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Characterisation of soils of the Khanapur micro-watershed using GIS in Hilly agro-climatic zone (Zone 9) of Belgaum district

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Abstract

Soil is the most precious natural resource. Soil resource inventory provides an insight into the potentialities and limitations for their optimum utilization through characterisation and evaluation of land resources. The Belgaum district is situated in the northwestern part of Karnataka state and has three agro-climatic zones (zone 3, 8 and 9). The Khanapur micro-watershed (4D7C9L1c) was selected as it is representing the Hilly agro-climatic zone (zone 9) of the district. The Khanapur micro-watershed is located between $15^0$36'30" to $15^0$38'0" N latitude and $74^0$31'10" to $74^0$32'30" E longitude with an average elevation of 682 m above Mean Sea Level. The climate of the Khanapur micro-watershed is sub-humid with mean annual rainfall of 1859.1 mm. Three pedons representing different landscape positions i.e., from upland, midland and lowland positions of Khanapur micro-watershed were selected and studied in detail. The texture of surface horizons of upland and midland pedon was sandy clay. Whereas, that of lowland was clayey in nature. Higher clay content in pedons of Khanapur micro-watershed might be attributed to the high degree of weathering due to excessive rainfall at Khanapur site. The bulk density of the pedons ranged from 1.34 to 1.48 Mg m^{-3} in Khanapur micro-watershed. The surface horizons of all the three pedons in the micro-watershed had shown lower bulk density values which could be attributed to higher organic matter content. The organic carbon content ranged from 1.60 to 5.78 g/kg in pedons of Khanapur micro-watershed. The lowland pedons of Khanapur were higher in organic carbon content than other pedons. The lower CEC values of Khanapur pedons is related to high rainfall which has resulted in intensive weathering and leaching of bases. The exchangeable bases in all the pedons were in the order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex.

Keywords: Pedons, exchangeable bases, CEC, micro-watershed

Introduction

Soil is the most precious natural resource. The sustainable development of land resources calls for optimal utilization of the land based on their potential and limitations. More than ever before, a renewed attention is being given to soils due to rapidly declining land area for agriculture, declining soil fertility and increasing soil degradation, wrong land use policies as well as irrational and imbalanced use of inputs (Kanwar 2004) [13]. In this endeavour, soil resource inventory provides an insight into the potentialities and limitations for their optimum utilization through characterisation and evaluation of land resources.

Belgaum district has three agro-climatic zones (zone 3, 8 and 9) and however, detailed information on morphological, physical and chemical properties is not available for these soils and hence keeping these factors in view, the present study was undertaken to characterise the soils of selected watershed representing the hilly agro-climatic zones of Belgaum district.

Materials and Methods

The Belgaum district is located east of the Western Ghats and is situated in the northwestern part of Karnataka state. The Khanapur micro-watershed (4D7C9L1c) was selected representing the Hilly agro-climatic zone (zone 9) of the district. The Khanapur micro-watershed is located between $15^0$36'30" to $15^0$38'0" N latitude and $74^0$31'10" to $74^0$32'30" E longitude with an average elevation of 682 m above Mean Sea Level. The geographical area of Khanapur micro-watershed is 586.2 ha. The location of micro-watersheds is shown in Fig. 1. The climate of the Khanapur micro-watershed is sub-humid with mean annual rainfall of 1859.1 mm.

After intensive traversing, pedon locations were selected in the micro-watershed depending upon soil heterogeneity in physiography. Three pedons representing different landscape positions were selected and studied in detail. Characterization of three pedons is presented in table 1. Morphological features of the pedons were described as per the procedure outlined in soil survey manual (Soil survey division staff, 1993). Soil samples representing each horizon of the pedons were collected and physico-chemical properties were determined using standard procedures (Black 1965) [5]. Maximum water holding capacity of the soils was determined by using Keen Raczkowaski brass cup as described by Sankaram (1960) [22]. Dispersion ratio was calculated using the relationship described by Middleton (1930) [16]. Dispersion ratio = (silt + clay dispersible in water)/ total silt + clay. Erosion Index was computed from the relationship described by Sahi *et al*. (1977) [20]. Erosion index = Dispersion ratio/ (Clay/0.5 water holding capacity).

