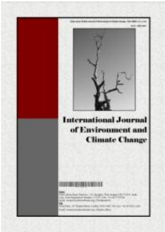

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Characterization and Classification of Soils from Southern Agro-climatic Zones of Karnataka, South India

Pradeep [a*], K. S. Anil Kumar [b] and Prabha Susan Philip [c]

[a] Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bangalore-65, India.
[b] ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Center, Bangalore-24, India.
[c] ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Center, Delhi-12, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The climate change and land degradation are both individually and in combination have profound influence on natural resource based livelihood systems and societal groups, but this land degradation is caused by land use changes and unsustainable management. The different land use systems practiced in southern agro-climatic zones of Karnataka have significant impact on soil carbon and fertility status of soils, a study was carried out to characterize and classify the soils of southern agro-climatic zones of Karnataka. Five pedons, one from each agro-climatic zone from cultivated land use were selected for the study. Soils of Hiriyur pedons were moderately shallow and rest were deep to very deep, red, well drained and appreciable amount of gravels were observed in all the pedons. Clay illuviation in sub-soil layers was observed hence sub-soil layer contained more clay than surface. The soil texture varied from sandy clay loam to sandy clay and clay. Bulk density of soil varied from 0.86 to 1.86 Mgm^{-3} in the surface. In all the profiles, bulk density increased with depth. Soil reaction varied from very strongly acidic to moderately acidic in Balehonnur and Brahmavara, moderately acidic to neutral in Hassan and Tiptur, neutral to moderately alkaline in Hiriyur. Cation exchange capacity was low and exchange complex was

**Corresponding author: E-mail: chikkanaragund3108@gmail.com;*

dominated by hydrogen and aluminum. Dominant cations were calcium and magnesium hence base saturation was high in the pedons due to leaching of bases and deposition in sub-surface horizons within the solum except in Brahmvara and Balehonnur was observed.

Keywords: Agro-climatic zones; climate change; Karnataka; land degradation; land use.

1. INTRODUCTION

Land degradation is a complex process which involves both the natural ecosystem and the socio-economic system, among which climate and land use changes are the two predominant driving factors. Land degradation has become a critical issue worldwide, especially in the developing countries, which leads to great concerns about food security. To improve livelihoods of human beings and to keep sustainable development of human society, healthy land ecosystems are basically essential elements. However, the key services of good quality land and their true values have been usually taken for granted and underestimated, leading to serious land degradation, which not only deteriorates the ecosystem services but also hinders regional sustainable development. Karnataka is the south western part of the Deccan peninsular India. It lies between 11 to 18^o N and 74^o to 78^o E longitude with geographical area of 1.91 lakh sq km. It experiences a wide variety of geological climate, vegetation and physiographic conditions. As a result, the soils of Karnataka are highly diverse and variable depending upon their conditions. The northern part of the state is dominated by shallow black soils to deep black soils. Southern agro-climatic zones of Karnataka namely coastal zone, hilly zone, northern and southern transition zone, eastern and southern dry zone and central dry zone which are varied in their climatic pattern, soil types, vegetation and land use are dominated by red sandy soil to red loamy soil, whereas heavy rain fall regions comprising Western Ghats and coastal districts are dominated by laterite and coastal alluvial soils. Hence with these varied agro-climatic conditions and diverse soil types, the state is suitable for cultivation of varied crops. Characterization and classification of soils form the basis for the exchange and extension of research findings and the properties of soil are determined by five environmental factors *viz.* climate, parent material, relief, organisms (fauna and flora), and time. Vegetation influences the soil through the addition of organic matter, action of roots in binding soil particles and amelioration of climatic conditions at soil surface [1]. Thus the morphology of soil is affected by the nature of organic matter added to the soil and the addition of water soluble compounds from leaves or decaying litter to the soil solution which influences the translocation of mineral substances during the leaching process [2]. The vegetation change from natural forests to different land use may have influenced the soil properties through the addition of leaf and litter fall, climate and management practices hence study was under taken with objectives to characterize and classify major soils of each agro-climatic zone of southern Karnataka, to evaluate soil organic carbon stocks and carbon sequestration potential of soils and to study relationship of soil organic carbon stocks with climate, soil type and different land use systems.

