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Effect of long term terrace cultivation on nutrient availability and lime requirements in acid soils of Kalimpong hills under mulberry farming

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ABSTRACT

This study was undertaken in 2011-12 to assess the effect of long term terrace cultivation on nutrient availability and lime ($CaCO_3$) requirements in acid soils of Kalimpong hills under mulberry farming. Soil samples were collected from the mulberry field of Regional Sericultural Research Station (RSRS) farm, Regional Sericultural Research Station Annexure (RSRSA) farm and farmers field from eight different villages. The overall pH mean in the soils of RSRS farm and farmers field was 6.0 and 5.0 in RSRSA farm. The overall mean of OC content in the RSRS farm was 1.80% followed by 1.50% in farmers' field and 1.30% in the RSRSA farm. The available nutrients e.g. nitrogen (N) 474.1 kg ha^{-1}; phosphorus (P) 14.4 kg ha^{-1}; potassium (K) 164.7 kg ha^{-1} and sulphur (S) 9.6 kg ha^{-1} were present in the soils of RSRSA research farm, however, these nutrients were 586.4 kg ha^{-1} (N); 17.9 kg ha^{-1}(P); 183.6 kg ha^{-1}(K) and 15.3 kg ha^{-1} (S) in the soils of RSRS research farm and 590.5 kg ha^{-1}(N); 19.5 kg ha^{-1}(P); 284.6 kg ha^{-1} (K) and 12.7 kg ha^{-1} (S) in the progressive farmers' field. The overall mean of the $CaCO_3$ requirements for reclamation of RSRSA farm soil was 2.30 mt ha^{-1} followed by 1.50 mt ha^{-1} in RSRS farm and 1.16 mt ha^{-1} in the farmers' fields. These data revealed that, the long term terrace cultivation under mulberry farming in acid soils of entire Kalimpong hills, significantly affects the nutrients availability and lime requirements. The nutrients availability at RSRS research farm and farmers' field under long term terrace cultivation was quite high than RSRSA research farm.

Key words: Acid soils, Lime requirements, Mulberry, Nutrients availability, Terrace cultivation.

INTRODUCTION

Mulberry (Morus spp) is an economically and traditionally very important deciduous plant 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. Mulberry leaves are basic food material for silkworm *Bombyx mori* L. The nutritious leaves are the most important growth regulating factors for these silkworms, because, being a monophagous insect, they derive almost all the essential nutrients from the mulberry leaves for their survival. Hence, good quality of nutritious mulberry leaves should be fed in abundant quantity for the quality silkworm seed and cocoon production.

It is a well known fact that, sericulture is an agro based industry and soil management is a formidable challenge to insure the 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 to 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 (Karlen *et al.*, 1997).

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Kalimpong, a block of Darjeeling district (W.B.) is a hilly range of Sub-Himalayan Mountains and a sericulture hub for production of bivoltine silkworm seed cocoons in Eastern and North-eastern India. Being an important crops and backbone of sericulture industry, it was obligatory to assess the effect of long term terrace cultivation practices on nutrient availability and lime ($CaCO_3$) requirement for reclamation in soils of Kalimpong hills under mulberry farming.

MATERIALS AND METHODS

The assessment of the effect of long term terrace cultivation practices on nutrient availability and lime ($CaCO_3$) required for reclamation of soils of Kalimpong hills, Darjeeling district of West Bengal under mulberry farming was undertaken in the year 2011-12. Both surface soil samples and soils profiles were analyzed from Regional Sericultural Research Station (RSRS), Kalimpong research farm, Regional Sericultural Research Station Annexure (RSRSA), Kalimpong research farm and progressive sericulture farmers' field from eight different villages namely Kharka Busty, Bhalukhop Makaldhara, Makaldhara, Khani, Gitdabling, Saurani, Dolapchand and Sangsay of the Kalimpong hills. The cultural practices of mulberry farming or intercropping of agricultural crops with mulberry are practiced from the last 50 years in the RSRS, research farm and progressive farmers' field; however, from last 20 years, this kind of practices are going on at RSRSA research farm.

