Agropedology, 2000, **10**, 59-66

Characterisation of coffee growing soils in Karnataka

V.K. Kharche, J. Sehgal and O. Challa*

National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 010
* Present Address : EA-220, Maya Enclave, Hari Nagar, New Delhi 110 064

Abstract

Fifteen soils from four dominant coffee growing estates representing red and lateritic soils of hot, subhumid to humid ecoregion in Chickmaglur and Coorg districts of the Western Ghat region of Karnataka state was studied for their morphological, physical and chemical properties. The study indicates that most of the soils supporting coffee plantations are found to be deep, well drained, moderately acidic, moderately base saturated with low to moderate water holding capacity. These soils were classified under Oxic Haplustepts, Ustic Palehumults, Kandic Paleustalfs and Kanhaplic Haplustalfs. Inceptisols having cambic "B" horizon are grouped as ustepts because of ustic moisture regime and a base saturation of more than 50 per cent and further as Oxic Haplustepts owing to the CEC of less than 24 cmol kg^{-1} clay. Clay illuviation is dominant pedogenic process qualifying some soils for Alfisols and Ultisols depending upon their base saturation. Owing to the low CEC of the clay fraction the Alfisols were placed under the Kandic and Kanhaplic subgroups.

Additional keywords : Coffee growing environs, Alfisols, Ultisols.

Introduction

Coffee ranks the first in the world among the non-alcoholic beverages. It is dominantly grown in the moist, hot regions of Africa, South America and Asia. Coffee cultivation in India is primarily confined to the red and latertic soils of hilly tracts of Western and Eastern Ghats. It is dominantly grown in the states of Karnataka, Kerala, Tamil Nadu and to a limited extent in Arunachal Pradesh, Assam, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura and West Bengal.

Well distributed annual rainfall of 2000-3000 mm with a dry spell of 2–3 months, moderate to high humidity and deep to very deep soils with moderately heavy texture and high base saturation with adequate organic carbon content are favourable for successful coffee cultivation (Muller 1966). The availability of blossom showers in February - March that is required for the flowering of arabica coffee has also been considered as a crucial parameter for determining the suitability of an area for coffee cultivation (CCRI 1985; Kharche 1996; Kharche *et al.* 1999)

Coffee is an important crop in India. In order to increase the area and productivity of coffee, efforts are to be made to study and characterise the climatic and soil-site conditions of the coffee growing areas. The information on coffee growing soils and their characterization is relatively scanty in our country.

With this view an attempt has been made in this study to characterise the different agro-environments prevailing in the dominant coffee growing areas.

Materials and methods

Fifteen soils from four typical coffee estates namely Netraconda, CCRI, Kollibyle and Nullore were selected from the hills of the Western Ghats in Karnataka (Chickmaglur and Coorg districts) where coffee is traditionally grown since many years. These coffee growing regions lie between 12°30' to 13°22' N latitudes and 75°28' to 75°45' E longitudes (Fig. 1), and represent agro-ecological subregion 19.2 on the agro-ecological subregion map of the country (Sehgal *et al.* 1995). Geological formations of the area are exclusively of Archean rocks (>3000 million years) which are composed of crystalline rocks and schist belts (Bourgeon 1989). The crystalline rocks chiefly comprise of granites, granatoid gneisses, charnockites and basic dykes of later intrusions. The schistose group consists of Dharwar system and the main rocks consist principally of hornblende, chlorite and mica minerals (Krishnan 1982). The physiography is the typical Malnad which forms a transition zone between Karnataka plateau (the maidan) and the Western Ghats. The elevation ranges from 830 to 920 m above the mean sea level. The soil moisture control section (20–60 cm in general) remains dry in some or all parts for 90 cumulative days or more in most years and moist in some parts for more than 180 cumulaive days suggesting that the soil moisture regime in the area is ustic (Sehgal and Mandal 1993). The mean annual soil temperature at a depth of 50 cm is 22°C or more and the difference between mean summer (June to August) and mean winter soil temperature (December to February) is less than 5°C thus qualifying the area for isohyperthermic temperature regime (Sehgal and Mandal 1994). The area forms a part of agro-ecological subregion 19.2 (Central and South Sahyadris and Coastal plains) of subhumid (moist) to humid and per humid ecoregion with deep, loamy to clayey, red and lateritic soils. These soils have low to medium available water holding capacity. The annual rainfall varies from 1800 to 2500 mm with mean annual temperatures of 22.2 to 22.6°C. The length of growing period in the study area varies from 270 to 300 days with a dry spell of 2 to 3 months (Fig. 2). There are very low amount of blossom showers during February - March in Kollibyle estate which is also evident from the dry period shown in figure 2.