2. MATERIALS AND METHODS

The study was undertaken with five pedons from five districts representing five agro-climatic zones of southern Karnataka Fig. 2 and site characteristics mentioned in Table 1. The research work was carried out at College of Agriculture, UAS, GKVK, Bangalore in collaboration with NBSS & LUP, Regional center, Hebbal, Bangalore. Soil profiles were dug with a dimension of 1 m width and 1.5 m length and depth extending to either bedrock or more than 150 cm whichever is shallower. Soil profile faces were cleaned and peds exposed to facilitate examination of morphological features. Descriptions were made according to procedures outlined by AIS&LUS [3], USDA Soil Survey Manual [4]. Soil horizons were differentiated based on colour, texture, structure and gravel content and horizon wise samples collected were shade dried, ground and sieved using 2 mm sieve. The depth wise soil samples from the study sites were analyzed for pH, electric conductivity (EC), cation exchange capacity (CEC), exchangeable cations, exchangeable sodium percentage (ESP) following standard procedures. Soil pH, EC and CEC were measured as per the procedure described by Jackson [5]. The soil organic carbon content determined by wet oxidation method of Walkley and Black [6]. Based on the studied characteristics soils were classified upto family level by USDA soil taxonomy [7].

Table 1. Morphological characteristics of different pedons

Horizons	Depth (cm)	Boundary	Colour		Texture	Structure	Consistency			Roots	Pores
			Dry	Moist			Dry	Moist	Wet		
1.Brahmavara - Cashew growing area											
Ap	0 - 12	cs	7.5YR 4/4	7.5YR 3/4	c	1F sbk		fr	so & po	m vf	c m
Bt1	12-37	cs	2.5YR 3/4	2.5YR 3/4	gc	1M sbk		fr	ss & ps	m vf	c m
Bt2	37 - 57	cw	2.5YR2.5/4	2.5YR2.5/4	vgc	2M sbk		fr	ms & mp	c vf	c m
Bt3	57 - 94	cw	2.5YR 2.5/4	2.5YR 2.5/4	vgc	2M sbk		fr	ss & ps	f f	c m
Bt4	94 -131	cs	-	2.5YR 4/6	egc	2M sbk		fr	ss & ps	f vf	c m
Bt5C	131- 162	cs	-	2.5YR 4/6	egsc	2M sbk/m		fr	ss & ps	f f	c m
Bt6C	162 - 180	Cs	-	2.5YR 4/6	egsc	2M sbk/m		fr	ss & ps	f f	c m
2. Balehonnur- Coffee-growing area											
Ap	0 -18	cs	-	10 YR 3/2	scl	2F sbk		fr	ss & ps	c vf	c m
Bt1	18 - 35	cs	-	7.5 YR 3/2	scl	2M sbk		fr	ss & ps	c mf	c f
Bt2	35 - 58	cs	-	7.5 YR 4/3	scl	1M sbk		fr	ms & ps	c f	c mf
Bt3	58 - 89	cs	-	5 YR 4/4	gscl	1M sbk		fr	ms & ps	f f	c vf
Bt4	89 - 123	cs	-	5 YR 4/4	gscl	2M sbk		fr	ms & ps	f f	c f
Bt5C	123 - 151	cs	-	5 YR 4/6	vgcl	2M sbk		fr	ms & ps	f vf	f f
3. Hassan- coconut+field crops growing area											
Ap	0 -20	cs	-	10YR 4/2	scl	1F sbk		fr	ss & ps	c mf	c f
Bt1	20 - 36	cs	-	5YR 3/3	vgscl	1M sbk		fr	ms & ps		c fm
Bt2	36 -90	cs	-	2.5YR 3/3	vgsc	1M sbk		fr	ms & ps		c fm
Bt3	90 - 109	cs	-	2.5YR 3/6	egsc	1M sbk		fr	vs & ps		c f
Bt4	109 - 129	cs	-	5YR 4/4	vgsc	1M sbk		fr	vs & mp		c vf
BC	129 -161	cs	-	7.5YR 4/4	vgscl	1M sbk/m		fr	vs & mp		f vf
CB	161 - 180	cs	-	7.5YR 6/4	gscl	m/sg		fr	so & po		f vf
4. Tiptur-Areca nut growing area											
Ap	0 -20	cs		2.5YR 3/4	c	2F sbk		fr	vs & mp	f f	c f
Bt1	20 -31	cs		5YR 3/4	c	2F sbk		vfr	vs & vp	f c	c f
Bt2	31 - 50	gs		2.5YR 3/4	sc	2M sbk		vfr	ms & mp	f c	c f
Bt3	50 - 87	gs		2.5YR 3/4	gsc	3M sbk		fr	vs & vp	f f	c vf
Bt4	87 - 110	cs		2.5YR 4/4	gsc	3M sbk		fr	vs & vp	f f	c vf
Bt5C	110 - 156	cs		2.5YR 3/3	vgsc	3M sbk		fr	vs & vp	f f	c vf
Bt6C	156 - 185	cs		2.5YR 3/6	sc	3M sbk		fr	vs & vp	f f	c vf