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, quartzite and mica are the major geologic formation in this area which act as parent materials for the formation of the soils of this area. River Teesta and its tributaries are the main water bodies. The climate is sub-tropical type (Sub-Himalayan region) where mean annual temperature is 21.0 °C, mean summer temperature (May, June and July) 24.6 °C and mean winter temperature (December, January and February) 15.2 °C (Fig. 1 and Fig. 2), respectively. The mean annual precipitation of this area was recorded 1876.3 mm, of which 90.3 percent occurs between June to September. Based on meteorological data, soil moisture regime has been grouped as 'Udic' and soil temperature regime as 'Thermic' respectively.

FIG 1: Temperature curves (2011-2012)

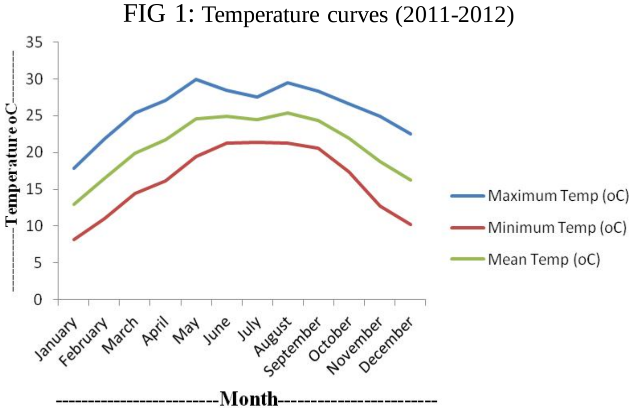
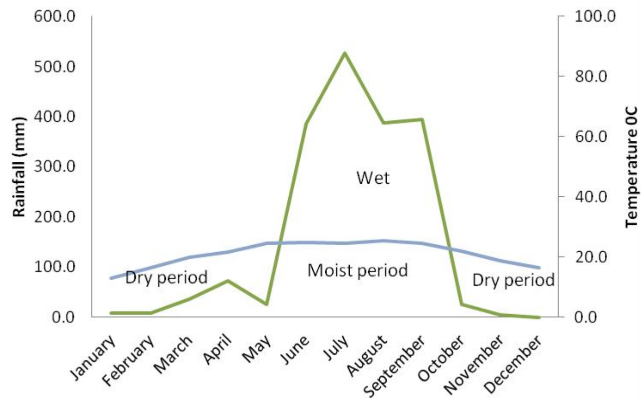


FIG 2: Ombrothermic diagram



Soil samples were collected, dried, sieved and analyzed by adopting the standard procedure (Black 1985; Jackson 1979). For available phosphorus analysis, Bray's (Bray's and Kurtz, 1945) method adopted for the soils having pH less the 5.5, however, the soils with above pH 5.5, Olsen's (Olsen *et al.,* -1954) method were adopted. For the study and interpretation of soils profile and soil classification was done as per the procedures of Soil Survey Manual (1970); Soil Survey Staff (1998; 2006).

RESULTS AND DISCUSSION

A. Morpho-physical characteristics of soils of Kalimpong hills: Morpho-physical properties of the soils of Kalimpong hills are given in Table 1. Based 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

TABLE 1: Morpho-physical characteristics of soils of Kalimpong hills

Horizon	Depth (m)	Colour (moist)	Sand	Silt	Clay	Texture	Structure	Consistence			Boundary	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: RSRSA, 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: Bhalukhop 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: Makaldhara							
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
					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

boundary. Sand, silt and clay percent in these areas ranged from 64-77%, 8-17% and 13-24% and classified as sandy loam to sandy clay loam. 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.

