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Characterization, Classification and Mineralogy of Benchmark Soils of Kalimpong Hills Under Mulberry Farming

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Abstract **– The characteristics, classification and mineralogical analysis of benchmark soils of Kalimpong hills, of West Bengal under mulberry farming were undertaken in 2011 - 12 to assess the morpho - physico - chemical characteristics and clay mineralogy of the soils. Soil samples were collected from the mulberry field of Regional Sericultural Research Station (RSRS) farm, Regional Sericultural Research Station Annexure (RSRSA) farm and sericulture farmers field from eight different villages namely Kharka Busty, Bhalukhop Makaldhara, Makaldhara, Khani, Gitdabling, Saurani, Dolapchand and Sangsay villages of Kalimpong hills. Based on soil samples analyzed, the soils of Kalimpong hills stated above are shallow to very deep in depth, light coloured, light textured with weak, medium to fine, granular to subangular blocky structure. The sand, silt and clay percent in soils RSRS farm, RSRSA farm and all the sericulture farmers field ranged from 64-76%, 8-17% and 13-20% respectively. The pH of these soils are ranged from 4.2-6.7, EC 0.05-1.07 dSm^{-1}, organic carbon content 0.21-2.49% and CEC mean 7.2-16.9 cmol (p+) kg^{-1} respectively which varied from plot to plot and terrace to terrace. These soils are dominated by the silicate clay minerals like kaolinite (1:1 lattice type), mica, vermiculite and gibbsite (Mica group 2:1 type non-expanding minerals), chlorite (2:1:1 or 2:2 type clay minerals) and talc etc. However, kaolinite and mica are the most dominant clay minerals in soils than others. The soils of Kalimpong hills have been classified into Coarse loamy, mixed, Thermic, Typic Udarthents and Coarse loamy, Mixed, Thermic, Typic Hapludepts.**

Keywords **– Soil Morphology, Physical and Chemical Properties, Clay Mineralogy, Soil Classification.**

I. Introduction

Mulberry (*Morus spp*) is an economically and traditionally very important plant of deciduous type for the development of sericulture industry. Mulberry plants belong to the family *Moraceae* and are successfully grown under tropical to temperate climatic conditions in various part of the country. Kalimpong hills are the hilly range of Sub-Himalayan Mountains popularly known as sericulture hub for production of bivoltine silkworm seed. The mulberry leaves are basic food material for silkworm *Bombyx mori* L. and nutritious leaves are the most important growth regulating factors for these silkworm. Being a monophagous insect, it derives almost all the nutrients essential for its growth from the mulberry leaves itself. Bulk of the bivoltine silkworm seed produced in this region is directly derived from protein of mulberry leaves; hence, silkworm should be feed with good quality of mulberry leaves in abundant quantity for the quality silkworm seed production.

It is well known fact that the sericulture is an agro based industry and soil management is a formidable challenge to insure productivity and profitability for sustainable sericulture. The yield and quality of mulberry leaves are directly or indirectly affected by “how the soil is handled”. From sericultural point of view, the soil characteristics may be referred as the ability of the soil to produce quality sericulture host plants in a sustainable manner. On the other hand, soil characteristics can be defined as the quality or capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation [1]. Clay minerals are naturally occurring inorganic materials (usually crystalline) found in soils and other earthy deposits [2]. It is the product of disintegration and decomposition of parent rocks and other silicate minerals at the earth’s surface. They reflect successive stages of mineralogical evolution depending on the various environmental conditions that have prevailed during soil formation [3; 4]. Soil minerals act as “chemical sponges” which play a vital role in soil fertility since mineral surfaces serve as potential sites for nutrient storage. The physico-chemical properties of soils primarily governed and dictated by the nature of clay minerals, including a profound effect on the nature, size and stability of the aggregates, in addition, these naturally occurring clays are good cation exchanger and play a very important role in plant nutrition ([5; 6; 7]. Keeping the importance of characteristics and mineralogy in the soil fertility and also to keep a systematic soil health database of this area for maintenance of mulberry plantations, it was obligatory to assess the characteristics, classification and mineralogy of benchmark soils of Kalimpong hills, Darjeeling district of West Bengal for sustainable sericulture.