5. Hiriyur- coconut+Red gram growing area											
Ap	0 -15	cs	5YR 4/4	5YR 3/4	scl	2M sbk	h	fr	ss & ps	f vf	c f
Bt1	15 - 33	cs	2.5YR 3/4	2.5YR 3/3	vgsc	2M sbk	vh	fr	ms mp	c vf	c m
Bt2	33 - 50	cs	2.5YR 4/4	2.5YR 3/4	vgscl	2M sbk	vh	fr	ms & mp	f m	c m
Bt3C	50 - 72	c s	2.5YR 3/4	2.5YR 3/4	egscl	3M sbk/m	vh	fr	ms & mp	f m	f m

Table 2. Site characteristics

Pedon	Village/Taluk	Location	Elevation (m)	Slope (%)	Drainage	Topography	Erosion	Parent material	Land use
Pedon 1	ZARS, Brahmavara	13° 25' 04.1" N, 74° 45' 35.4" E	21	3 - 5	Well	Undulating	Moderate	quartzite schist	Cashew
Pedon 2	Balehonnur, Koppa Taluk	13° 21' 46.2" N, 75° 25' 25.8" E	818	5 - 10	Well	Undulating	Severe	Schist	Coffee
Pedon 3	Madnur village, Channarayanapatna taluk	12° 58' 35.1" N, 76° 15' 45.6" E	942	0 - 1	Well	Nearly level	Slight	Granite	Coconut with Field crops
Pedon 4	Alburu village, Tiptur taluk	13° 09' 42.3" N, 76° 34' 53.9" E	815	1 - 3	Well	Nearly level	Slight	Granite	Areca nut
Pedon 5	Babbur village, Hiriyur taluk	13° 56' 58.5" N, 76° 37' 59.9" E	601	1 - 3	Well	undulating	Moderate	Granite schist	Coconut with Redgram