Table 1: Horizon Depth (cm) Morphological description

Pedon No. : 1
Location : Khanapur watershed
Lat-long position : 15°37'9.1''
74°31'37.9''
Parent rock : Peninsular gneiss
Physiography / Elevation : Upland

Horizon	Depth (cm)	Morphological description
Ap	0-20	Reddish brown (5 YR 4/4 D); sandy clay; moderate, medium, subangular blocky; slightly hard, moderately sticky and slightly plastic; clear smooth boundary; common roots.
BA	20-35	Reddish brown (5 YR 4/4 D); sandy clay; moderate, medium, subangular blocky; slightly hard, moderately sticky and slightly plastic; clear smooth boundary; common roots.
B_1	35-55	Yellowish red (5 YR 5/6 D); sandy clay loam; moderate, medium, subangular blocky; moderately hard, slightly sticky and slightly plastic; clear smooth boundary; very few roots.
B_2	55-85	Yellowish red (5 YR 5/8 D); gravelly sandy clay; moderate, medium, subangular blocky; moderately hard, slightly sticky and moderately plastic; no roots.

Pedon No. : 2
Location : Khanapur watershed
Lat-long position : 15°37'42.1''
74°31'48.7''
Parent rock : Peninsular gneiss
Physiography / Elevation : Midland

Horizon	Depth (cm)	Morphological description
Ap	0-20	Dark brown (7.5 YR 4/4 D); sandy clay; moderate, medium, subangular blocky; slightly hard, slightly sticky and slightly plastic; clear smooth boundary; common roots.
BA	20-40	Dark brown (7.5 YR 4/4 D); sandy clay; moderate, medium, subangular blocky; moderately hard, slightly sticky and moderately plastic; clear smooth boundary; very few roots.
Bt	40-93	Dark reddish brown (5 YR 3/4 D); sandy clay; moderate, medium, subangular blocky; moderately hard, moderately sticky and moderately plastic; clear smooth boundary; no roots.
BC	93-110+	Reddish brown (5 YR 4/4 D); sandy clay; moderate, medium, subangular blocky; moderately hard, slightly sticky and moderately plastic; no roots.

Pedon No. : 3
Location : Khanapur watershed
Lat-long position : 15°37'49.5''
74°32'19.4''
Parent rock : Peninsular gneiss
Physiography / Elevation : Lowland

Horizon	Depth (cm)	Morphological description
Ap	0-20	Yellowish brown (10 YR 5/8 D); clay; moderate, medium, subangular blocky; slightly hard, slightly sticky and moderately plastic; clear smooth boundary; common roots.
BA	20-58	Yellowish brown (10 YR 5/6 D); clay; moderate, medium, subangular blocky; moderately hard, slightly sticky and moderately plastic; clear smooth boundary; few roots.
Bt	58-100	Brownish yellow (10 YR 6/8 D); clay; moderate, medium, subangular blocky; moderately hard, moderately sticky and moderately plastic; very few roots.
BC	100-130+	Yellowish red (5 YR 5/6 D); gravelly clay; moderate, medium, subangular blocky, vesicular structure with yellow, pink and black material in the pores; hard, slightly sticky and slightly plastic; no roots.

Results and Discussion

Soil Morphology

The pedons 1, 2 and 3 were from upland, midland and lowland positions of Khanapur micro-watershed. The texture of surface horizons of upland and midland pedon was sandy clay. Whereas, that of lowland was clayey in nature. This variation in texture is mainly attributed to the deposition of finer fractions transported from uplands and midlands. Similar findings were reported by Arun Kumar *et al*. (2002) [2]. The structure of surface horizons of all the pedons of Khanapur micro-watershed was somewhat well developed irrespective of physiography as moderate, medium and sub angular blocky. These findings are in conformity with those reported by Sanjeev *et al*. (2005) [21]. The consistency of soils of Khanapur micro-watershed was slightly hard in surface horizon irrespective of physiography.

