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Characterization and classification of some tea-growing soils of Jorhat district, Assam

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Abstract: Four representative tea-growing soils in flood plains of East-Jorhat Development Block of Jorhat district were studied to understand the intrinsic pedogenic characteristics through morphology, selected physical and chemical characteristics to place them in the sub groups of Ultisols and Inceptisols. Soils on very gently sloping plains (P1 and P2) are very deep, well-drained and have brownish-yellow to yellowish-brown matrix, loamy A horizons to clay-loam argillic B horizons, extremely (pH 4.4) to very strongly acid (pH 4.9), low cation exchange capacity and low base saturation status (< 35 percent). Soils on nearly level plains are moderately (P3) to imperfectly drained (P4) with dark yellowish brown to yellowish brown, sandy loam to loam A horizons and have yellowish brown to light yellowish brown or brownish yellow matrix in B horizons with sandy loam to sandy clay loam textures with an aluminium saturation of 48 (P1) to 63 percent (P3). The strongly acid subsoils (P4) have brown to yellowish brown matrix with sandy loam to loam texture and base saturation of more than 35 percent in the soil control section. The soils have aluminium saturation 48 to 77 per cent compared to that in pedon P3 (29 to 63%). The ratio of pH dependent CEC to ECEC was considered as reliable indicator ranging from 0.90 to 2.60 in soils on very gently sloping plains to 0.77 to 1.91 in soils on nearly level plains indicating differential rates of weathering. The soils on very gently sloping plains (P1 and P2) were classified as *Typic Hapludults* whereas, soils on nearly level plains as *Ruptic Ultic Dystrudepts* (P3) and *Ruptic Alfic Dystrudepts* (P4).

Key words: *Base saturation, pH dependant CEC, tea growing soils, Jorhat*

Introduction

In Assam, tea is grown in 321,319 hectares (ha) covering 4.81 percent (Economic Survey 2009). During soil resource inventory programme in Assam (1: 250,000 scale), it was reported that tea growing soils were classified under the subgroups of *Dystrudepts* and *Udifluvents* (Sen *et al.* 1999; Vadivelu *et al.* 2004). Tea is largely grown in Brahmaputra plains of Jorhat district. In Jorhat district, the *Dystrudepts* were estimated to cover an area of 49,446 ha in Brahmaputra plains (Vadivelu *et al.* 2004). However, there is scanty of systematic soil information on tea-growing regions of Jorhat. Hence, an attempt was made in this article to briefly outline the morphological, physical and chemical characteristics of four representative tea grown soils of Brahmaputra plains in East Jorhat Development block and to classify them in the Soil Taxonomy (USDA).

Materials and Methods

The study area is situated in East Lahing gaon panchayat of East Jorhat Development Block of Jorhat district in between 26^{o}49' to 26^{o}51' N latitude and 94^{o}26' to 94^{o}30' E longitude covering 123 ha (Fig.1). The topography is very gently sloping to nearly level plains at an elevation of 100 to 125 m above mean sea level. The geology is alluvium formed in Brahmaputra arc that runs parallel to the mighty river Brahmaputra. These alluvium deposits have the time span in between upper Pleistocene to upper Holocene (Geological Survey of India 1989). The climate is humid sub tropical with mean annual rainfall of 2076.8 mm. The moisture regimes is udic with hyperthermic soil temperature regime as mean winter and mean summer soil temperature differs by 5^{o}C or more (Vadivelu *et al.* 2004; Velayutham *et al.* 1999). Four representative soils, on two landforms situations such as very gently sloping plains (P1 and P2) and nearly level plains (P3 and P4) were chosen for this study. Soil sampling was carried out during January to February, 2010. Two soil pits were excavated on each of two landforms for describing morphological characteristics (Soil Survey Staff 2003). The air dry soil samples were crushed and passed through 2 mm sieve. The soil samples were analysed in the laboratory for physical and chemical parameters using standard procedures. The particle size analysis was done by International pipette method, soil pH in 1: 2 soil water ratio and in *1 N* KCl solution, organic carbon by Walkley and Black method (1934), extractable Al^{3+} by *1 N* KCl, cation exchange capacity (CEC) by *1 N* ammonium acetate at pH 7.0 (Page *et al.* 1982), total potential acidity by $BaCl_2$-TEA (at pH 8.0±0.2) (Hesse 1971), exchangeable calcium (Ca) and magnesium (Mg) by EDTA titration and effective cation exchange capacity (ECEC) by adding sum of bases extracted by neutral *1 N* ammonium acetate and *1 N* KCl extractable aluminium (van Reeuwijk 1993). CEC by sum of cations was determined as sum of cations plus total potential acidity (Soil Survey Staff 1998). The pH dependent CEC was calculated as CEC by sum of cations subtracted from ECEC (Pratt and Alvahydo 1966). The aluminium saturation index was calculated as *1 N* KCl extractable aluminium divided by ECEC and multiplied by 100. Base saturation was calculated as sum of bases divided by CEC and multiplied by 100, whereas, base saturation of sum of cations was calculated as sum of bases divided by CEC of sum of cations (sum of cations + total potential acidity) and multiplied by 100

