							(%)		0.33 Bar	15 Bar	AWC
Raichur series (RCHmB1g$_0$)														
P1	Ap	0-19	4.25	6.70	10.95	28.80	60.25	Clay	1.25	52.83	51.57	34.61	26.13	8.48
P1	Bw	19-55	3.20	4.10	7.30	29.25	63.50	Clay	1.26	52.45	53.89	26.17	20.64	5.53
P1	Bss1	55-88	3.50	4.05	8.55	27.30	64.30	Clay	1.28	51.69	54.21	34.38	23.51	10.87
P1	Bss2	88-120	3.10	3.80	6.90	26.40	66.10	Clay	1.31	50.57	54.27	21.59	14.53	7.06
P1	Bss3	120-148	2.35	4.12	6.47	25.35	68.80	Clay	1.35	49.05	55.43	31.26	21.84	9.42
SWA			3.20	4.35	7.75	27.42	64.59	**Clay**	1.29	51.38	53.67	29.60	21.33	8.27
Kagalgomb series (KGBmA1g$_0$)														
P2	Ap	0-30	3.30	6.40	9.70	36.52	54.70	Clay	1.20	54.71	49.57	32.94	27.10	5.84
P2	Bw	30-60	2.40	5.25	7.65	35.10	56.90	Clay	1.24	53.20	50.23	36.14	29.55	6.59
P2	Bss1	60-91	3.80	5.05	8.85	24.95	66.40	Clay	1.25	52.83	52.98	34.70	25.51	9.19
P2	Bss2	91-121	4.08	4.62	8.70	21.20	69.60	Clay	1.29	51.32	53.30	37.39	29.35	8.04
P2	Bss3	121-142	3.10	4.20	7.30	22.60	69.90	Clay	1.30	52.07	55.28	21.26	16.84	4.43
P2	Bss4	142-178	4.20	4.10	8.30	20.90	70.10	Clay	1.32	50.56	55.46	42.71	35.83	6.88
SWA			3.68	4.94	8.41	26.88	64.60	Clay	1.23	53.48	52.30	34.19	27.36	6.83

Note: BD – bulk density, MWHC – maximum water holding capacity, SMC – soil moisture constants.

Table 3: Infiltration rate of Benchmark soil series

Sl. No.	Elapsed time (MINS)	Infiltration rate (cm hr^{-1})	
		Raichur series	Kagalgomb series
1	5	8.3	6.8
2	10	6.5	5.8
3	20	5.2	4.3
4	30	3.7	3.1
5	45	2.6	2.3
6	60	2.1	1.4
7	90	1.8	0.9
8	120	1.7	0.9
9	Basic Infiltration rate	1.7	0.9

Table 4: Chemical properties of Benchmark soil series

Pedon no.	Horizon	Depth (cm)	pH (1:2.5 soil: water)	EC (1:2.5 soil: water)	OC	Free $CaCO_3$	Available nutrients				DTPA extractable			
							N	P_2O_5	K_2O	S	Zn	Fe	Cu	Mn
				(dS m^{-1})	(%)	(%)	kg ha^{-1}			mg kg^{-1}	mg kg^{-1}			
Raichur series (RCHmB1g$_0$)														
P1	Ap	0-19	7.8	0.3	0.44	4.75	178	81.75	485	11.33	0.51	4.6	0.78	5.3
P1	Bw	19-55	8.4	0.5	0.28	3.37	189	28.19	466	18.43	0.17	4.6	0.52	2.7
P1	Bss1	55-88	8.2	0.6	0.20	3.75	178	08.90	450	12.89	0.16	4.6	0.50	2.4
P1	Bss2	88-120	8.4	0.6	0.18	1.62	178	14.84	469	17.32	0.17	4.5	0.53	2.6
P1	Bss3	120-148	8.3	0.7	0.14	3.50	167	15.87	481	26.06	0.16	5.2	0.57	2.3
SWA			8.2	0.5	0.24	3.39	178	27.92	470	17.20	0.23	4.7	0.58	3.1
Kagalgomb series (KGBmA1g$_0$)														
P2	Ap	0-30	8.7	0.1	0.93	8.50	448	20.13	410	21.50	0.56	9.7	1.15	4.8
P2	Bw	30-60	8.8	0.2	0.79	9.12	381	67.59	614	12.38	0.16	5.6	0.59	2.2
P2	Bss1	60-91	8.8	0.2	0.56	10.25	347	57.52	625	8.73	0.11	4.6	0.59	2.0
P2	Bss2	91-121	9.0	0.2	0.43	10.00	381	76.21	671	11.99	0.14	6.0	0.64	2.7
P2	Bss3	121-142	9.2	0.3	0.37	12.25	437	61.83	395	55.90	0.35	9.5	1.63	6.9
P2	Bss4	142-178	9.1	0.3	0.26	18.00	246	80.53	404	10.55	0.13	5.5	0.72	2.7
SWA			8.9	0.2	0.56	11.35	373	60.64	519	20.17	0.32	8.1	0.89	3.5

pH- Soil reaction, EC- Electrical conductivity, OC- Organic carbon, Free $CaCO_3$- Calcium carbonate