Physical characteristics

Granulometric data and bulk density values presented in the table 2 indicated that the clay content of Khanapur upland pedon (pedon 1) varied from 34.2 to 36.3 per cent. Higher clay content was observed in subsurface horizon at 20-35 cm depth. The clay content in midland pedon of Khanapur micro-watershed (Pedon 2) increased from surface to a maximum of 41.3 percent in Bt horizon, below which it decreased slightly. In lowland pedon of Khanapur (pedon 3) the clay content was higher in middle horizons compared to upper horizon and varied from 40.5 to 55.7 per cent. The clay content of soil in all the profiles increased with depth and clay was found accumulated in the intermediate layers as observed elsewhere by Gowaikar and Datta (1971) [12]. High clay content with its accumulation in the intermediate layers indicates the degree of maturity of the profiles (Barshad, 1958; Gowaikar and Datta, 1971) [3, 12]. Higher clay content in pedons of Khanapur micro-watershed might be attributed to the high degree of weathering due to excessive rainfall at Khanapur site. Silt content varied from 8.4 to 15.0 per cent in pedons of and Khanapur micro-watershed with higher value observed at surface horizons of lowland pedons. Moreover, in the pedons of Khanapur micro-watershed, the very fine sand and fine sand content decreased with depth whereas, coarse sand and very coarse sand content increased with depth. Total sand content in all the pedons of Khanapur micro-watershed followed a decreasing trend up to certain depth and then slightly increased below. In upland pedon (pedon 7), the total sand content ranged from 52.3 to 54.4 per cent, in midland pedon (pedon 8) from 47.7 to 51.2 per cent and in lowland pedon (pedon 9) from 33.1 to 44.5 per cent. The upland pedon exhibited higher sand content than lowland pedon, which could be attributed to removal of finer fractions and consequent enrichment of sand fractions on the upper slopes.

The bulk density of the pedons ranged from 1.34 to 1.48 Mg m^{-3} in Khanapur micro-watershed. The surface horizons of all the three pedons in the micro-watershed had shown lower bulk density values which could be attributed to higher organic matter content. In all the pedons, progressive increase of bulk density with depth was probably related to increase in coarse fragments or filling of pores by illuvial materials leading to compaction (Madhan *et al*. 2012) [15]. The maximum water holding capacity ranged between 22.30 and 34.74 per cent in Khanapur micro-watershed (Table 3). 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) [27] in soils of Ramganga catchment in Uttar Pradesh and Thangasamy *et al*. (2005) [34] in soils of Savagiri micro-watershed in Chittoor district of Andhra Pradesh.

Table 2: Particle size distribution and bulk density of the pedons of selected micro-watersheds

Horizon	Depth (cm)	V.C. sand (1.0-2.0 mm)	C. sand (0.50-1.0 mm)	M. sand (0.25-0.50 mm)	F. sand (0.10-0.25 mm)	V.F. sand (0.05-0.10 mm)	Total sand (0.05-2.0 mm)	Silt (0.002-0.05 mm)	Clay (<0.002 mm)	Textural class	Bulk density (Mg m^{-3})
Khanapur											
Pedon 1 (Upland)											
Ap	0-20	5.3	9.7	15.0	14.1	10.0	54.0	10.9	35.1	Sandy clay	1.39
BA	20-35	4.8	9.3	14.8	14.0	9.5	52.3	11.4	36.3	Sandy clay	1.43
B_1	35-55	8.7	9.7	13.5	14.0	8.5	54.4	11.4	34.2	Sandy clay loam	1.41
B_2	55-85	11.3	12.1	10.2	13.0	6.6	53.1	11.9	35.0	Sandy clay	1.47
Pedon 2 (Midland)											
Ap	0-20	9.4	8.7	11.7	13.5	7.6	50.9	11.8	37.2	Sandy clay	1.37
BA	20-40	12.0	9.8	11.7	11.6	5.1	50.2	9.3	40.5	Sandy clay	1.41
Bt	40-93	12.2	11.1	11.5	7.9	4.9	47.7	11.0	41.3	Sandy clay	1.44
BC	93-110+	14.6	13.6	11.2	7.4	4.4	51.2	8.4	40.4	Sandy clay	1.48
Pedon 3 (Lowland)											
Ap	0-20	9.7	7.0	5.9	13.3	8.6	44.5	15.0	40.5	Clay	1.34
BA	20-58	10.3	7.7	5.0	10.0	6.6	39.5	12.3	48.2	Clay	1.37
Bt	58-100	10.7	7.8	4.2	7.2	3.2	33.1	11.2	55.7	Clay	1.44
BC	100-130+	12.7	9.3	4.1	7.0	3.1	36.1	10.7	53.2	Clay	1.42