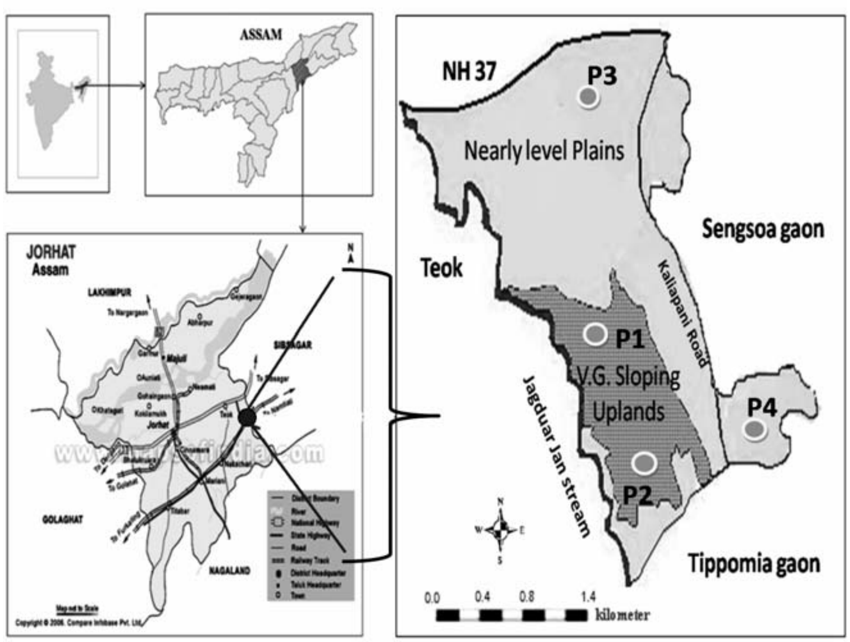

Fig. 1. Location map of the study area

Results and Discussion

Soil morphology and textural characteristics

The four pedons of Brahmaputra plains under the study area are very deep despite the report of study in three of them is confined to less than 150 cm (P1, P2 and P4). These soils have matrix hue 10 YR, value 4 to 6 and chroma 3 to 6 with loam to clay loam textures in very gently sloping plains (P1 and P2) and sandy loam to sandy clay loam in P3 and loam in P4 (Table 1). The soils on very gently sloping plains show decreasing trend of sand (48-27% in P1 and 41-32% in P2), irregular distribution of silt which is more than 35 percent throughout profile and gradual increase of clay (16-34% in P1 and 22-34% in P2) to define particle size as *fine loamy* at family level (Soil Survey Staff 2010). The subsoil clay increase in P1 and P2 is 1.2 times more to that of surface horizons to designate argillic horizon (Bt) with supportive field evidence of appearance of patchy clay skins on ped surfaces. The clay rich subsoils in tea gardens have tremendous negative effect on proliferation of tea roots and soil productivity (Do 1980). The soils on nearly level plains have erratic distribution of sand more than 50 percent with depth in P3 with silt of 23.4 to 27.5 percent. The high inflictions in sand and silt distribution is observed in P4 with sand content more than 50 percent upto 26 cm, whereas, silt content more than 45 percent in 41 to 57 cm (Table 2). These soils have clay content of 18 to 25 percent with gradational increase upto 100 cm to qualify *fine loamy* particle size at family level. The erratic sand and silt distribution in soils of Brahmaputra plains were reported due to frequent seasonal floods that alter the mode of stratification within the alluvial profiles (Vadivelu *et al.* 2003).