B. Chemical characteristics and nutrients availability of soils of Kalimpong hills

1. Regional Sericultural Research Station (RSRS), Kalimpong research farm: Chemical characteristics and nutrients availability of soils of RSRS, Kalimpong research farm are given in Table 2. Based on terrace wise soil samples analyzed from 11 plots of this research farm, the pH of the soils varied from 5.03 to 6.90 with mean range from 5.58 to 6.31. The overall mean of this farm was recorded as 6.0. While studying the terrace wise pH range, minimum pH 5.03 was recorded in some terraces of plot no.1 and maximum pH 6.90 in some terraces of plot no. 2. The EC of the farm ranged from 0.06 to 1.07 dSm with mean range from 0.08 to 0.30 dSm and overall mean 0.20 dSm. The minimum EC 0.06 dSm was recorded in some terraces of plot no.2 and 5 whereas maximum EC 1.07 dSm in some terraces of plot no. 2. The organic carbon content of the farm varied from 0.84 to 2.34% with mean range from 1.20 to 2.08% and overall mean of entire farm 1.80%. Likewise pH and EC, minimum OC content 0.84% was recorded in some terraces of plot no. 5 whereas maximum 2.34% in some terraces of plot no. 3. The terrace wise variation of nitrogen availability in this farm was quite high which ranged from 338.7 to 722.5 kg ha^{-1} with mean range from 453.5 to 710.0 kg ha^{-1} and overall mean 586.4 kg ha^{-1}. Minimum nitrogen availability was reported in the terraces of plot no. 3 and maximum in plot no. 9. Next to the nitrogen, phosphorus is equally important for the growth and development of the plants. Like, nitrogen, phosphorus availability in this farm also varied and ranged from 14.1 to 23.3 kg ha^{-1} with mean range from 15.5 to 19.1 kg ha^{-1} and overall mean 17.9 kg ha^{-1}. The terrace wise availability of potassium ranged from 112.0 to 291.2 kg ha^{-1} with mean range from 138.2 to 253.9 kg ha^{-1} and overall mean183.6 kg ha^{-1} whereas the available sulphur varied from 5.6 to 23.5 kg ha^{-1} with mean range from 11.3 to 20.5 kg ha^{-1} and overall mean 15.3 kg ha^{-1}. Likewise, pH, EC, OC, N and P, the availability of potassium and sulphur also varied significantly from plot to plot and terrace to terrace.

TABLE 2: Chemical characteristics and nutrients availability of soils of RSRS, Kalimpong Research farm.

PlotNo.	pH (1:2.5)		EC (dSm)		Organic C (%)		Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	5.03-6.41	6.14	0.09-1.02	0.30	1.23-2.25	1.89	466.6-602.1	536.2	14.3-17.9	15.5	179.2-291.2	220.3	15.7-23.5	20.5
2	5.90-6.90	6.31	0.06-1.07	0.26	1.44-2.19	1.79	564.5-700.0	620.9	18.1-20.2	19.1	112.0-268.8	212.8	10.1-22.4	15.9
3	5.84-6.25	6.01	0.08-0.09	0.08	1.38-2.34	1.75	338.7-534.4	453.5	14.6-17.9	17.6	112.0-179.2	141.9	5.6-15.7	11.3
4	5.95-6.51	6.14	0.08-0.21	0.12	1.29-2.28	1.78	414.0-629.7	469.6	15.7-21.3	18.6	112.0-179.2	153.1	12.3-23.0	17.1
5	5.57-6.46	5.95	0.06-0.27	0.13	0.84-1.41	1.20	481.7-504.3	504.3	14.1-17.9	17.3	112.0-179.2	138.2	5.6-15.7	10.6
6	5.50-6.33	6.01	0.10-0.18	0.12	1.14-1.86	1.57	519.3-564.5	536.9	14.6-22.9	18.7	145.6-246.4	182.9	13.4-22.4	17.6
7	5.95-6.25	6.11	0.19-0.28	0.24	1.56-1.89	1.68	526.8-700.0	692.4	14.6-17.9	16.2	179.2-246.4	141.9	9.0-15.7	12.3
8	5.70-6.40	6.01	0.10-0.19	0.12	1.68-1.77	1.73	632.2-677.4	654.8	15.2-23.3	18.8	145.6-291.2	216.5	13.4-22.4	17.2
9	5.54-6.33	5.99	0.07-0.15	0.10	1.92-2.10	2.01	692.4-722.5	710.0	15.2-18.1	17.1	212.8-291.2	253.9	14.6-23.5	17.9
10	5.42-5.70	5.58	0.08-0.10	0.10	1.74-2.19	1.97	639.7-662.3	647.3	15.7-22.9	18.7	134.4-179.2	160.5	12.3-14.6	13.1
11	5.70-6.08	5.90	0.10-0.15	0.12	1.83-2.22	2.08	526.8-700.0	624.7	15.8-23.1	18.9	145.6-224.0	197.9	11.2-17.9	14.9
Mean	6.01		0.15		1.77		586.42		17.86		183.63		15.31	
SD	0.18		0.08		0.24		89.76		1.21		39.28		3.14	
SEm(±)	0.06		0.02		0.07		27.06		0.37		11.84		0.95	