Table 5: Exchangeable cations of Benchmark soil series

Pedon no.	Horizon	Depth (cm)	Ca	Mg	Na	K	CEC	BS (%)	ESP (%)
			cmol (p^+) kg^{-1}						
Raichur series (RCHmB1g$_0$)									
P1	Ap	0-19	37.87	13.98	2.18	0.87	65.42	86.56	3.43
P1	Bw	19-55	38.51	11.32	2.98	0.54	63.31	86.19	4.78
P1	Bss1	55-88	34.09	10.27	3.76	0.72	60.57	81.27	6.21
P1	Bss2	88-120	34.11	12.57	3.82	1.13	62.12	82.22	6.14
P1	Bss3	120-148	33.93	9.42	4.27	1.48	61.71	79.56	6.91
SWA			33.70	11.51	3.40	0.94	62.02	83.16	5.49
Kagalgomb series (KGBmA1g$_0$)									
P2	Ap	0-30	48.48	9.49	3.43	0.67	63.49	97.76	5.40
P2	Bw	30-60	46.82	11.69	5.69	0.59	65.79	93.92	8.65
P2	Bss1	60-91	39.67	13.60	8.56	0.43	62.14	95.36	13.78
P2	Bss2	91-121	32.97	12.40	11.95	0.57	64.65	87.99	18.48
P2	Bss3	121-142	31.52	17.82	12.64	0.65	61.94	95.78	20.41
P2	Bss4	142-178	25.41	15.44	13.28	0.53	64.13	84.51	20.71
SWA			37.47	13.40	9.26	0.57	63.69	92.55	14.63

Note: CEC- Cation exchange capacity, ESP- Exchangeable sodium percentage, Ca, Mg, Na, K- Exchangeable cations.

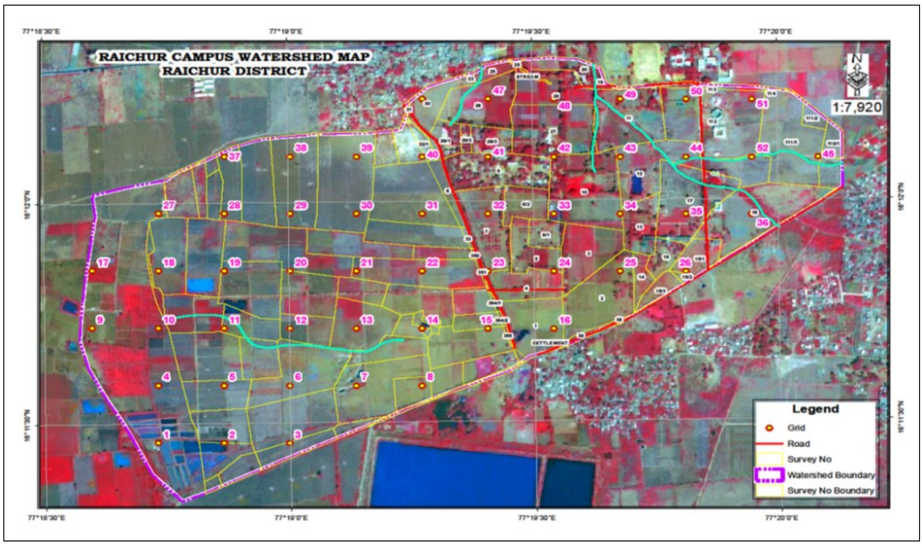

Fig 1: Satellite imagery of the Raichur soil series

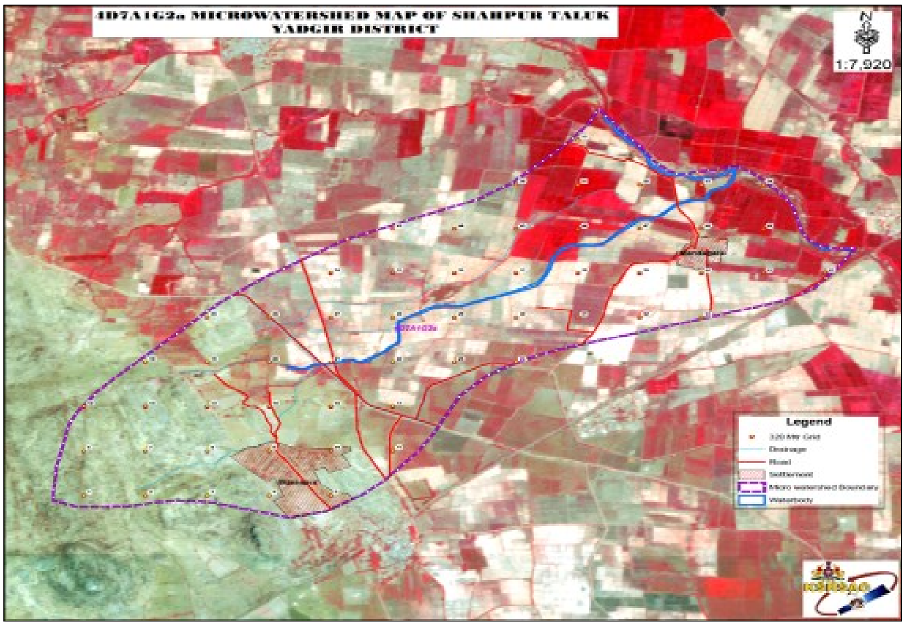

Fig 2: Satellite imagery of the Kagalgomb soil series

Conclusion

Raichur series and Kagalgomb series are the important Benchmark soil series in Hyderabad-Karnataka region and extensively distributed in Raichur and Yadgiri districts, respectively. Both the soil series comes under deep black soils category and the important features of these soils includes high swelling & shrinkage and slickensides in the subsurface horizons.

Both the series are highly clayey and pose problems for irrigation due to slow permeability. So, provision of drainage is essential for irrigated farming. Kagalgomb soils are highly calcareous and sodic in the sub surface horizons. The higher shrink-swell potential coupled with higher exchangeable sodium content of Kagalgomb soils with depth will leads to secondary salinity and sodicity problems if irrigation water is used indiscriminately without adequate drainage facilities. Available nitrogen status is low in both the soil series so application of FYM is recommended to improve the available nitrogen status and application of $ZnSo_4$ is recommended to improve the Zinc status.

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