Table 3: Physical properties of the pedons in selected micro-watersheds

Horizon	Depth (cm)	Max. WHC (%)	% silt + clay	Suspension per cent	Dispersion ratio	Erosion index
Khanapur						
Pedon 1 (Upland)						
Ap	0-20	25.51	46.0	22.1	0.48	0.17
BA	20-35	26.26	47.7	21.9	0.46	0.17
B_1	35-55	22.30	45.6	19.5	0.43	0.14
Pedon 2 (Midland)						

Ap	0-20	29.11	49.1	20.1	0.41	0.16
BA	20-40	29.35	49.8	19.7	0.39	0.14
Pedon 3 (Lowland)						
Ap	0-20	31.80	55.5	18.4	0.33	0.13
BA	20-58	34.41	60.5	20.2	0.33	0.12
Bt	58-100	34.74	66.9	20.9	0.31	0.10

*WHC- Water holding capacity

Table 4: Chemical properties of soils in the pedons of selected micro-watersheds

Horizon	Depth (cm)	pH (1:2)	EC (1:2) (dS m^{-1})	Organic Carbon (g kg^{-1})	CEC (cmol(p+) kg^{-1})	Exchangeable cations (cmol(p+) kg^{-1})			
						Ca	Mg	K	Na
Khanapur									
Pedon 7 (Upland)									
Ap	0-20	5.72	0.05	4.18	2.4	0.4	0.2	0.11	0.2
BA	20-35	5.76	0.05	4.16	2.6	0.6	0.2	0.11	0.2
B_1	35-55	5.27	0.05	4.14	2.0	0.5	0.2	0.09	0.1
B_2	55-85	5.86	0.07	3.04	1.8	0.6	0.1	0.18	0.1
Pedon 8 (Midland)									
Ap	0-20	5.67	0.04	4.64	3.1	0.8	0.6	0.16	0.4
BA	20-40	6.16	0.04	3.88	4.8	2.2	0.7	0.20	0.3
Bt	40-93	5.82	0.04	2.20	4.3	1.8	0.6	0.22	0.2
BC	93-110+	6.30	0.04	1.60	4.2	1.4	0.7	0.16	0.2
Pedon 9 (Lowland)									
Ap	0-20	5.82	0.03	5.78	4.1	1.9	0.5	0.08	0.3
BA	20-58	6.10	0.04	5.32	6.4	3.4	0.6	0.15	0.4
Bt	58-100	7.22	0.09	2.53	7.2	4.0	0.5	0.08	0.4
BC	100-130+	7.35	0.09	2.21	6.9	3.8	0.5	0.10	0.4

Table 5: Correlation matrix of Dispersion ratio (DR) and Erosion index (EI)

Correlations co-efficients		
Soil parameter	**DR**	**EI**
% clay	0.34	-0.47**
% sand	-0.34	0.45**
	1.0	0.60**
EI	0.60**	1.0
Exch Na (cmol(p+) kg^{-1})	0.73**	0.16
% silt+clay	0.34	-0.45**
OC (g kg^{-1})	-0.26	-0.41*

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed).

Dispersion ratio and erosion index

According to criterion of Middleton (1930) [16], soils having dispersion ratio >0.15 and erosion ratio >0.10 are erodible in nature. So, the soils of the Khanapur micro-watershed were found to be erodible using above criteria. The dispersion ratio (DR) and erosion index (EI) values ranged from 0.33 to 0.48 and 0.13 to 0.17 for the surface soils of Khanapur micro-watersheds (Table 3). Lower DR and EI values were observed in the soils of Khanapur micro-watershed. The DR and EI in all the pedons of Khanapur micro-watershed decreased with increasing soil depth. This may be attributed to higher clay content and soil aggregation in the lower depths. A significant negative correlation was observed between erosion index and per cent clay (r= -0.47**). Similar observation was made by Singh *et al*. (2006) [29].

Chemical characteristics

Chemical characteristics of the soils are presented in the table 4. The pH values ranged between 5.27 and 7.35 in soils of Khanapur micro-watershed. The lower pH values in surface horizons of all the pedons of Khanapur micro-watershed was mainly due to leaching of bases because of high rainfall (Sivashankaran *et al*. 1993) [32]. The upland pedon of Khanapur has relatively lower pH value than that of lowland pedon. This increase in soil reaction down the slope could be due to leaching of bases from higher topography and getting deposited at lower elevation (Sitanggang *et al*. 2006) [31]. All the pedons of Khanapur micro-watershed had shown normal or low EC values indicating the non-saline nature of the soils on the basis of limits suggested by Muhr *et al*. (1963) [17] for judging salt problem of soils (EC < 1dSm^{-1} as 'normal' and EC 1-2 dSm^{-1} as critical for germination). The reason might be the free drainage conditions which favoured the removal of released bases by percolating water. Pillai and Natarajan (2004) [18] also reported similar low EC values indicating the non-saline nature of soils of Garakahalli micro-watershed.