2. Regional Sericultural Research Station Annexure (RSRSA), Kalimpong research farm: Details of the data of 5 plots of Regional Sericultural Research Station Annexure (RSRSA), Kalimpong research farm are given in Table 3. The pH of the soils of this farm ranged from 4.20 to 6.50 with mean range from 4.65 to 5.50 and the overall pH mean of the farm was recorded as 5.0. While studying the terrace wise pH range, minimum pH 4.20 was recorded in some terraces of plot no.4 and maximum pH 6.50 in some terraces of plot no. 1. The EC of the farm ranged from 0.05 to 0.40 dSm with mean range from 0.06 to 0.14 dSm and overall mean 0.10 dSm. The minimum EC as reported above was recorded in some terraces of plot no.2 and 3 and maximum in some terraces of plot no. 1. The organic carbon content of this farm varied from 0.36 to 1.98% with mean range from 1.17 to 1.58% and overall mean of entire farm 1.30%. Minimum 0.36 % OC content was recorded in plot no. 5 and maximum 1.98% in plot no. 1. Likewise, RSRS research farm, the terrace wise variation of nitrogen availability in this farm was also quite high which ranged from 353.7 to 654.8 kg ha^{-1} with mean range from 422.7 to 553.1 kg ha^{-1} and overall mean 474.1 kg ha^{-1}. Minimum nitrogen availability 353.7 kg ha^{-1} was reported in the terraces of plot no. 3 and maximum 654.8 kg ha^{-1} in plot no. 1. The phosphorus and potassium availability in this farm also varied which ranged from 9.4 to 19.0 kg ha^{-1} and 112.0 to 313.6 kg ha^{-1} with mean range from 14.0 to15.6 kg ha^{-1} and 135.5 to 201.6 kg ha^{-1} respectively. The overall mean of phosphorus and potassium of this farm was 14.4 kg ha^{-1} and 164.7 kg ha^{-1}. The minimum availability of phosphorus was reported in plot no. 5 and maximum in plot no. 4 whereas minimum availability of potassium was in plot no. 2 and maximum in plot no. 3 respectively. The available sulphur ranged from 5.6 to 20.2 kg ha^{-1} with mean range from 7.6 to 14.6 kg ha^{-1} and overall mean 9.6 kg ha^{-1}.

3. Progressive farmers' field: Details of the analytical data of the 16 progressive farmers' field from 8 sericulture villages of Kalimpong hills are given in Table 4. The pH of the soils of the progressive farmers' field ranged from 5.10 to 6.73 with mean range from 5.70 to 6.53 and the overall mean of the farmers' field was recorded as 6.0. While studying the terrace wise pH range, minimum pH 5.10 as stated above was recorded in terraces of progressive farmers' field of Sangsay village and maximum pH 6.73 in terraces of the

TABLE 3: Chemical characteristics and nutrients availability of soils of RSRSA, Kalimpong research farm

PlotNo.	pH (1:2.5)		EC (dSm)		Organic C (%)		Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	4.50-6.50	5.50	0.09-0.40	0.13	0.54-1.98	1.28	398.8-654.8	479.0	14.6-17.9	15.6	168.0-257.6	201.6	7.8-13.4	8.5
2	4.30-5.30	4.74	0.05-0.10	0.06	0.51-1.80	1.32	429.0-609.6	553.1	11.7-18.4	14.0	112.0-235.2	148.4	6.7-13.4	8.7
3	4.30-5.60	4.75	0.05-0.28	0.12	0.54-1.8	1.27	353.7-639.7	476.9	11.2-17.9	14.1	112.0-313.6	187.7	9.0-15.7	8.6
4	4.20-5.40	4.65	0.06-0.18	0.14	1.20-1.90	1.58	413.9-479.2	439.0	10.1-19.0	14.1	128.8-257.6	135.5	5.6-20.2	14.6
5	4.50-5.80	5.12	0.08-0.13	0.06	0.36-1.68	1.17	398.9-451.6	422.7	9.4-17.9	14.3	123.2-224.0	150.4	6.7-10.1	7.6
Mean	4.952		0.102		1.324		474.14		14.42		164.72		9.6	
SD	0.36		0.04		0.15		50.37		0.67		28.34		2.83	
SEm(±)	0.16		0.02		0.07		22.52		0.30		12.68		1.27	