Morphological properties of the soils were studied as per the standard procedures (Soil Survey Staff 1975) and the soils were analysed for physical and chemical properties as per standard procedures (Black *et al.* 1965; Page *et al.* 1965). Based on these properties the soils were classified as per US comprehensive system of Soil Classification (Soil Survey Staff 1994).

Results and discussion

In the study area coffee is grown on rolling to undulating uplands which have moderately to steeply sloping landscapes with intervening valleys. Most of the sloping upland soils are well drained both at the surface and internally, and are gravelly in nature. However, the valley soils that are occasionally flooded have moderate to imperfect drainage and have shallow ground watertable. Out of the fifteen soils studied from different coffee estates, four representative soils are selected and are discussed in this paper.

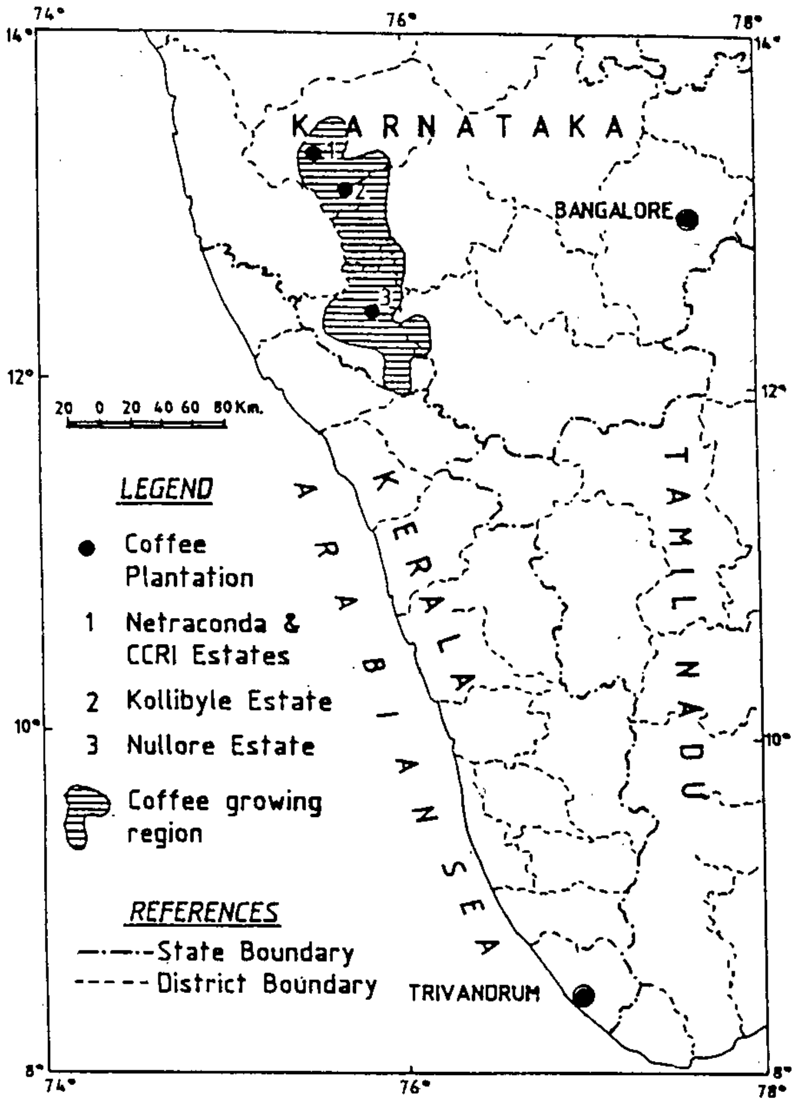

Fig. 1 : Location of coffee growing regions.