Table 3. Physico-chemical properties of pedons

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH H_2O (1:2.5)	pH KCl (1:2.5)	EC (dSm^{-1})	OC (%)
Pedon 1 - Brahmavara Cashew growing area							
0 – 12	35.23	5.1	59.67	5.11	4.98	0.035	2.28
12 – 37	34.25	9.68	56.07	5.13	4.55	0.018	0.85
37 – 57	34.96	8.75	56.29	4.98	4.21	0.013	0.44
57 – 94	30.09	8.66	61.25	5.02	4.47	0.016	0.34
94 -131	42.61	1.04	56.35	5.04	4.65	0.015	0.14
131 – 162	51.72	3.74	44.54	4.82	3.98	0.014	0.16
162 - 180	55	7.58	37.42	4.98	4.28	0.012	0.06
Pedon 2 -Balehonnur Coffee-growing area							
0 -18	48.75	17.8	33.45	5.15			2.11
18 - 35	48.7	17.66	33.64	5.27	5.05	0.04	1.13
35 - 58	47.66	16.46	35.88	5.25	5.01	0.03	0.54
58 - 89	53.9	13.21	32.89	5.26	4.98	0.02	0.34
89 - 123	61.69	10.79	27.52	5.29	5.01	0.01	0.15
123 - 151	42.76	30.01	27.23	5.35	5.12	0.01	0.15
Pedon 3 - Hassan coconut+field crops growing area							
0 -20	72.17	6.57	21.26	6.37			0.46
20- 36	55.78	9.08	35.14	6.47	6.03	0.07	0.56
36 -90	54.17	7.22	38.61	6.22	5.97	0.09	0.34
90 - 109	52.2	5.6	42.2	6.25	6.02	0.01	0.16
109 - 129	50.53	2.49	46.98	6.36	6.12	0.09	0.15
129 -161	64.8	5.14	30.06	6.24	5.85	0.1	0.07
161 - 180	71.89	7.17	20.94	6.51	6.26	0.09	0.09
Pedon 4 -Tiptur Areca nut growing area							
0 - 20	45.51	7.17	47.32	7.15			0.85
20 -31	46	7.12	46.88	7.04	6.65	0.08	0.83
31 - 50	48.99	3.05	47.96	7.19	6.73	0.07	0.46
50 - 87	54.1	3.04	42.86	6.91	6.13	0.06	0.42
87 - 110	54.68	3.56	41.76	7.05	6.61	0.07	0.34
110 - 156	55.15	7.65	37.2	6.96	6.13	0.07	0.42
156 - 185	54.85	5.59	39.56	6.95	6.57	0.07	0.18

Pedon 5 -Hiriyurcoconut+Red gram growing area							
0 -15	64.89	12.1	23.01	7.92			0.54
15 - 33	53.17	9.68	37.15	8.05	7.89	0.08	0.42
33 – 50	58.58	14.71	26.71	8.15	8.01	0.17	0.56
50 - 72	63.79	14.2	22.01	8.17	7.95	0.16	0.16

Table 4. Chemical properties of pedons

Pedon	Depth (cm)	CEC (cmol (p+) kg^{-1} soil) NH_4OAc	CEC [cmol (p+) kg^{-1} soil] (sum of cations)	BS NH_4OAc (%)	BS (sum of cations) (%)	CEC /Clay ratio	Extractable acidity	H^{+1}	Al^{+3}
Pedon 1	0 -12	7.53	46.30	90.30	15	0.13	39.50	0.01	0.18
	12 - 37	6.84	41.25	69.33	12	0.12	36.50	0.02	0.20
	37- 57	4.42	32.82	86.42	12	0.08	29.00	0.04	0.18
	57 - 94	3.89	37.06	78.66	8	0.06	34.00	0.03	0.14
	94 -131	3.31	22.19	72.06	11	0.06	19.80	0.02	0.11
	131 - 162	2.65	16.53	78.64	13	0.06	14.45	0.02	0.12
	162 - 180	1.32	35.34	63.86	2	0.04	34.50	0.04	0.14
Pedon 2	0 -18	10.01	33.07	80.62	24	0.30	25.00	0.02	0.16
	18 - 35	9.78	17.80	74.68	41	0.29	10.50	0.01	0.12
	35 - 58	8.85	17.63	74.88	38	0.25	11.00	0.01	0.11
	58 - 89	8.23	17.04	91.66	44	0.25	9.50	0.01	
	89 - 123	7.68	14.76	82.85	43	0.28	8.40	0.01	
	123 - 151	6.67	18.51	84.86	31	0.24	12.85	0.02	
Pedon 3	0 - 20	19.32	31.67	94.03	57	0.91	13.5	0.03	
	20 - 36	16.52	26.58	94.33	59	0.47	11.00	0.02	
	36 - 90	13.20	18.87	97.46	68	0.34	6.00	0.01	
	90 - 109	13.20	19.28	93.02	64	0.31	7.00	0.01	
	109 - 129	12.84	24.75	87.58	45	0.27	13.50	0.02	
	129 - 161	11.52	23.12	96.56	48	0.38	12.00	0.01	
	161 - 180	18.16	25.59	85.84	61	0.87	10.00	0.03	
Pedon 4	0 -20	20.43	27.08	93.37	70	0.43	8.00	0.02	0.11
	20 -31	19.68	18.80	82.84	87	0.42	2.50	0.01	0.10
	31 - 50	15.12	16.62	83.47	76	0.32	4.00	0.03	
	50 - 87	14.12	18.75	83.21	63	0.33	7.00	0.02	
	87 - 110	10.08	23.37	92.99	40	0.24	14.00	0.01	
	110 - 156	8.80	18.26	93.83	45	0.24	10.00	0.02	
	156 - 185	6.38	22.61	95.76	27	0.16	16.50	0.03	
Pedon 5	0 -15	23.13	28.23	93.95	77	1.01	6.50	0.02	
	15 - 33	35.98	36.05	94.65	94	0.97	2.00	0.02	
	33 - 50	22.2	31.19	84.21	60	0.83	12.50	0.01	
	50 - 72	35.21	68.42	96.33	50	1.60	34.50	0.02	