The organic carbon content ranged from 1.60 to 5.78 g/kg in pedons of Khanapur micro-watershed. The lowland pedons of Khanapur were higher in organic carbon content than other pedons. The distribution of organic carbon is mainly associated with physiography. These findings are in conformity with those findings of Walia and Rao (1996) [35]. The organic carbon content of surface soil was greater than sub surface horizons. This could be attributed to the addition of plant residues or leaf litter which resulted in higher organic carbon content. These observations are in accordance with results of Basava raju *et al*. (2005) [4] in soils of Chandragiri Mandal of Chittoor district of Andhra Pradesh. The slightly higher organic carbon content in soils of Khanapur pedons is due to high rainfall and forest vegetation prevailing there (Ananthanarayana *et al*. 1974) [1]. The lower CEC values of Khanapur pedons is related to high rainfall which has resulted in intensive weathering and leaching of bases (Gowaikar and Datta, 1971) [12]. The exchangeable bases in all the pedons were in the order of Ca^{+2} > Mg^{+2} > Na^{+} > K^{+} on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility (Sharma *et al*. 1996) [25] The low value of exchangeable monovalent cations, compared to divalents was due to preferential leaching of monovalent than divalent. These findings are in accordance with Das and Roy (1979) [8].

Correlation co-efficients

The correlation co-efficient values revealed that per cent sand and erosion index (EI) had positive and significant relationship (r=0.45**). It indicated that presence of high amount of sand fraction in the soil increase soil erodibility. Significant and negative relationship of EI was observed with per cent clay (-0.47**) and per cent silt+ clay (-0.45**). This negative correlation suggested that soil erodibility decreased with increase in clay content. Similar observations were recorded by Sharma *et al*. (1987) [24] and Singh and Kundu (2008) [29]. Dispersion ratio (DR) was positively and significantly correlated with exchangeable sodium (r = 0.73**). Erosion index had shown significant and negative relationship with organic carbon (-0.41*). The results are in conformity with Kumar *et al*. (2002) [14]. The dispersion ratio was found to be significantly and positively correlated with erosion index at 0.01 level of significance (r = 0.60*). Similar results have also been obtained by Chakrabarti (1971) [6], Sharma *et al*. (1987) [24] and Kumar *et al*. (2002) [14]. As the dispersion ratio increased, erosion index also increased indicating greater susceptibility of these soils to water erosion.