II. Materials and Methods

The characteristics, classification and mineralogical analysis of benchmark soils of Kalimpong hills of West Bengal under mulberry farming was undertaken in year 2011-12 to assess the morphological, physical, chemical and mineralogical characteristics of the soils. Both surface soil samples and soils profiles were analyzed from two own Research farms i.e. Regional Sericultural Research Station (RSRS) and Regional Sericultural Research Station Annexure (RSRSA) and sericulture farmers field from eight different villages namely Kharka Busty, Bhalukhop Makaldhara, Makaldhara, Khani, Gitdabling, Saurani, Dolapchand and Sangsay villages of Kalimpong hills.

The Kalimpong hilly area lies between 26°31' to 27°13' N latitudes and 87°59' to 88°53' E longitudes and situated at an altitude of about 3550 feet (1076 m) above MSL. Sandstone and quartzite and mica are the major geologic formation in this area which is responsible for the formation of the soils as parent materials. Teesta and its tributaries rivers are the main water bodies. The climate is sub-tropical type (Sub-Himalayan region) with mean annual precipitations 1876.3 mm, of which 90.3 percent occurs between June to September. Based on rainfall and temperature data, soil moisture regime is '*Udic*' and soil temperature regime is '*Thermic'*.

Soil samples were collected, dried, sieved and analyzed adopting the standard procedure [8; 9]. For separation of clay particles for X-ray diffraction analysis of clay mineralogy, [10; 11; 12] method were adopted. Similarly, study and interpretation of soil profile and soil classification at family level was done as per the procedures [13; 14; 15].

III. Result and Discussion

3.1 *Morpho - Physical Properties of Soils of Kalimpong Hills*

Morpho-physical properties of the soils are given in Table 1. Bases on the soil profiles studied, the soils of Kalimpong hills are shallow to very deep in depth; dark yellowish brown (10 YR 4/4) to brown (10 YR 5/4 and 6/4) in colour; sandy loam to sandy clay loam texture; single grain to fine, medium, subangular blocky structure; dry semi hard, moist very friable to friable, wet slightly sticky to sticky and wet slightly plastic consistency; very fine to fine, few to many pores and clear to gradual smooth to wavy horizon boundary. Poor soil structure and low consistency was due to light soil texture and both soil properties also varied with the soil texture. Sand, silt and clay percent in these areas ranged from 64-77%, 8-17% and 13-24% respectively which classified as sandy loam to sandy clay loam. The clay content increased upto 24% in the lower horizons increases pedon 7. It was due to migration/ illuviation pedogenic processes. There was no much migration or illuviation of clay content in soils of entire area. It was because of severe erosion due to heavy rainfall, excessive sloping land and small size terrace.

The variation of colour was due to prevalence of well drained conditions, admixture of organic matter [16; 17; 18] whereas the variation in soil texture was caused by slope, terrace and translocation or illuviation of clay in lower horizons [19]. The variation in soil structure and consistency was due to variation in clay content of pedons [17; 20]. The high clay content in lower horizons in few soils profiles was due to illuviation or vertical migration of clay [16; 17; 21; 22; 23].

Table 1. Morpho-physical properties of soils of Kalimpong hills.