3. RESULTS AND DISCUSSION

3.1 Morphological Characteristics

Morphological properties of all the five pedons are given in Table 2. The soil profile was excavated to depth of 180 cm. The lowermost layer was Bt6C (162-180 cm). Pedon was deep to very deep due to variation in topography and slope gradient [8]. Solum depth reflects the balance between soil formation and soil loss by erosion in any area. The 12 cm thick Ap horizon was dark brown (7.5YR 3/4) in colour under moist condition. Texture was clayey with weak, fine, sub-angular blocky structure. Consistency was friable when moist under wet condition consistency was non-sticky and non-plastic. The sub-soil B horizons were designated as Bt1, Bt2, Bt3, Bt4, Bt5C and Bt6C with depth interval of 12-37, 37-57, 57-94, 94-131, 131-162, 162-180 cm respectively. The colour was varying from dark reddish brown (2.5YR 3/4/2.5YR 2.5/4) and further with depth under dry and moist condition to red (2.5YR 4/6). Due to the differential degrees of weathering and erosion, decrease in organic matter and relative accumulation of iron oxides with intense leaching of bases leaving sesquioxides and their further oxidation and reddening might have contributed to the pedogenic process rubrifaction [9]. Texture was varying from gravelly clay (Bt1) to extremely gravelly sandy clay (Bt6C) and this varied textural difference attribute to available water holding capacity, generally apart from texture, parent material, difference in clay, rainfall and organic carbon influence water availability to plants. The structure was varying from weak medium sub-angular blocky (Bt1) to moderate medium sub-angular blocky structure and massive (Bt6C), the weak structure development is due to low clay and low organic carbon content. Similar results were also observed by Sitanggang *et al*. [10]. Consistency under dry condition was varying from slightly hard (Bt1) to very hard (Bt6C) but under moist condition it was friable. The consistency under wet condition was slightly sticky to slightly plastic, this physical behaviour of soils influenced by dry, moist and wet conditions was not only due to the textural make up but also due to type of clay minerals present in these soils, [11,12].