Table 1. Morphological characteristics of soils

Horizon	Depth (cm)	Colour (Moist)	Texture	Structure	Other diagnostic features
		Pedon P1	Landform: Very gently sloping (1-3% slope) plains		
A	0-21	10YR 4/3	Loam	m1sbk	--
BA	21-38	10YR 5/6	Loam	m1sbk	--
Bt1	38-57	10YR 5/8	Loam	m2sbk	--
Bt2	57-80	10YR 5/6	Clay loam	m2sbk	Patchy argillans
Bt3	80-100	10YR 5/6	Clay loam	m2sbk	Patchy argillans
Bt4	100-135	10YR 5/6	Clay loam	m2sbk	Patchy argillans
		Pedon P2	Landform: Very gently sloping (1-3% slope) plains		
A	0-24	10YR 4/3	Loam	m1sbk	--
BA	24-78	10YR 5/4	Loam	m1sbk	--
Bt1	78-101	10YR 6/4	Loam	m2sbk	Patchy argillans
Bt2	101-122	10YR 6/6	Clay loam	m2sbk	Patchy argillans
Bt3	122-140	10YR 6/6	Clay loam	m2sbk	Patchy argillans
Bt4	140-161	10YR 6/6	Clay loam	m2sbk	Patchy argillans
		Pedon P3	Landform: Nearly level (0-1% slope) plains		
A	0-14	10YR 5/4	Sandy loam	m1sbk	--
Bw1	14-27	10YR 5/6	Sandy loam	m1sbk	--
Bw2	27-45	10YR 6/4	Sandy clay loam	m1sbk	--

Bw3	45-71	10YR 6/6	Sandy clay loam	m2sbk	--
Bw4	71-90	10YR 6/6	Sandy clay loam	m2sbk	--
Bw5	90-125	10YR 6/6	Sandy clay loam	m2sbk	--
		Pedon P4	Landform: Nearly level (0-1% slope) plains		
A	0-11	10YR 4/3	Sandy loam	m1 sbk	--
BA	11-26	10YR 4/3	Sandy loam	m1sbk	--
Bw1	26-41	10YR 5/4	Sandy loam	m2sbk	--
Bw2	41-57	10YR 5/3	Loam	m2sbk	--
Bw3	57-75	10YR 5/3	Loam	m2sbk	Strong brown prominent many mottles (7.5 YR 4/6)
Bw4	75-94	10YR 5/4	Loam	m2sbk	Strong brown prominent many mottles (7.5 YR 4/6)
Bw5	94-137	10YR 5/6	Loam	m2sbk	Strong brown prominent many mottles (7.5 YR 4/6)