Horizon	Depth (m)	Colour (moist)	Sand	Silt	Clay	Texture	Structure	--Consistence--			Boun-dary	Pores
			(%)					Dry	Moist	Wet		
Pedon 1: RSRS, Kalimpong farm												
Ap	0.00-0.15	10 YR 5/4 (m)	73	10	17	Sl	sbk-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A11	0.15-0.42	10 YR 4/4 (m)	70	12	18	Sl	sbk-1-m	dsh	mfr	wss wps	cs	c-vf-f
B11	0.42-0.70	10 YR 4/4 (m)	66	14	20	Scl	sbk-1-m	dh	mfr	ws wp	gs	c-vf-f
B12	0.70-1.10	10 YR 4/4 (m)	64	16	20	Scl	sbk-1-m	dh	mfr	ws wp	-	c-vf-f
Pedon 2: RSRS Annexure, Kalimpong farm												
Ap	0.00-0.12	10 YR 5/4 (m)	73	11	16	Sl	sbk-1-f	dsh	mfr	wss wps	cs	c-vf-f
A11	0.12-0.39	10 YR 4/4 (m)	66	18	16	Sl	sbk-1-m	dsh	mfr	wss wps	gs	c-vf-f
B11	0.39-0.86	10 YR 4/4 (m)	66	14	20	Scl	sbk-1-m	dsh	mfr	wss wps	-	c-vf-f
Bc	0.86+	Weathered parent materials of rocks										
Pedon 3: Kharka Busty												
Ap	0.00-0.20	10 YR 4/3 (m)	76	11	13	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.20-0.43	10 YR 6/4 (m)	77	9	14	Sl	gr-1-f				-	c-vf-f
Ac	0.43+	Weathered parent materials of rocks										
Pedon 4: Balukhap Makaldhara												
Ap	0.00-0.15	10 YR 6/4 (m)	73	10	17	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.15-0.37	10 YR 5/4 (m)	71	11	18	Sl	sbk-1-f	dsh	mvfr	wss wps	cw	c-vf-f
B11	0.37-0.65	10 YR 5/4 (m)	68	12	20	Scl	sbk-1-f	dsh	mfr	ws wp	gs	c-vf-f
B12	0.65-1.10	10 YR 5/4 (m)	70	10	20	Scl	sbk-1-f	dsh	mfr	ws wp	-	c-vf-f
Pedon 5: Makaldara												
Ap	0.00-0.18	10 YR 4/4 (m)	69	11	20	Scl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.18-0.47	10 YR 4/4 (m)	68	10	22	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B11	0.47-0.69	10 YR 4/4 (m)	68	9	23	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B12	0.69-1.05	10 YR 4/4 (m)	70	9	21	Scl	sbk-1-m	dsh	mfr	ws wp	-	c-vf-f

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Table 1. Morpho-physical properties of soils of Kalimpong hills.

Horizon	Depth (m)	Colour (moist)	Sand	Silt	Clay	Texture	Structure	------Consistence------			Boun-dary	Pores
			(%)					Dry	Moist	Wet		
Pedon 6: Khani												
Ap	0.00-0.12	10 YR 4/6 (m)	68	17	15	Sl	gr-1-f	dvs	mvfr	wss wps	cs	c-vf-f
A12	0.12-0.33	10 YR 4/5 (m)	71	15	14	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
B12	0.33-0.55	10 YR 4/5 (m)	70	15	15	Sl	sbk-1-m	dsh	mvfr	wss wps	-	c-vf-f
Ac	0.55+	Weathered parent materials of rocks										
Pedon 7: Gitdabling												
Ap	0.00-0.18	10 YR 5/4 (m)	65	15	20	Scl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.18-0.38	10 YR 5/4 (m)	64	13	23	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B11	0.38-0.60	10 YR 4/6 (m)	64	12	24	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B12	0.60-0.85	10 YR 4/6 (m)	66	12	22	Scl	sbk-1-m	dsh	mfr	ws wp	-	c-vf-f
Pedon 8: Gitdabling												
Ap	0.00-0.20	10 YR 5/4 (m)	71	12	17	Sl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.20-0.39	10 YR 5/4 (m)	66	13	21	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B11	0.39-0.60	10 YR 4/4 (m)	66	12	22	Scl	sbk-1-m	dsh	mfr	ws wp	gs	c-vf-f
B12	0.60-0.95	10 YR 4/4 (m)	65	13	22	Scl	sbk-1-m	dsh	mfr	ws wp	-	c-vf-f
Pedon 9: Saurani												
Ap	0.00-0.18	10 YR 6/4 (m)	71	10	19	Sl	gr-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.18-0.47	10 YR 5/4 (m)	70	12	18	Sl	sbk-1-f	dsh	mvfr	wss wps	gs	c-vf-f
B11	0.47-0.69	10 YR 5/4 (m)	65	12	23	Scl	sbk-1-f	dsh	mfr	ws wp	gs	c-vf-f
B12	0.69-1.05	10 YR 5/4 (m)	66	11	23	Scl	sbk-1-f	dsh	mfr	ws wp	-	c-vf-f
Pedon 10: Dolapchand												
Ap	0.00-0.12	10 YR 5/4 (m)	76	11	13	Sl	sbk-1-f	dsh	mvfr	wss wps	cs	c-vf-f
A12	0.12-0.35	10 YR 4/4 (m)	77	11	12	Sl	sbk-1-m	dsh	mvfr	wss wps	cs	c-vf-f
B11	0.35-0.70	10 YR 4/4 (m)	75	9	16	Sl	sbk-1-m	dh	mfr	ws wp	gs	c-vf-f
B12	0.70-1.10	10 YR 4/4 (m)	74	11	15	Sl	sbk-1-m	dh	mfr	ws wp	-	c-vf-f
Pedon 11: Sangsay Busty												
Ap	0.00-0.18	10 YR 5/4 (m)	72	8	20	Scl	sbk-1-f	dsh	mfr	ws wp	cs	c-vf-f
A12	0.18-0.42	10 YR 4/4 (m)	67	10	23	Scl	sbk-1-m	dsh	mfr	ws wp	cs	c-vf-f
B11	0.42-0.72	10 YR 4/4 (m)	65	12	23	Scl	sbk-2-m	dh	mfr	ws wp	gs	c-vf-f
B12	0.72-1.05	10 YR 4/4 (m)	67	11	22	Scl	sbk-2-m	dh	mfr	ws wp	-	c-vf-f