3.2 Physical and Chemical Properties of Soils

The physical and chemical properties of soils are presented in Tables 3 and 4. Soil reaction in all the profiles ranged from slightly acidic to alkaline with pH varying from 4.82 to 8.17. This acidic pH may be due to acidic parent material and leaching of bases due to the high rainfall prevalent in this area. The variation in pH with depth may be due to weathering and leaching of bases from sloping landforms. In all the profiles pH (KC1) was less than that of pH (H_20). This indicates that all the soils under natural pH conditions carry a net negative charge and contain considerable amount of reserve acidity. The Al^{3+} content in the soils range from 0.10 to 0.20 cmol (p+) kg^{-1} soil. The organic carbon content in the surface layers of the profiles ranged from 0.46 to 2.28, whereas in the sub-soil horizon it decreased in almost all the horizons with increasing depth except in pedon 3 where it increased in the lower most horizon. The high soil organic carbon content may be due to the slow organic matter decomposition at higher altitudes, where temperature is low and rainfall is high and low soil organic carbon due to lack of proper management. The CEC of the surface soil ranged from 7.53 to 23.13 cmol (p+) kg^{-1} and it decreased with depth. The higher level of CEC at surface soil could be considered as a result of higher organic matter content. The base saturation of soils ranged from 80.62 to 94.03per cent in the surface layers. The relatively high base saturation in surface layer could be attributed to the recycling of basic cations through vegetation.

Generally organic carbon content in surface horizon was high due to the dense forest in Western Ghats and deposition of plant litter along with the alluvium [13]. Among all, the pedons of Balehonnur and Brahmavara showed comparatively higher organic carbon content in the surface mainly due to high amount of litter added by cashew and coffee to the soil (Fig.1). Lower organic carbon in Hiriyur due low organic matter deposition associated with poor biomass production and enhanced mineralization due to high temperature. Organic carbon content decreases with depth due to the leaching environment existing in the area, coupled with very high rainfall of high intensity. These results are in agreement with Patil and Dasog.

In pedon 1: Umbric epipedon was present withargillic subsurface horizon. The base saturation by sum of cations is less than 35 and hence, the soils are classified under Ultisol. Moisture regime is ustic and temperature regime is isohyperthermic. Organic carbon is more than 0.75per cent in the surface horizon and the decrease in clay from maximum in argillic horizon was more than 20per cent. The clay content was more than 35 per cent and CEC/ clay ratio was less than 0.24. Therefore, soils are classified as clayey-skeletal, kaolinitic, acid, isohyperthermic family of Rhodic Kandiustults.

In pedon 2: The base saturation by sum of cations is more than 35 per cent. Moisture regime is ustic and temperature regime is isohyperthermic. Organic carbon is more than 0.75per cent in the surface and sub-surface horizon. The clay content was less than 35per cent and CEC/ clay ratio was more than 0.24. Therefore, soils are classified as fine-loamy, mixed, acid, semi-active, isohyperthermic family of Ustic Haplohumults.

In pedon 3: The base saturation by sum of cations is more than 35 per cent. Moisture regime is ustic and temperature regime is isohyperthermic. Organic carbon is less than 0.75per cent in the surface and sub-surface horizon. The clay content was less than 35per cent and CEC/ clay ratio was more than 0.24. Therefore, soils are classified as clayey-skeletal, mixed, semi-active, isohyperthermic family of Typic Rhodustalfs.

In pedon 4: The base saturation by sum of cations is more than 35 per cent. Moisture regime is ustic and temperature regime is isohyperthermic. Organic carbon is more than 0.75per cent in the surface and sub-surface horizon. The clay content was less than 35 per cent and CEC/ clay ratio was more than 0.24. Therefore, soils are classified as fine, mixed, semi-active, isohyperthermic family of Rhodic Paleustalfs.