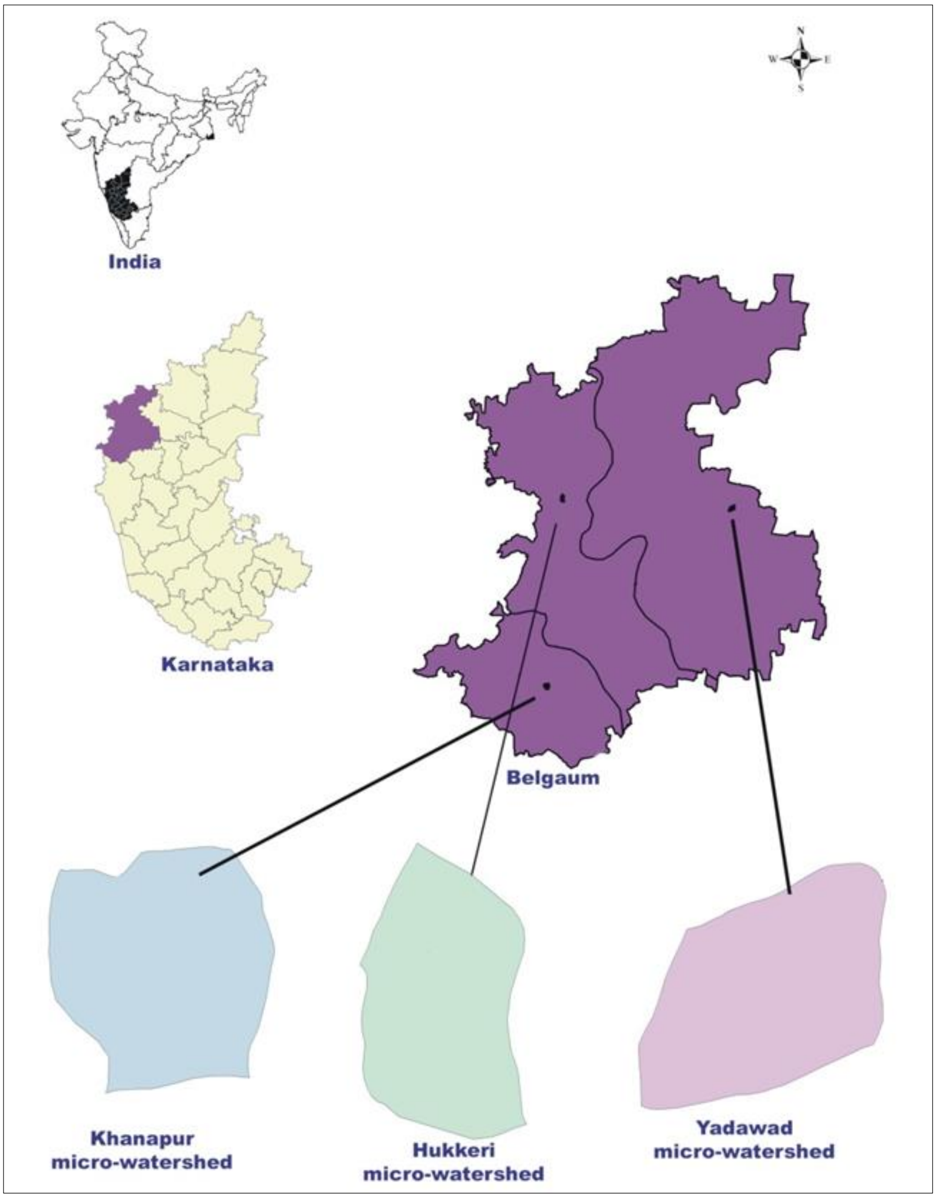

Fig 1: Location map of the study area

References

1. Anathanarayana R, Mithyantha MS, Perur NG. Fertility status of acid soils of Karnataka. Mysore Journal of Agricultural Sciences. 1974;8:209-214.
2. Arun Kumar V, Natarajan S, Sivasamy R. Characterization and classification of soils of lower Palar-Manimuthar watershed of Tamil Nadu. Agropedology. 2002;12:97-103.
3. Barshad I. Chemistry of the soils. Reinhold Publication New York; c1958. p. 356
4. Basava Raju D, Naidu MVS, Ramavatharam N, Venkaiah K, Rama Rao G, Reddy KS. Characterization