These soils are very deep (>150 cm) and are reddish brown to dark red in colour (Table 1) which may be due to intensive weathering and oxidative conditions existing in these areas of humid tropics. Structurally these soils are fine granular to medium subangular blocky in the A horizons and medium to coarse, subangular blocky in the B and C horizons. Most of the soils show thin patchy argillans in the subsoil. Texture of the soils varies from sandy clay loam in the surface, and sandy clay to clay-loam in the subsurface (Table 2). The increase in clay content is a general feature of these soils indicating the process of illuviation. The soils in general are gravelly in nature and the gravel content is more in the subsoil. The available water capacity (AWC) varies from 4.1 to 13.2 per cent in different horizons and is low due to the dominance of kaolin minerals. Plant available water capacity (PAWC) of the soils varies from 117 to 136 mm.

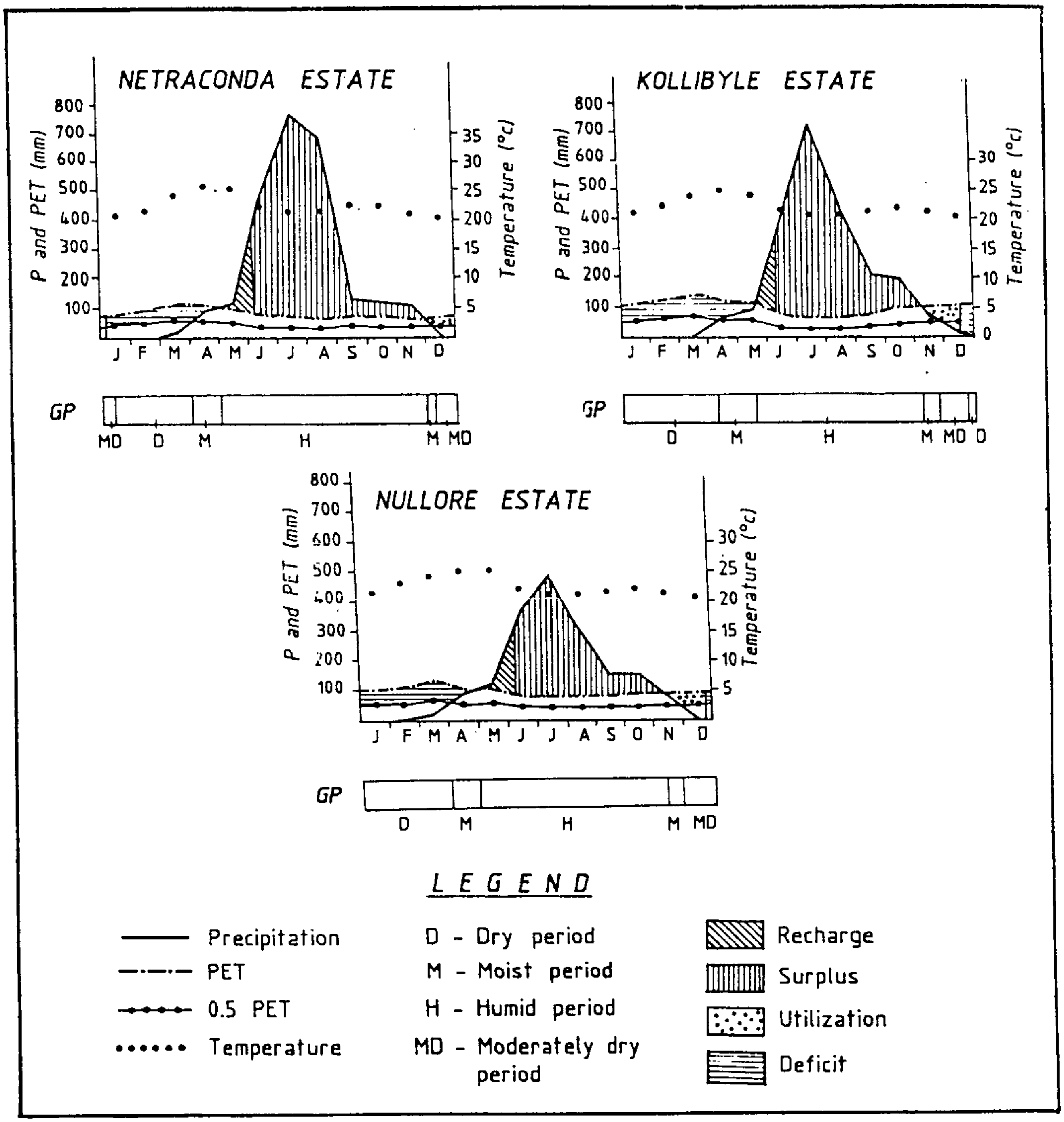

Fig. 2. : Water balance and growing periods.

Table 1. Morphological properties of soils

Horizon	Depth (cm)	Colour (moist)	Texture	Boundary D	Boundary T	Structure S	Structure G	Structure T	Consistence D	Consistence M	Consistence W	Porosity S	Porosity Q	Clay Cutans Th	Clay Cutans Q	Roots S	Roots Q
							Netraconda - Oxic Haplusteps										
Ap	0–14	5YR 4/3	scl	c	s	f	1	sbk	s	fr	ssps	fm	c			fm	m
Bw1	14–43	5YR 4/6	l	g	w	m	1	sbk	sh	fr	ssps	mc	c			fm	c