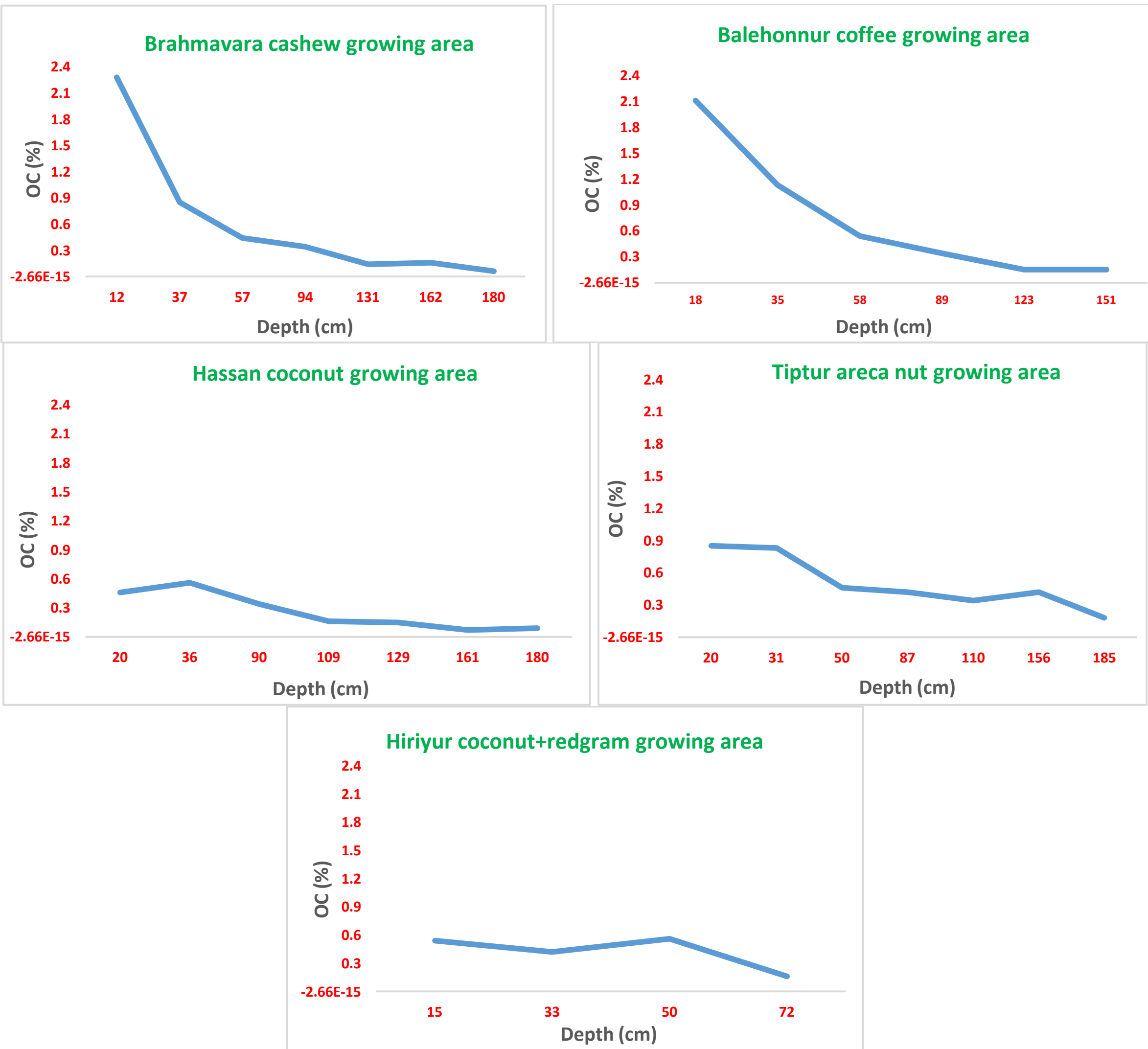

Fig. 1. Depth wise distribution of organic carbon in different pedons

In pedon 5:The base saturation by sum of cations is more than 35 per cent. Moisture regime is Aridic and temperature regime is isohyperthermic. Organic carbon is less than 0.75 per cent in the surface and sub-surface horizon. The clay content was less than 35 per cent and CEC/ clay ratio was more than 0.24. Therefore, soils are classified as loamy-skeletal, mixed, super-active, isohyperthermic family of Typic Rhodustalfs.