Table 2. Physical and chemical characteristics of soils

Depth (cm)	Particle Size distribution (%)			pH			Organic carbon (O.C.) (%)
	Sand	Silt	Clay	H_2O	1 (N) KCl	ΔpH	
Pedon P1: Very gently sloping plains							
0-21	48.0	36.0	16.0	4.43	3.70	-0.73	0.89
21-38	41.6	39.9	18.5	4.67	3.78	-0.89	0.42
38-57	39.7	38.8	21.5	4.56	3.76	-0.80	0.18
57-80	35.8	37.7	26.5	4.52	3.76	-0.76	0.22
80-100	31.2	38.3	30.5	4.43	3.72	-0.71	0.29
100-135	27.4	38.6	34.0	4.69	3.71	-0.98	0.22
Pedon P2: Very gently sloping plains							
0-24	40.7	37.3	22.0	4.87	3.63	-1.24	0.87
24-78	39.7	38.3	22.0	4.56	3.78	-0.78	0.71
78-101	36.2	39.3	24.5	4.53	4.24	-0.29	0.40
101-122	34.7	35.8	29.5	4.58	4.48	-0.10	0.33
122-140	31.1	38.9	30.0	4.69	4.36	-0.33	0.35
140-161	31.8	34.7	33.5	4.74	4.55	-0.19	0.36

Pedon P3: Nearly level plains							
0-14	58.5	27.1	14.0	4.43	3.76	-0.67	1.20
14-27	54	27.5	18.5	4.16	3.77	-0.39	0.58
27-45	54.5	25.5	20.0	4.05	3.71	-0.34	0.31
45-71	51.9	26.1	22.0	4.73	3.78	-.095	0.33
71-90	50.6	23.4	26.0	4.73	3.76	-0.97	0.36
90-125	50.8	25.2	24.0	4.71	3.80	-0.91	0.27
Pedon P4: Nearly level plains							
0-11	50.3	31.2	18.5	5.01	4.04	-0.97	0.83
11-26	54.7	25.3	20.0	5.03	4.25	-0.78	0.43
26-41	41.2	36.9	21.9	5.48	4.11	-1.37	0.32
41-57	26.9	48.6	24.5	5.18	4.13	-1.05	0.34
57-75	29.8	45.7	24.5	5.30	4.12	-1.18	0.38
75-94	38.5	39.5	22.0	5.33	4.46	-0.87	0.41
94-137	46.6	31.4	22.0	5.35	3.98	-1.37	0.43

Chemical characteristics

The soils on very gently sloping plains (P1 and P2) are very strongly acid (pH 4.5-5.0) except in Ap horizon of P1 having extremely acid pH (<4.5) (Table 2). The soils on nearly level plains are strongly acid throughout depth in P4, whereas, P3 has extreme acid within 50 cm. These soils have an ideal soil pH rating for tea (pH 4.5 to 6.6) (Kacar 1984), except in P1 and P3, where, extremely acid conditions may have adverse effect on tea growth and productivity. The extreme acidity of these soils can be explained by the oldness of the tea gardens and period of inappropriate fertilization methods (Ozyazici *et al.* 2010). Under Indian conditions, it was reported that the tea growth can be affected negatively by pH values above 5.7 and below 3.5 (Bhattacharyya and Dey 1983). The pH in 1N KCl extract is used to workout pH. The low pH in Ap horizons (-0.67 to -1.24) is due to presence of organic carbon (0.8 to 1.2 percent) (Eswaran and Bin 1978), whereas, low pH in B horizons of these soils is due to net negative charge of clay (Gangopadhyay *et al.* 1986). Except in P3, the organic carbon in surface horizons is less than 1% indicating that these tea gardens are old. Similar kind of organic carbon distribution was reported in tea grown soils of West Bengal (Ray and Mukhopadhyay 2012). These extremely acid to strong acid soils have more than 50 percent aluminium saturation index and high exchangeable aluminium in P1 (1.74 to 3.35 cmol (p+) kg^{-1}), P2 (1.67 to 2.60 cmol (p+) kg^{-1}) and P3 (1.21 to 2.28 cmol (p+) kg^{-1}) with gradual increase with depth. The low concentration of exchangeable aluminium in surface horizons is due to mobilization of aluminium along with organic carbon and its subsequent adsorption by clay minerals in subsoils (Gangopadhyay *et al.* 1986; Sahoo *et al.* 2010). These soils have wider exchangeable Ca to Mg ratio indicating the dominance of calcium bearing minerals (Baruah *et al.* 2011). The CEC of less than less than 10 cmol (p+) kg^{-1} and ECEC of less than 5 cmol (p+) kg^{-1} is recorded in P1, P2 and P3, whereas, in P4, the CEC is more than 10 cmol (p+) kg^{-1} throughout the profile. The low CEC/clay ratio with depth (0.29 to 0.46 for P1 and P2) indicates the occurrence of low activity clays (Bhattacharyya *et al.* 2010) and mixed mineralogy (Smith 1986). The depth trends of CEC and ECEC is irregular but shows decreasing trend of CEC clay ratio. The total potential acidity of soils varies from 5.37 (in P4) to 9.31 (P1 and P3) with irregular depth trends. The pH dependent CEC/ECEC ratio as an indicator of relative degree of weathering in tropical soils (Pratt and Alvahydo 1966) shows maximum of 2.6 in P2 and minimum of 0.77 in P4. The ascending order of weathering sequence based on this indicator is as follows: P2> P1> P3> P4 (Table 3). These soils have low base saturation (< 35 percent) except in P4, where base saturation is in between 39 to 58 percent.