Bw2	43–75	2.5YR 5/6	scl	c	s	m	1	sbk	sh	fi	ssps	mc	c			fm	f
Bw3	75–110	2.5YR 4/6	sl	c	s	m	2	sbk		fi	ssps	mc	c			mc	c
BC1	110–161	2.5YR 5/6	sl	c	s	m	2	sbk		fi	ssps	mc	c			mc	f
BC2	161–210	7.5YR 6/6	sl			m	2	sbk		fi	ssps	fm	c			vf	f
							CCRI - Ustic Palehumuls										
Ap	0–17	7.5YR 4/4	scl	c	s	m	2	sbk	sh	fr	ssps	mc	c			fm	m
AB	17–54	7.5YR 5/4	scl	c	s	m	2	sbk	h	fr	ssps	mc	c			fm	f
Bt1	54–81	5YR 4/6	cl	g	s	m	2	sbk		fr	sps	fm	c	tn	p	f	f
Bt2	81–111	2.5YR 4/6	cl	g	s	m	2	sbk		fr	ssps	fm	f	mtk	p	vf	f
BC1	111–158	2.5YR 4/8	cl	g	s	m	2	sbk		fr	ssps	fm	f			vf	f
BC2	158–186	2.5YR 4/8	cl			m	2	sbk		fr	ssps	fm	c			vf	f
							Kollibyle - Kandic Paleustalfs										
Ap	0–14	10YR 4/3	scl	c	s	m	2	sbk	sh	fi	ssps	mc	c			mc	m
Bt1	14–33	10YR 4/3	scl	c	s	m	2	sbk	s	fi	ssps	mc	c	tn	p	fm	c
Bt2	33–69	10YR 4/4	sc	g	s	m	3	sbk	s	fi	ssps	mc	c	tn	p	mc	f
Bt3	69–105	5YR 3/1	sc	g	s	m	2	sbk		fr	ssps	mc	c	tn	p	mc	c
Bt4	105–137	5YR 5/6	c	g	s	m	2	sbk		fr	ssps	mc	c	tn	p	mc	f
Bt5	137–171	5YR 5/6	cl	g	s	m	2	sbk		fr	ssps	fm	c			mc	f
BC	171–183	5YR 3/4	sc			m	2	sbk		fr	ssps	fm	c	–	–	vf	f
							Nullore - Kanhaplic Haplustalfs										
Ap	0–16	5YR 3/4	l	c	s	fm	2	sbk	sh	fi	ssps	fm	c			fm	c
Bt1	16–42	5YR 4/5	cl	c	s	m	2	sbk	sh	fr	ssps	mc	c	tn	p	fm	c
Bt2	42–65	2.5YR 4/5	cl	c	s	m	3	sbk		fr	ssps	mc	c	tn	p	fm	c
Bt3	65–96	2.5YR 4/6	cl	g	w	m	3	sbk		fr	ssps	fm	c	tn	p	fm	c
Bt4	93–130	2.5YR 4/6	cl	g	w	m	3	sbk		fr	ssps	fm	c	tn	p	f	f
BC	130–180	2.5YR 4/6	cl			c	3	sbk		fr	ssps	fm	c			f	f