farmers' field of Bhalukhop Makaldhara village. The EC of the farmers' field ranged from 0.05 to 0.34 dSm with mean range from 0.09 to 0.20 dSm and overall mean 0.10 dSm. The minimum EC as reported above was recorded in the farmers' field of Makaldhara and maximum in Kharka busty village. The organic carbon content within the progressive farmers' field ranged from 0.21 to 2.49% with mean range from 0.80 to 1.94% and overall mean of entire farmers' field was 1.50%. Minimum 0.21 % OC content was recorded in farmers' field of Khani village and maximum 2.49% in Kharka busty village.

The nitrogen, phosphorus, potassium and sulphur availability within the progressive farmers' field was similar to the RSRS and RSRSA research farms, which varied from terrace to terrace and plot to plot in every village. The nitrogen availability within the farmers' field ranged from 316.1 to 730.1 kg ha^{-1} with mean range from 432.8 to 675.1 kg ha^{-1} and overall mean 590.5 kg ha^{-1}. Minimum nitrogen availability 316.1 kg ha^{-1} was reported in the farmers' field of Khani village and maximum 730.1 kg ha^{-1} in Bhalukhop Makaldhara village. Phosphorus availability in the farmers' field ranged from 12.3 to 26.0 kg ha^{-1} with mean range from 15.0 to 23.5 kg ha^{-1} and the overall mean was 19.5 kg ha^{-1}. The minimum availability of phosphorus was reported in Khani village and maximum in Kharka busty and Bhalukhop Makaldhara village. The available potassium among the farmers' field ranged from 123.2 to 425.6 kg ha^{-1} with mean range from 210.0 to 372.4 kg ha^{-1} and overall mean 284.6 kg ha^{-1} whereas the available sulphur ranged from 6.7 to 21.3 kg ha^{-1} with mean range from 10.4-15.4 kg ha^{-1} and overall mean was 12.7 kg ha^{-1}.

C. Exchangeable bases and lime requirements (LR) in soils of kalimpong hills

1. RSRS, Kalimpong farm: Analytical data of exchangeable bases and lime ($CaCO_3$) required to reclaim the soils of RSRS, Kalimpong research farm is given in Table 5. The exchangeable Ca in the soils of RSRS research farm ranged from 2.6 to 4.4 cmol (p$^+$) kg^{-1} and overall mean was 3.6 cmol (p$^+$) kg^{-1}; whereas, the exchangeable Mg ranged from 0.8 to 3.1 cmol (p$^+$) kg^{-1} with overall mean 2.1 cmol (p$^+$) kg^{-1}. Likewise, exchangeable Na ranged from 0.6 to 2.1 cmol (p$^+$) kg^{-1} with overall mean 1.3 cmol (p$^+$) kg^{-1} and exchangeable K ranged from 0.31 to 0.60 cmol (p$^+$) kg^{-1} with overall mean 0.48 cmol (p$^+$) kg^{-1} respectively. The variation of

TABLE 4: Chemical characteristics and nutrients availability of soils of progressive farmers' field

PlotNo.	pH (1:2.5)		EC (dSm)		Organic C (%)		Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Kharka Busty	6.08-6.67	6.31	0.07-0.34	0.18	1.29-2.49	1.94	587.1-700.0	643.5	20.2-26.0	23.5	123.2-257.6	210.0	6.7-13.4	10.4
Bhalukhop Makaldhara	6.23-6.73	6.53	0.06-0.16	0.11	1.74-2.19	1.92	617.2-730.1	675.1	17.9-26.0	21.3	123.2-302.4	252.0	6.7-21.3	13.6
Makaldhara	5.40-6.34	5.88	0.05-0.13	0.09	0.90-1.29	1.53	474.2-579.5	562.6	15.7-19.0	16.9	369.6-425.6	333.2	6.7-12.3	10.7
Khani	5.90-6.00	5.90	0.10-0.12	0.10	0.21-0.39	0.80	316.1-376.3	432.8	12.3-15.7	15.0	179.2-224.0	280.0	14.6-16.8	12.0
Gitdabling	5.22-6.14	5.70	0.06-0.14	0.10	0.78-0.84	1.50	587.1-632.2	617.8	15.2-22.9	17.9	212.8-224.8	294.0	9.0-12.3	12.7
Saurani	5.97-6.21	5.90	0.12-0.14	0.20	1.32-1.65	1.80	481.7-595.6	590.9	22.6-25.7	23.1	358.4-380.8	372.4	11.2-12.3	14.9
Dolapchand	5.53-5.93	5.90	0.07-0.09	0.20	1.50-1.89	1.30	579.5-677.4	532.5	17.9-20.2	21.3	224.0-347.2	319.2	6.7-14.6	12.6
Sangsay	5.10-6.39	5.80	0.06-0.19	0.16	1.08-1.89	1.60	526.8-700.0	668.6	14.6-19.3	17.2	201.6-224.0	215.6	12.3-13.4	15.4
Mean	5.99		0.14		1.55		590.48		19.53		284.55		12.79	
SD	0.28		0.05		0.37		80.91		3.17		57.03		1.80	
SEm(±)	0.10		0.02		0.13		28.61		1.12		20.16		0.64	