Table 3. Ion exchangeable characteristics of the soils

Depth (cm)	Sum of cations				Sum of cations	Exch. aluminium	ECEC	CEC	Total potential acidity	pH depednent CEC	CEC/ Clay ratio	pH dep. CEC/ ECEC ratio	Aluminium saturation index (%)	Base saturation (%)	
	Ca	Mg	Na	K										Sum of cations	NH$_4$OAc
	---cmol (p$^+$) kg^{-1}---														
Pedon P1: Landform: Very gently sloping plains (Well drained)															
0-21	1.07	0.51	0.22	0.06	1.86	1.74	3.60	7.34	8.98	7.24	0.46	2.01	48	25	14
21-38	0.56	0.39	0.32	0.09	1.36	1.88	3.24	7.55	9.18	7.30	0.41	2.25	58	18	13
38-57	0.62	0.49	0.26	0.09	1.45	2.10	3.55	9.18	8.23	6.13	0.43	1.73	59	16	15
57-80	0.63	0.31	0.25	0.08	1.27	2.61	3.88	9.79	9.31	6.70	0.37	1.73	67	13	12
80-100	0.63	0.32	0.25	0.10	1.30	3.35	4.65	9.50	7.52	4.17	0.31	0.90	72	14	15
100-135	0.32	0.31	0.22	0.10	0.95	3.14	4.09	9.70	8.59	5.45	0.29	1.33	77	10	10
Pedon P2: Landform: Very gently sloping plains (Well drained)															
0-24	0.62	0.55	0.36	0.11	1.64	1.67	3.31	8.98	7.88	6.21	0.41	1.88	50	18	17
24-78	0.63	0.32	0.32	0.09	1.36	2.39	3.75	6.12	8.06	5.67	0.28	1.51	64	22	14
78-101	0.38	0.20	0.27	0.07	0.92	1.87	2.79	5.71	9.13	7.26	0.23	2.60	67	16	9
101-122	0.66	0.39	0.26	0.07	1.38	2.18	3.56	5.91	8.23	6.05	0.20	1.70	61	23	14
122-140	0.99	0.54	0.27	0.08	1.88	2.39	4.27	6.52	8.65	6.26	0.22	1.47	56	29	18
140-161	0.55	0.42	0.33	0.09	1.39	2.60	3.99	6.10	8.39	5.79	0.18	1.45	65	23	14
Pedon P3: Landform: Nearly level plains (Well drained)															
0-14	1.38	0.99	0.39	0.26	3.02	1.21	4.23	7.52	9.31	8.10	0.54	1.91	29	40	25
14-27	1.05	0.68	0.36	0.07	2.16	2.01	4.17	7.72	8.11	6.10	0.42	1.46	48	28	21
27-45	0.68	0.42	0.42	0.11	1.63	2.14	3.77	6.73	8.23	6.09	0.34	1.62	57	24	17
45-71	0.52	0.42	0.35	0.04	1.33	2.28	3.61	6.93	8.95	6.67	0.32	1.85	63	19	13
71-90	0.69	0.57	0.51	0.05	1.82	2.21	4.03	9.30	8.23	6.02	0.36	1.49	55	20	18
90-125	0.87	0.54	0.62	0.06	2.09	2.21	4.3	9.70	7.52	5.31	0.40	1.23	51	22	22
Pedon P4: Landform: Nearly level plains (Imperfectly drained)															
0-11	2.04	1.42	0.54	0.11	4.11	0.8	4.81	10.49	6.81	6.11	0.57	1.27	17	39	38
11-26	2.87	2.01	0.38	0.06	5.32	--	5.32	14.25	5.37	5.37	0.71	1.01	--	37	50
26-41	2.82	1.75	0.56	0.04	5.17	--	5.17	12.08	6.44	6.44	0.55	1.25	--	43	45
41-57	3.93	3.31	0.34	0.06	7.64	--	7.64	13.27	5.96	5.96	0.54	0.78	--	58	56
57-75	4.05	3.51	0.33	0.07	7.96	--	7.96	13.66	6.11	6.11	0.56	0.77	--	58	57
75-94	3.77	2.53	0.33	0.06	6.69	--	6.69	12.87	6.17	6.17	0.59	0.92	--	52	52
94-137	2.93	1.79	0.21	0.06	4.99	--	4.99	12.79	6.14	6.14	0.58	1.23	--	39	45