3.2 *Chemical Properties of Soils of Kalimpong Hills*

Data of nutrients status of soils of RSRS farm are given in Table 2, RSRSA farm in Table 3 and farmers' fields in Table 4. Based on terrace wise soil samples from all the plots were analysed, the soils of the Kalimpong hills are slight to strong acidic nature. The pH of the soils of RSRS farm ranged from 5.03 to 6.9 with mean range from 5.58 to 6.31 whereas pH of soils of RSRSA farm ranged from 4.2 to 6.5 with mean range from 4.65 to 5.50. Likewise, pH of farmers' fields ranged from 5.1 to 6.73 with mean range from 5.56 to 6.70. It has been observed that, the soils of RSRSA farm was strong acidic as compare to RSRS farm and farmers' field soils. It might be due to less cultural duration with lack of lime application, leaching of bases, slope and size of terraces etc. various workers from entire parts of the country also reported that the leaching of bases, intensive weathering and sloping landforms was major factor in the variation of pH with depths, physiography and terrace [16; 19; 24; 25].

The organic carbon content varied from 0.84 to 2.34% with mean range from 1.2 to 2.08% in the soils of RSRS farm**,** 0.36 to 1.98% with mean range from 1.17 to 1.58% in the soils of RSRSA from and 0.21 to 2.49% with mean range from 0.29 to 2.37% in the farmers' fields respectively. The organic carbon significantly correlates with the pH and increased or decreased accordingly. In general, soils of Kalimpong hills have medium to high organic carbon content except farmers' field of Khani village and few terraces of RSRSA farm. The soils of Darjeeling hills under various land use are light textured, strong to moderately acidic in reaction with low exchangeable cations and high organic carbon content [26; 27; 28; 29]. Sikkim AGRISNET, Food Security and Agriculture Department, Government of Sikkim also reported that the soils of Sikkim are light textured with strong to moderate acidity and low to high organic carbon content [30].