Table 2. Physical properties of soils

Horizon	Depth (cm)	Coarse fragments >2.0mm	Particle size distribution(%) Sand (2.0-0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)	Textural class	Bulk density Mg m^{-3}	Moisture Retention (%) 33 kPa	1500 kPa	AWC %	PAWC mm
					Netraconda - Oxic Haplustepts						
Ap	0–14	57	49.3	22.4	28.3	scl	1.40	23.4	14.5	8.9	17.4
Bw1	14–43	45	45.8	28.1	26.1	l	1.48	25.5	17.7	7.8	33.4
Bw2	43–75	34	46.4	27.3	26.3	scl	1.54	23.8	15.1	8.7	42.8

Bw3	75-110	17	58.8	26.2	15.0	sl	1.51	20.4	14.2	6.2	32.7
BC1	110-161	9	57.1	28.3	14.6	sl	1.50	16.5	10.6	5.9	45.1
BC2	161-210	28	62.5	29.7	7.8	sl	1.50	13.8	9.7	4.1	30.1
				CCRI - Ustic Palehumults							
Ap	0-17	-	54.6	21.2	24.2	scl	1.34	19.9	11.3	8.6	19.6
AB	17-54	-	50.7	23.2	26.1	scl	1.40	20.0	10.7	9.3	48.2
Bt1	54-81	11	35.0	26.1	38.9	cl	1.40	22.8	12.7	10.1	38.2
Bt2	81-111	58	39.0	21.9	39.[illegible]	cl	1.51	22.9	12.3	10.6	48.0
BC1	111-158	41	40.7	22.8	36.5	cl	1.50	21.2	11.3	9.9	69.8
BC2	158-186	-	45.2	23.6	31.2	cl	1.50	20.0	10.9	9.1	38.2
				Kollibyle - Kandic Paleustalfs							
Ap	0-14	11	62.8	15.0	22.2	scl	1.30	17.9	11.3	6.6	12.0
Bt1	14-33	26	58.7	14.5	26.8	scl	1.31	17.2	10.7	6.5	16.2
Bt2	33-69	61	49.8	12.0	38.2	sc	1.45	18.5	10.3	8.2	42.8
Bt3	69-105	5	46.0	13.1	40.9	sc	1.47	26.1	15.5	10.6	56.1
Bt4	105-137	2	43.7	14.0	42.3	c	1.50	26.9	13.9	13.0	62.4
Bt5	137-171	-	44.9	16.5	38.6	cl	1.51	21.0	7.8	13.2	67.8
BC	171-183	-	47.6	17.3	35.1	sc	1.50	20.5	12.0	8.5	15.3
				Nullore - Kanhaplic Haplustalfs							
Ap	0-16	-	47.4	29.5	23.1	l	1.51	20.8	12.6	8.2	19.8
Bt1	16-42	-	45.9	23.3	30.8	cl	1.55	21.9	13.0	8.9	35.8
Bt2	42-65	-	36.0	28.9	34.5	cl	1.51	22.4	13.2	9.2	31.9
Bt3	65-96	-	36.5	30.3	33.2	cl	1.53	24.1	15.8	8.3	39.3
Bt4	93-130	-	37.3	32.5	30.2	cl	1.46	25.1	16.1	9.0	44.7
BC	130-180	-	39.2	33.9	26.9	cl	1.47	21.8	14.1	7.7	56.6

The intensive leaching of bases due to high rainfall have resulted in the acidic nature (pH 5.2-6.5) of the soils (Table 3). The organic carbon (OC) content is high in the surface (1.6-2.7%) and it decreases with depth in all soils. Cation exchange capacity (CEC) is low (2.1 to 10.5 cmol(+)kg^{-1}) indicating the kaolinitic mineralogy of the soils. The amount of exchangeable bases and base saturation (BS) are low due to the leaching environment.