Classification of soils

The soils were classified based on intrinsic properties *viz*., morphological characteristics, and physical and chemical properties (Soil Survey Staff 2010). Soils on very gently sloping plains (P1 and P2) show clay illuviation with more than 1.2 times over surface horizon and low base saturation (< 35 percent) to place them in the Ultisol (Soil Survey Staff 1975) and classified as *Typic Hapludults*. In P3 and P4, the B horizons are cambic with 10 to 50 percent of illuvial part that otherwise meet the requirement of argillic (Bt) with horizon and base saturation of less than 35 percent in P3. To classify them as *Ruptic Ultic Dystrudepts* (P3), whereas, in P4, soils are classified as *Ruptic Alfic Dystrudepts* as base saturation is in between 39 to 58 percent.

Conclusion

Four tea grown soils are very gently sloping to nearly level plains of Jorhat district were characterized and classified in the subgroups of Inceptisols and Ultisols based on base saturation and clay illuviation (argillans in genetic B horizons). The pH dependent CEC/ ECEC ratio was used as an indicator to assess the degree of weathering sequence in the order of P2> P1> P3> P4. The study shows the influence of topography in controlling the pedogenic processes and its physico-chemical characteristics of tea grown soils that will certainly help in taking effective measures for sustainable management and fertility status of soils.

References

Baruah, B.K., Das, B., Haque, A., Medhi, C. and Misra, A.K. (2011). Sequential extraction of common metals (Na, K, Ca and Mg) from surface soil. *Chem. Pharm. Research* **3(5),** 565-573.

Bhattacharyya, N.G. and Dey, S.K. (1983). Role of pH and aluminum phosphate availability of tea soils. *Two and a Bud* **30**, 61-64

Bhattacharyya, T, Sarkar, D., Pal, D.K., Mandal, C., Baruah, U., Telpandey, B. and Vaidya, P. H. (2010). Soil information system for resource management – Tripura as a case study. *Current Science* **99(9):** 1208-1216.

Do, N.Q. (1980). *Tea Cultivation*. Agricultural Publishing House, Hanoi, pp. 10-106.

Economic Survey of Assam. (2009). Directorate of Economics and Statistics, Planning & Development Department, Assam.