The cation exchange capacity mean of RSRS farm ranged from 9.9 to 16.9 cmol (p+) kg^{-1}, RSRSA farm ranged from 7.2 to 8.8 cmol (p+) kg^{-1} and farmers' field ranged from 8.8 to 16.4 cmol (p+) kg^{-1} respectively. Cation exchange capacity of soils also varied from plot to plot and terrace to terrace and its availability significantly correlates with pH of soil, slope gradient and size of plot. In general, soils of RSRS Annexure found low available sulphur content followed by RSRS farm and farmers' field. Exchangeable bases in all three experimental areas in the Kalimpong hills were almost in the order: $Ca^{2+} \geq Mg2^{+} > Na^{+} \geq K^{+}$ and the base saturation varied from 45.1 to 59.4%. This results correlates with the Ray and Mukhopadhyay [26].

Table 2. Chemical properties of soils of RSRS, Kalimpong farm.

Plot No.	pH (1:2.5)	EC (dSm^{-1})	Organic C (%)	Exchangeable bases mean [cmol (p+) kg^{-1}]						ESP (%)	BS (%)
				Ca	Mg	Na	K	Sum	CEC		
1	6.14	0.30	1.89	2.6	1.7	1.2	0.5	6.0	11.1	10.8	53.8
2	6.31	0.26	1.79	4.2	2.9	2.1	0.6	9.8	16.9	12.4	58.0
3	6.01	0.08	1.75	3.7	2.1	1.4	0.6	7.8	14.2	9.9	54.6
4	6.14	0.12	1.78	4.0	3.1	1.7	0.3	9.1	16.4	10.4	55.7
5	5.95	0.13	1.20	3.4	1.6	0.9	0.3	6.2	11.6	7.8	53.5
6	6.01	0.12	1.57	3.7	2.2	0.9	0.6	7.4	13.5	6.7	54.4
7	6.11	0.24	1.68	3.1	2.7	1.2	0.6	7.6	13.8	8.7	55.2
8	6.01	0.12	1.73	3.3	1.8	1.3	0.5	6.9	12.6	10.3	54.8
9	5.99	0.10	2.01	4.4	2.4	1.8	0.5	9.1	16.4	11.0	55.7
10	5.58	0.10	1.97	3.4	0.8	0.6	0.4	5.2	9.9	6.1	52.0
11	5.90	0.12	2.08	3.6	2.2	1.2	0.5	7.5	13.6	8.8	54.9
Mean	6.00	0.20	1.80	3.6	2.1	1.3	0.5	7.5	13.6	9.3	54.8

Table 3. Chemical properties of soils of RSRSA, Kalimpong farm.

Plot No.	pH (1:2.5)	EC (dSm^{-1})	Organic C (%)	Exchangeable bases mean [cmol (p+) kg^{-1}]						ESP (%)	BS (%)
				Ca	Mg	Na	K	Sum	CEC		
1	5.50	0.13	1.28	1.9	0.8	1.1	0.46	4.26	8.8	12.5	48.4
2	4.74	0.06	1.32	1.4	1.1	0.7	0.36	3.56	7.9	8.9	45.1
3	4.75	0.12	1.27	1.5	1	0.7	0.40	3.60	7.8	9.0	46.2
4	4.65	0.14	1.58	1.6	0.7	0.6	0.40	3.30	7.2	8.3	45.8
5	5.12	0.06	1.17	2.1	0.9	0.6	0.40	4.00	8.4	7.1	47.6
Mean	5.00	0.10	1.30	1.7	0.9	0.7	0.40	3.70	8.0	9.2	46.6

Table 4. Chemical properties of soils of progressive farmers' field.

Village's Name	pH (1:2.5)	EC (dSm^{-1})	Organic C (%)	Exchangeable bases mean [cmol (p+) kg^{-1}]						ESP (%)	BS (%)
				Ca	Mg	Na	K	Sum	CEC		
Kharka Busty	6.31	0.18	1.94	4.0	2.8	1.8	0.5	9.0	15.4	11.6	58.3
Bhalukhop Makaldara	6.53	0.11	1.92	3.1	2.5	1.8	0.5	7.9	13.6	13.2	58.2
Makaldhara	5.88	0.09	1.53	2.6	0.8	1.3	0.7	5.4	10.0	13.0	53.5
Khani	5.90	0.10	0.80	2.5	1.0	0.9	0.6	4.9	9.2	9.3	53.1
Gitdabling	5.70	0.10	1.50	3.4	1.5	1.3	0.6	6.7	12.2	10.1	55.1
Saurani	5.90	0.20	1.80	2.1	1.7	1.2	0.8	5.7	10.6	11.3	54.0
Dolapchand	5.90	0.20	1.30	2.5	1.9	1.3	0.7	6.3	11.4	11.0	55.0
Sangsay	5.80	0.16	1.60	3.3	2.0	1.4	0.5	7.1	12.9	11.0	55.1
Mean	6.00	0.10	1.50	2.9	1.7	1.4	0.6	6.6	11.9	11.3	55.3