classification and evaluation of soils in Chandragiri mandal of Chittoor district Andhra Pradesh. Agropedology. 2005;15:55–62.
5. Black CA. Methods of Soil Analysis. Part 2. American Society of Agronomy Inc Publisher Madison Wisconsin USA; c1965. p. 849-1348.
6. Chakrabarti DC. Investigation on erosion and water stable aggregates of certain soils of North-Eastern Nepal. Journal of the Indian Society of Soil Science. 1971;19:441-446.
7. Dabral PP, Murry RL, Lollen P. Erodibility status under different land uses in Dikrong river basin of Arunachal Pradesh. Indian Journal of Soil Conservation. 2001;29:280-282.
8. Das SN, Roy BB. Characterization of category soils. Indian Journal of Agricultural Chemistry. 1979;12:43-52.
9. Dasog GS, Acton DF, Mermut AR. Genesis and classification of clay soils with Vertic properties in Saskatchewan. Soil Science Society of America Journal. 1987;51:1243-1250.
10. Dasog GS, Hadimani AS. Genesis and chemical properties of some Vertisols. Journal of the Indian Society of Soil Science. 1980;28:49-56.
11. Dasog GS. Studies on genesis and classification of some black soils of command areas of Ghataprabha and Malaprabha project. M Sc Agri Thesis. University of Agricultural Sciences Bangalore. 1975
12. Gowaikar AS, Datta NP. Influence of moisture regime on genesis of laterite soils in south India Indian Morphology and Chemistry of Soil. Journal of the Indian Society of Soil Science. 1971;19:279-292.
13. Kanwar JS. Address by the guest of honour 69th annual convention of the Indian Society of Soil Science held at the Acharya NG Ranga Agricultural University Hyderabad. Journal of the Indian Society of Soil Science. 2004;52:295-296.
14. Kumar S, Sharma JC, Sharma IP. Water retention characteristics and erodibility indices of some soils under different land uses in North West Himalayas. Indian Journal of Soil Conservation. 2002;30:29-35.
15. Madhan MM, Dasog GS, Mrudula G, Vijay SBM. Study of soil characteristics modified by physiography in Hanumankoppa miro-watershed under northern transitional zone of Karnataka. The Andhra Agricultural Journal. 2012;59:568-573.
16. Middleton HE. Properties of soils which influence soil erosion *Technical Bulletin* 178 United States Department of Agriculture. 1930:1-16
17. Muhr GR, Datta NP, Shankara Subraney N, Dever F, Lecy VK, Donahue RR. Soil testing in India. USAID mission to India. 1963.
18. Pillai MY, Natarajan A. Characterization and classification of dominant soils of parts of Garakahalli watershed using remote sensing technique. Mysore Journal of Agricultural Sciences. 2004;38:193-200
19. Rudramurthy HV, Dasog GS, Vasuki N. Genesis and classification of associated red and black Pedons of north Karnataka. Mysore Journal of Agricultural Science. 1996; 30:321-330.
20. Sahi BP, Singh SN, Sinha AC, Acharya B. Erosion Index - A new index of soil erodibility Journal of the Indian Society of Soil Science. 1977;25:7-10.
21. Sanjeev KC, Singh K, Tripathi D, Bandari AR. Morphology genesis and classification of soils from two important land uses in outer Himalayas. Journal of the Indian Society of Soil Science. 2005;53:394–398.
22. Sankaram A. Keen Raczkowaski Box Measurements. A Laboratory Manual for Agricultural Chemistry Asia Publishing House Bombay. 1960:142.
23. Satyanarayana T, Biswas TD. Chemical and mineralogical studies of associated black and red soils. Mysore Journal of Agricultural Sciences. 1970;8:253-264
24. Sharma IP, Kanwar BS, Gupta MP. Physico-chemical properties of Kangra soils in relation to their erodibility. Indian Journal of Soil Conservation. 1987;15:43-47.
25. Sharma RK, Swami BN, Shyampura RL, Giri JD, Singh SK. Characterization of some soils of Haldi ghat region of Rajasthan in relation to land physiography. Journal of the Indian Society of Soil Science. 1996;47:329-333
26. Sharma VK, Anil Kumar. Characterization and classification of the soil of upper Maul Khad catchment in wet temperate zone of Himachal Pradesh. Agropedology. 200313:39-49
27. Singh HN, Sharma AK, Prakash O. Characterization and classification of some cultivated soils of Ramganga catchment in the soils of Uttar Pradesh. Agropedology. 1999;9:41-46
28. Singh IS, Agrawal HP. Characteristics and classification of some rice growing soils of Chandauli district of Uttar Pradesh. Agropedology. 2003;13:11-16.
29. Singh R, Kundu DK. Erodibility of major soil sub-groups of eastern region of India. Indian Journal of Soil Conservation. 2008;36:172-178
30. Singh R, Singh KD, Parandiyal AK. Characterization and erodibility of soils under different land uses for their management and sustained production. Indian Journal of Soil Conservation. 2006;34:226-228
31. Sitanggang M, Rao YS, Ahmed N, Mahapatra SK. Characterization and classification of soils in watershed area of Shikohpur Gurgaon district Haryana. Journal of the Indian Society of Soil Science. 2006;54:106–110
32. Sivasankaran K, Mithyantha MS, Natesan S, Subbarayappa CT. Physicochemical properties and nutrient management of red and lateritic soils under Zplantation crops in Southern India. NBSS Publications. 1993;37:280
33. Soil Survey Division Staff. Soil Survey Manual. United States Department of Agriculture Washington DC 1-411. 1993
34. Thangasamy A, Naidu MVS, Ramavatharam N, Raghava Reddy C. Characterization classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh for sustainable land use planning. Journal of the Indian Society of Soil Science 2005;53:11–21.
35. Walia CS, Rao YS. Genesis characteristics and taxonomic classification of some red soils in Bundelkhand region of Uttara Pradesh. Journal of the Indian Society of Soil Science. 1996;44:576-581