exchangeable bases among the terraces of this research farm was almost in the irregular trend in the order: $Ca^{2+} \geq Mg^{2+} > Na^{+} \geq K^{+}$. The cation exchange capacity in this farm varied from 9.9 to 16.9 cmol (p^+) kg^{-1}, with overall mean 13.6 cmol (p^+) kg^{-1}, whereas the exchangeable sodium percent (ESP) and base saturation (BS) ranged from 6.1 to 12.4% with overall mean 9.3% and 52.0 to 58.0% with overall mean 54.8%, respectively. While calculating the doses of LR based on the base saturation method for reclamation of the RSRS farm soil, the lime ($CaCO_3$) requirement (LR) of this research farm varied from plot to plot, ranging from 0.7 to 1.7 mt ha^{-1} with overall mean 1.5 mt ha^{-1} to raise the base saturation level to 60% from the initial base saturation level.

Exchangeable bases and LR in soils of RSRSA, Kalimpong farm

2. RSRSA, Kalimpong research farm: Analytical data of the exchangeable bases and lime ($CaCO_3$) required to reclaim the soils of RSRSA research farm is given in Table 6. The exchangeable Ca in this research farm ranged from 1.5 to 2.1 cmol (p^+) kg^{-1} and overall mean was 1.7 cmol (p^+) kg^{-1}; whereas, the exchangeable Mg ranged from 0.7 to 1.1 cmol (p^+) kg^{-1} with overall mean 0.9 cmol (p^+) kg^{-1}. Likewise, exchangeable Na ranged from 0.6 to 1.1 cmol (p^+) kg^{-1} with overall mean 0.7 cmol (p^+) kg^{-1} and exchangeable K ranged from 0.36 to 0.46 cmol (p^+) kg^{-1} with overall mean 0.40 cmol (p^+) kg^{-1} respectively. The variation of exchangeable bases among the terraces of this research farm was almost similar to RSRS, Kalimpong research farm, but these bases were quite low while comparing with RSRS research farm. The cation exchange capacity (CEC) in this farm varied from 7.2 to 8.8 cmol (p+) kg^{-1}, with overall mean 8.0 cmol (p^+) kg^{-1}, whereas the exchangeable sodium percent (ESP) and base saturation (BS) ranged from 7.1 to 12.5% with overall mean 9.2% and 45.1 to 48.4% with overall mean 46.6% respectively. While calculating the doses of LR based on the base saturation method for reclamation, the lime ($CaCO_3$) requirement of this research farm also varied like RSRS, Kalimpong research farm. Lime requirement of this research farm ranged from 2.2 to 2.6 mt ha^{-1} and overall mean 2.3 mt ha^{-1} to raise the base saturation level to 60% from the initial base saturation level.