3.3 *X-ray Diffraction analysis of Clay Minerals of Soils of Kalimpong Hills*

The X-ray diffractograms of soils of RSRS and RSRSA farms showing mineralogy are given in fig. 1 and fig. 2 and list of minerals present in Table 5 and 6. The x-ray diffractograms of the clay minerals analyzed from the RSRS and RSRSA farms are almost similar. They slightly differ only in the relative intensity of the peak. These benchmark soils indicates that, the soils of Kalimpong hills are mostly dominated by the silicate clay minerals like kaolinite, dickite and nacrite, (1:1 lattice type), saponite, vermiculite and smectite (smectite group 2:1 expanding type), mica and muscovite (Mica group 2:1 non-expanding type), chlorite (2:1:1 or 2:2 type) and talc etc. However, mica and kaolinite are the most dominant clay minerals in these soils than others.

The semi-quantitative estimation based on relative peak intensities of Mg-glycerol saturated clay observed in XRD pattern that, soils of Kalimpong hills farm are dominated by the silicate clay minerals like kaolinite at 7.8 Å, 4.41 Å, 4.31 Å, 4.13 Å and 3.59 Å whereas the presence of large amount of mica in the clay fraction can be well established from the presence of very strong peaks at 10.1 Å, 4.8 Å, 4.6 Å and 3.32 Å. The presence of the small peak at 27.0 Å alongwith its higher order at 22.0 Å, 16.6 Å, 14.3 Å, 12.4 Å, 12.0 Å, 4.8 Å and 4.6Å in the diffractograms also indicates the dominancy of mica-smectite regular, chlorite-smectite regular, chlorite and vermiculite in the clay fractions. Dominancy of these minerals can also be verified in the diffractograms of K and Mg saturated clay fractions.

Comprehensive reviews on the nature and distribution of clay minerals in Indian soils were published earlier [31; 32]. The methods of their identification and quantification were reviewed by Raman and Ghosh [33]. The detailed study on mineralogy of Indian soils was also carried out by various Indian workers [34; 35; 36; 37; 38].

Soils of Kalimpong hills and its surrounding areas have been included under brown forest soil group in the soil map of India [39]. Study of clay mineralogy of soils of Kalimpong hills and surrounding areas was first done by these workers [40; 12; 41]. While studying the mineralogy of sand silt and clay fraction of a pedon of soils of Darjeeling Himalayan region, Sahu and Ghosh [29] reported that the mica, kaolinite, gibbsite, chlorite and vermiculite was the dominating clay minerals in the Kalimpong hills with the weathering sequence of biotite (sand) – mica – vermiculite (silt) – vermiculite. They also reported that the Kaolinite in the clay fractions have originated from the weathering of the feldspars. Similar findings were also reported by Maurya *et al.* [28] in the high altitude soils of Darjeeling hills.

Table 5. List of clay minerals present in the RSRS farm.