Table 3. Chemical properties of soils

Horizon	Depth (cm)	pH (water)	pH (KCl)	OC (%)	Exchangeable cations Ca	Mg	Na	K	Acidity ($BaCl_2$ TEA Extn.)	CEC (NH_4OAc pH7) cmol	Sum of cations	BS (NH_4OAc pH7)	Sum of cations
					c mol (p+) Kg^{-1}							%	
					Netraconda - Oxic Haplustepts								
Ap	0-14	5.8	5.3	1.82	4.50	0.71	0.11	0.35	8.2	9.4	13.9	60.3	40.8
Bw1	14-43	5.9	5.3	1.60	3.60	1.13	0.16	0.72	7.3	8.1	12.9	60.2	43.4
Bw2	43-75	6.5	5.2	0.77	2.50	0.60	0.19	0.47	4.4	4.4	8.2	73.7	45.8
Bw3	75-110	6.5	5.1	0.46	1.75	0.71	0.17	0.44	3.7	4.2	6.8	73.1	45.1
BC1	110-161	6.3	4.9	0.31	2.00	0.57	0.25	0.25	3.8	4.3	6.9	72.8	45.3
BC2	161-210	6.5	4.5	0.19	1.11	0.23	0.11	0.10	2.0	2.1	3.5	73.8	44.3

					CCRI - Ustic Palehumults								
Ap	0–17	5.8	5.3	1.60	4.00	0.80	0.15	0.31	8.8	8.8	14.1	59.8	37.3
AB	17–54	5.3	4.9	1.11	2.11	0.81	0.14	0.61	8.6	7.8	12.3	47.0	29.8
Bt1	54–81	5.2	4.9	0.50	2.30	0.64	0.17	0.42	8.5	8.1	12.0	43.5	29.4
Bt2	81–111	5.5	4.9	0.26	2.40	0.52	0.12	0.36	8.1	7.0	11.5	48.6	29.5
BC1	111–158	5.6	4.9	0.18	2.50	0.50	0.20	0.31	8.0	6.4	11.9	54.8	30.5
BC2	158–186	5.6	4.9	0.11	2.40	0.48	0.20	0.29	7.6	6.1	11.0	55.2	30.6
					Kollibyle - Kandic Paleustalfs								
Ap	0–14	5.9	5.1	1.80	4.13	1.56	0.16	0.77	9.2	9.4	15.8	70.4	42.0
Bt1	14–33	6.1	4.7	1.05	4.13	0.82	0.24	0.49	8.5	8.1	14.2	70.1	40.0
Bt2	33–69	5.8	4.5	0.61	3.01	0.78	0.12	0.13	7.6	6.1	11.6	66.2	34.8
Bt3	69–105	5.8	4.6	0.32	3.50	0.75	0.12	0.23	8.5	6.5	13.1	70.7	35.1
Bt4	105–137	5.7	4.6	0.24	3.30	0.71	0.10	0.21	7.8	6.6	12.1	65.4	35.7
Bt5	137–171	5.8	4.4	0.20	3.51	0.78	0.11	0.11	7.2	6.4	11.7	70.4	38.5
BC	171–183	5.8	4.4	0.14	3.05	0.70	0.12	0.16	7.0	6.1	11.0	66.1	36.6
					Nullore - Kanhaplic Haplustalfs								
Ap	0–16	5.6	4.8	2.71	3.88	1.40	0.70	0.83	8.9	10.5	15.7	64.8	43.3
Bt1	16–42	6.3	4.5	1.66	2.40	0.49	0.39	0.97	4.3	6.0	8.6	70.8	49.4
Bt2	42–65	6.2	5.1	1.05	3.38	0.74	0.16	1.25	5.5	7.6	11.0	72.7	50.3
Bt3	65–96	6.2	4.9	1.00	3.38	0.68	0.18	0.90	5.2	7.1	10.3	72.4	49.9
Bt4	93–130	6.1	5.0	0.95	3.25	0.68	0.23	0.59	5.3	7.0	10.0	67.6	47.3
BC	130–180	6.2	5.1	0.90	3.20	0.61	0.20	0.60	3.8	6.3	8.4	73.2	54.9

The soils show varying degree of development which is evident from the presence of cambic to argillic subsurface diagnostic horizons. Morphogenetic expression of most of the soils show considerable homogeneity and has evidence of translocation of clay. They fulfil the criteria of clay increase down the profile to qualify for the argillic horizon. Most of the soils have >35 per cent BS (by sum of cations) and qualify for Alfisols; however, some soils (CCRI) with <35 per cent BS are classified as Ultisols. The other soils which do not show well developed argillic horizons but have cambic horizon are grouped under Inceptisols.