TABLE 5: Exchangeable bases and LR in soils of RSRS, Kalimpong research farm

Plot No.	Exchangeable bases mean [cmol (p+) kg^{-1}]						ESP (%)	Initial BS (%)	LR (mt ha-1) @ 60% BS
	Ca	Mg	Na	K	Sum	CEC			
1	2.6	1.7	1.2	0.47	5.97	11.1	10.8	53.8	1.5
2	4.2	2.9	2.1	0.60	9.80	16.9	12.4	58.0	0.7
3	3.7	2.1	1.4	0.55	7.75	14.2	9.9	54.6	1.7
4	4.0	3.1	1.7	0.33	9.13	16.4	10.4	55.7	1.6
5	3.4	1.6	0.9	0.31	6.21	11.6	7.8	53.5	1.7
6	3.7	2.2	0.9	0.55	7.35	13.5	6.7	54.4	1.7
7	3.1	2.7	1.2	0.62	7.62	13.8	8.7	55.2	1.5
8	3.3	1.8	1.3	0.50	6.90	12.6	10.3	54.8	1.5
9	4.4	2.4	1.8	0.53	9.13	16.4	11.0	55.7	1.6
10	3.4	0.8	0.6	0.35	5.15	9.9	6.1	52.0	1.7
11	3.6	2.2	1.2	0.46	7.46	13.6	8.8	54.9	1.5
Mean	3.58	2.14	1.30	0.48	7.50	13.64	9.35	54.78	1.52
SD	0.51	0.65	0.44	0.11	1.43	2.28	1.93	1.51	0.29
SEm(±)	0.15	0.20	0.13	0.03	0.43	0.69	0.58	0.45	0.09

TABLE 6: Exchangeable bases and LR in soils of RSRSA, Kalimpong research farm

Plot No.	Exchangeable bases mean [cmol (p+) kg-1]						ESP (%)	Initial BS (%)	LR (mt ha^{-1}) @ 60% BS
	Ca	Mg	Na	K	Sum	CEC			
1	1.9	0.8	1.1	0.46	4.26	8.8	12.5	48.4	2.2
2	1.4	1.1	0.7	0.36	3.56	7.9	8.9	45.1	2.6
3	1.5	1.0	0.7	0.40	3.60	7.8	9.0	46.2	2.4
4	1.6	0.7	0.6	0.40	3.30	7.2	8.3	45.8	2.2
5	2.1	0.9	0.6	0.40	4.00	8.4	7.1	47.6	2.3
Mean	1.7	0.9	0.74	0.40	3.744	8.02	9.16	46.62	2.34
SD	0.29	0.16	0.21	0.04	0.38	0.61	2.01	1.35	0.17
SEm(±)	0.13	0.07	0.09	0.02	0.17	0.27	0.90	0.60	0.07

Exchangeable bases and LR in soils of progressive farmers' field

3. Progressive farmers' field: Analytical data of the exchangeable bases and lime ($CaCO_3$) required to reclaim the soils of the progressive farmers' field is given in Table 7. The exchangeable Ca in progressive farmers' field ranged from 2.1 to 4.0 cmol (p^+) kg^{-1} and overall mean was 2.9 cmol (p^+) kg^{-1}; whereas, the exchangeable Mg ranged from 0.8 to 2.8 cmol (p^+) kg^{-1} with overall mean 1.7 cmol (p^+) kg^{-1}. Likewise, exchangeable Na ranged from 0.9 to 1.8 cmol (p^+) kg^{-1} with overall mean 1.4 cmol (p^+) kg^{-1} and exchangeable K ranged from 0.38 to 0.72 cmol (p^+) kg^{-1} with overall mean 0.53 cmol (p^+) kg^{-1} respectively. The variation of exchangeable bases among the farmers' field was almost similar to the RSRS research farm, but these bases were quite high while comparing with RSRSA research farm. The cation exchange capacity in progressive farmers field varied from 9.2 to 15.4 cmol (p+) kg^{-1}, with overall mean 11.9 cmol (p^+) kg^{-1}, whereas the exchangeable sodium percent (ESP) and base saturation (BS) ranged from 9.3 to 13.2% with overall mean 11.3% and 53.1 to 58.3% with overall mean 55.3% respectively. While calculating the doses of LR based on the base saturation method, the lime ($CaCO_3$) requirement of the farmers' field ranged from 0.55 to 1.45 mt ha^{-1} and overall mean was 1.16 mt ha^{-1} to raise the base saturation level to 60% from the initial base saturation level.