Soil Depth (m)	**D spacings (Å)**	**Minerals**	**D spacings (Å)**	**Semi-quantitative Peak Area**
0.15-0.42	3.4	Mica	25.986	mica-smectite regular glycerol (27.0)
	4.1	Mica	21.551	mica-smectite regular glycerol (22.0)
	5.25	Mica	16.674	smectite glycerol
	6.2	Chlorite	14.255	Chlorite (14.3)
	7.0	Chlorite	12.628	smectite (12.4)
	7.75	Vermiculite	11.481	chlorite-smectite regular (12.0)
	8.75	Mica	10.117	Muscovite (10.1)
	9.5	Talc	9.3097	Talc (9.3)
	11.25	Kaolinite	7.8305	Kaolinite
	18.2	Mica	4.8744	vermiculite (4.8)
	19.2	Vermiculite	4.6227	vermiculite (4.6)
	20.2	Nacrite	4.3960	Nacrite (4.41)
	20.75	Saponite	4.2828	Saponite (4.31)
	21.6	Smectite	4.1142	Dickite/ Smectite (4.13)
	22.1	Phyllite	4.022	Phyllite (4.0)
	23.0	Muscovite	3.8668	-
	24.8	Chlorite	3.5066	Kaolinite (3.59; Smectite (3.58)
	26.8	Mica	3.3265	Mica (3.32)
	28.5	Chlorite	3.1319	Talc (3.12)

Table 6. List of clay minerals present in the RSRS Annexure farm.

Soil Depth (m)	D spacings (Å)	Minerals	D spacings (Å)	Semi-quantitative Peak Area
0.12-0.39	4.1	Mica/Smectite	21.551	-
	6.2	Chlorite	14.255	-
	8.75	Mica	10.117	-
	12.5	Kaolinite	7.0813	Kaolinite (7.15)
	18.2	Mica	4.8744	-
	19.2	Gibbsite	4.6209	vermiculite (4.6)
	21.0	Kaolinite	4.2303	Dickite (4.23)
	23.0	Muscovite	3.8668	-
	24.8	Chlorite	3.5908	Kaolinite (3.590; Smectite (3.58)
	26.8	Mica	3.3265	-
	28.5	Chlorite	3.1319	-

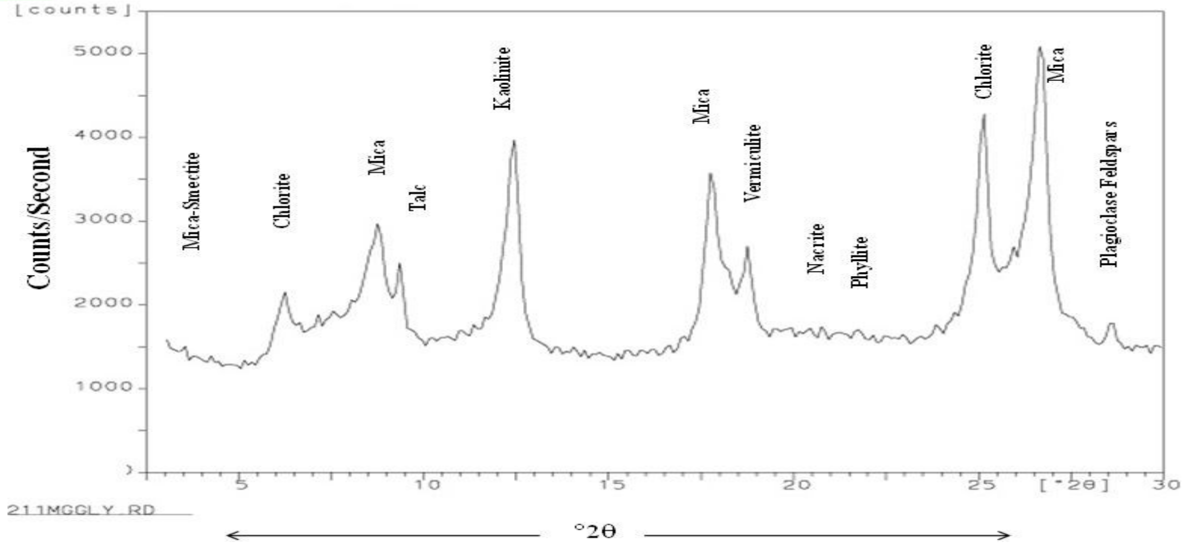

Fig. 1. X-ray diffraction (XRD) analysis of soils of RSRS, Kalimpong Farm.