The Kollibyle soils are classified under Paleustalfs and the Nullore soils are grouped as Haplustalfs. Since the CEC is low (<24 cmol(p^+)kg^{-1} clay) they qualify for Kandic and Kanhaplic subgroups. The CCRI soils with high organic matter and showing no decrease of clay with depth in the profile are classified as Ustic Palehumults. The Netraconda soils are placed under Inceptisols due to isohyperthermic temperature regime and are classified as Ustepts because of high BS (>50%) and under Oxic Haplustepts since CEC is less than 24 cmol (p^+) kg^{-1} clay in major part of the soil from 25 to 100 cm.

Conclusions

The soils in the coffee growing areas of the region are deep, well drained, moderately acidic with low cation exchange capacity and low exchangeable bases and low to moderate available water capacity. These are classified as Oxic Haplustepts (Netraconda), Ustic Palehumults (CCRI), Kandic Paleustalfs (Kollibyle) and Kanhaplic Haplustalfs (Nullore).

Acknowledgements

The first author is grateful to the Indian Council of Agricultural Research for the award of a Senior Research Fellowship during this study. Grateful acknowledgements are also due to Dr. W. Krishnamurthy Rao, Former Head, Agronomy Division of Central Coffee Research Institute for guidance and help during the field work.

References

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., and Clark, F.E. (1965). 'Methods of Soil Analysis', Part I, (American Society of Agronomy Inc. (Pb.) : Madison, Wisconsin, USA), 770p.

Bourgeon, G. (1989). Reconnaissance Soil Map of Forest Area : Western Karnataka and Goa. French Institute of Pondicherry, 96p.

CCRI (Central Coffee Research Institute) (1985). Coffee Guide. Coffee Board Research Department, Coffee Research Station, Chikmagalur, 199p.

Kharche, V.K. (1996). Developing soil-site suitability criteria for some tropical plantation crops, Ph.D. thesis, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Kharche, V. K. Sehgal, J., and Challa O. (1999). Evaluation of land resources for coffee plantation. A case study in Karnataka. *Journal of Indian Society of Soil Science.* **47** : 754-760.

Krishnan, M.S. (1982). 'Geology of India and Burma' 6th edition, (CBS Publ. : New Delhi), 536p.

Muller, L.E. (1966). Coffee Nutrition. In : Nutrition of Fruit Crops (Ed. N.F. Childers), (Horticultural Publications : New Jersey, USA).

Page, A.L., Miller, R.H., and Keeney, D.R. (1965). 'Methods of Soil Analysis', Part 2, (American Society of Agronomy Inc. (Pub.) : Madison, Wisconsin, USA), p.1159.

Pillai, K.M. (1984). 'A Textbook of Plantation Crops' (Vikas Publishing House : New Delhi), 168p.

Rao, W.K.M. (1993). Fertilizer Management in Coffee. In Fertilizer Management in Commercial Crops (Ed. H.L.S. Tandon), pp.133-147. *(Fertilizer Development and Consultation Organization* : New Delhi).

Sehgal, J.L., and Mandal, D.K. (1993). Soil Moisture Regimes of India. NBSS Publication No. *41*, Nagpur.

Sehgal, J.L., Mandal, D.K., and Mandal, C. (1995). Agro-ecological Subregions of India (Map) Published by NBSS&LUP, Nagpur.

Soil Survey Staff (1975). 'Soil Taxonomy - A basic system of soil classification for making and interpreting soil surveys' (USDA Agriculture Handbook No. 436, : Washington, D.C.)

Soil Survey Staff 1994. 'Keys to Soil Taxonomy', 5th Edition. SMSS Technical Monograph No. 19, (Pocahontas Press Inc. : Blackburg, Virginia) 556p.

Received : October, 1999 ; Accepted : March, 2000.