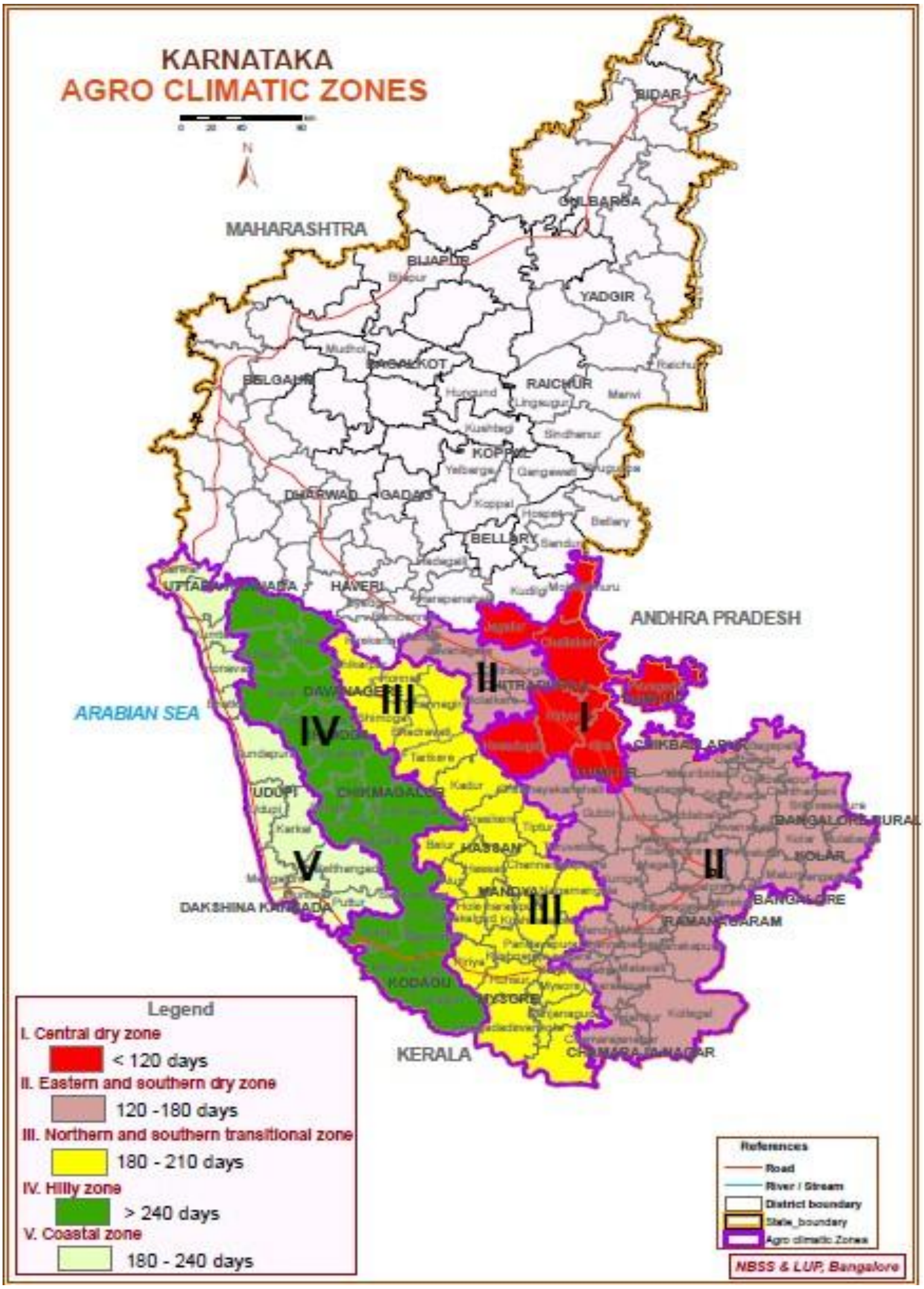

Fig. 2. Location map of study area with agro-climatic zones and LGP

4. CONCLUSION

Characterization and classification of soils in different land use systems of southern agro-climatic zones of Karnataka form the basis to achieve sustainable land management and climate smart way of cropping. The impact of land use on the quality of resource can be monitored time to time using pedological approach and suitable measures can be adopted according to the requirements to mitigate impacts of climate change on land quality. Studies on this direction throws light on the ground realities of land resource and its quality. The information so gained forms as a base for future land use planning in an effective manner.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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