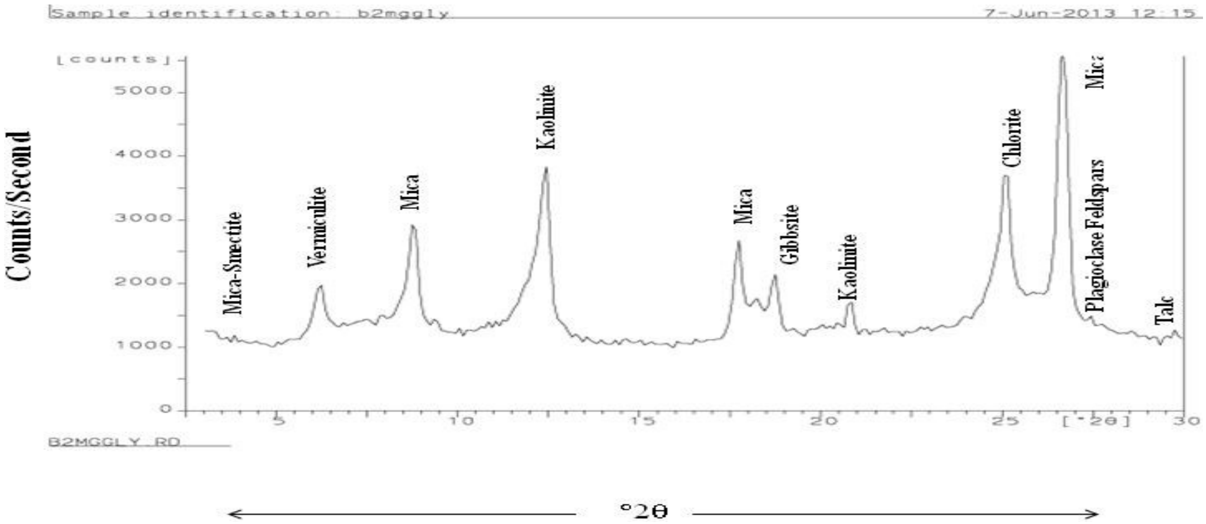

Fig. 2. X-ray diffraction (XRD) analysis of soils of RSRS, Annexure, Kalimpong Farm

3.4 *Soil Classification*

Based on morphology, physico-chemical properties and meteorological data, pedon 2, 3, 6 and 10 in soils of Kalimpong hills have been classified as Coarse loamy, mixed, Thermic, Typic Udarthents. It is may be due to soil depth, gravelliness and absence of diagnostic horizons other than ochric epipedon (Soil Survey Staff, 1998). Relief and time are the limiting soil forming factors for soil texture, depth and poor soil health. Likewise, pedon 4, 5,7,8,9 an 11 have ochric epipedon and cambic diagnostic sub-surface horizon and hence, grouped in order Inceptisols. Owing to 'udic' moisture regime, 'thermic' temperature regime, absence of duripan, calcic/ petrocalcic horizon within 100 cm from the mineral soil surface and less than 35% clay content, these soils grouped under 'Coarse loamy, Mixed, Thermic, Typic Hapludepts at family level.

IV. Conclusion

The characteristics, classification and mineralogical analysis of benchmark soils of Kalimpong hills, Darjeeling district of West Bengal under mulberry farming are shallow to very deep in depth, light coloured, light textured with weak, medium to fine, granular to subangular blocky structure. The pH of these soils are ranged from 4.2-6.7, EC 0.05-1.07 dSm^{-1}, organic carbon content 0.21-2.49% and CEC mean 7.2-16.9 cmol (p+) kg^{-1} respectively which varied from plot to plot and terrace to terrace. These soils are dominated by the silicate clay minerals like kaolinite (1:1 lattice type), mica, vermiculite and gibbsite (Mica group 2:1 type non-expanding minerals), chlorite (2:1:1 or 2:2 type clay minerals) and talc etc. However, kaolinite and mica are the most dominant clay minerals in soils than others. The soils of Kalimpong hills have been classified into Coarse loamy, mixed, Thermic, Typic Udarthents and Coarse loamy, Mixed, Thermic, Typic Hapludepts.

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