Eswaran, H. and Bin, W.C. (1978). A study of a deep weathering profile on granite in peninsular Malaysia: Physicochemical and micromorphological properties. *Soil Science Society of America Journal* **42:** 145-149.

Gangopadhyay, S.K., Debnath, N.C. and Banerjee, S.K. (1986). Characteristics of some high altitude soils of Sikkim forest division. *Journal of the Indian Society of Soil science* **34,** pp 830-838.

Geological Survey of India. (1989). *Regent advances in the study of Tertiary stratigraphy of North East India*: A critical resume. Key papers presented in Group. Discussion on Tertiary stratigraphy of North East India. Special Publication No. **23,** 1-21.

Hesse, P.R. (1971). *A text book of soil chemical analysis*. Chemical Pub**.** Co. University of Michigan.

Kacar, B. (1984). *Fertilization of tea*. Tea Industry Publ. No. 4, Ankara, pp: 356.

Page**,** A. L., Miller, R.H. and Keeney, D.R. **(**1982). Methods of Soil Analysis. Part-II. Chemical and Microbiological Properties. *American Society of Agronomy*, Madison, Wisconsin, USA. Pratt, P.F. and Alvahydo, R. (1966). *Cation exchange characteristics of soils of Saopaulo, Brazil.* IRI Research Institute, Inc., Bull. **31,** New York, p. 31.

Ozyazici, G., Ozyazici, M.A., Ozdimir, O.Surucu, A. (2010). Some physical and chemical characteristics of tea grown soils in Rize and Artwin Province. *Anadolu Journal of Agricultural Sciences* **25**(2): 94-99.

Ray, S.K. and Mukhopadhyay, D. (2012). A study on physicochemical properties of soils under different tea growing regions of West Bengal. *International Journal of Agricultural Sciences* **4** (8): 325-329.

Sahoo, A.K., Sarkar. D., Baruah, U. and Butte, P.S. (2010). Characterisation, classification and evaluation of soils of Langol Hill, Manipur for rational land use planning. *Journal of the Indian Society of Soil Science* **58**(4): 355-362.

Sen, T.K., Chamuah, G.S., Sehgal, J. and Velayutham, M. (1999). *Soil of Assam for optimizing land use.* NBSS Publ. **66b**, NBSS & LUP (ICAR), Nagpur, India.

Smith, G.D. (1986). *The Guy Smith Interview:* Rationale for concepts in Soil Taxonomy. *SMSS Technical* Monograph No. **11**, SMSS, SCS, USDA.

Soil Survey Staff (1975). *Soil Taxonomy. A Basic System and Soil Classification for Making and Interpreting Soil Surveys.* USDA. Agriculture Handbook No. **436**.

Soil Survey Staff (2003). *Soil Taxonomy*. Agricultural Handbook, **436**, 3rd Edition, USDA, Washington, DC.

Soil Survey Staff (2010). *Keys to oil Taxonomy*, Eleventh Edition. USDA, Washington DC.

Vadivelu, S., Baruah, U., Bhaskar, B.P., Thampi, J., Walia, C.S., Sarkar, D. and Nayak, D.C. (2003). A land use plan for Jorhat district of Assam. *Agropedology* **13,** 1-10.

Vadivelu, S., Baruah, U., Bhaskar, B.P., Mandal, C., Sarkar, D., Walia, C.S. and Gajbhiye, K.S. (2004). *Soil Resource Atlas, Jorhat District (Assam),* NBSS Publ. **107**, NBSS & LUP (ICAR), Nagpur, India.

van Reeuwijk, L.P. (1993). *Procedures for Soil Analysis*. ISRIC. Wageningen, the Netherlands. Velayutham, M., Mandal, D.K., Mandal, C. and Sehgal, J.L. (1999). *Agro-ecological Sub Regions of India for Planning and Development.* NBSS Publ. **35**, NBSS & LUP (ICAR), Nagpur, India.

Walkley, A. and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method, *Soil Science* **37:** 29-38.

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