D. Effect of long term terrace cultivation on nutrient status and LR in soils of kalimpog hills: Mulberry farming or intercropping of agricultural crops with mulberry was practiced since 50 years back in the RSRS, research farm and progressive farmers' field; however, from last 20 years, this kind of practices were going on at RSRSA research farm and continuing. While studying the effect long term terrace cultivation on nutrient availability and LR, it was found that, the nutrients availability in the soils of RSRSA research farm was quite low as compare with the RSRS research farm and progressive farmers' field. Similarly, the LR in the RSRSA research farm soils was also very high. The overall mean of the pH of the soils of RSRSA farm was 5.0 whereas it was 6.0 in the RSRS research farm and progressive farmers' field. The EC among these farms were almost similar whereas the overall mean of OC in the RSRSA farm was 1.3% followed by 1.8% in RSRS research farm and 1.5% in the farmers' field. Likewise, available NPK and S in the soils of RSRSA farm was very low as compare to the rest of the site. The overall mean of the available nutrients e.g. nitrogen 474.1 kg ha^{-1}; phosphorus 14.4 kg ha^{-1}; potassium 164.7 kg ha^{-1} and sulphur 9.6 kg ha^{-1} respectively was in the soils of RSRSA research farm, however, these nutrients were 586.4 kg ha^{-1} (N); 17.9 kg ha^{-1}(P); 183.6 kg ha^{-1}(K) and 15.3 kg ha^{-1} (S) in the soils of RSRS research farm and 590.5 kg ha^{-1}(N); 19.5 kg ha^{-1}(P); 284.6 kg ha^{-1} (K) and 12.7 kg ha^{-1} (S) in the progressive farmers' field. The overall mean of the $CaCO_3$ requirements for reclamation of RSRSA farm soil was 2.30 mt ha^{-1} followed by 1.50 mt ha^{-1} in RSRS farm and 1.16 mt ha^{-1} in the farmers' fields. The comparative statements of the overall mean of the available nutrients and LR ($CaCO_3$) in the soils of RSRS research farm, RSRSA research farm and progressive farmers' field are given in Table 8.

A. Morpho-physical characteristies of soils of Kalimpong hills: While studying the morpho-physical properties of the soils of the Kalimpong hills, it was found that, there was no much morpho-physical variation this soil. However, the

TABLE 7: Exchangeable bases and LR in soils of progressive farmers' field

Village's Name	Exchangeable bases mean [cmol (p+) kg-1]						ESP (%)	BS (%)	LR (mt ha^{-1}) @ 60% BS
	Ca	Mg	Na	K	Sum	CEC			
Kharka Busty	4	2.8	1.8	0.38	8.98	15.4	11.6	58.3	0.60
Bhalukhop	3.1	2.5	1.8	0.51	7.91	13.6	13.2	58.2	0.55
Makaldara									
Makaldhara	2.6	0.8	1.3	0.65	5.35	10.0	13.0	53.5	1.40
Khani	2.5	1	0.9	0.48	4.88	9.2	9.3	53.1	1.35
Gitdabling	3.4	1.5	1.3	0.52	6.72	12.2	10.1	55.1	1.30
Saurani	2.1	1.7	1.2	0.72	5.72	10.6	11.3	54.0	1.45
Dolapchand	2.5	1.9	1.3	0.57	6.27	11.4	11.0	55.0	1.25
Sangsay	3.3	2	1.4	0.41	7.11	12.9	11.0	55.1	1.40
Mean	2.94	1.78	1.38	0.53	6.62	11.91	11.31	55.29	1.16
SD	0.62	0.68	0.30	0.11	1.37	2.04	1.32	1.98	0.37
SEm($\pm$)	0.22	0.24	0.11	0.04	0.48	0.72	0.47	0.70	0.13

variation in soil depth was due to nature of terrace, rocky phase, sloppy land developed on hill side and soil erosion etc., whereas the light texture was due to sandstone, quartzite and other light textured secondary rocks acted as parent material for the formation of this soil. Poor soil structure and low consistency was due to light soil texture. The clay content increased in the lower horizons of pedon 7 was due to migration/ illuviation pedogenic processes, but, 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 terrace size.

The variation of colour was due to prevalence of well drained conditions, admixture of organic matter (Ram *et al.,* 2013; Swarnam *et al.,* 2004; Rao *et al.,* 2008) whereas the variation in soil texture was caused by slope, terrace and translocation or illuviation of clay in lower horizons. (Nayak *et al.,* 2002). The variation in soil structure and consistency was due to variation in clay content of pedons (Rao *et al.*, 2008; Singh and Agrawal 2003). The high clay content in lower horizons in few soil profiles was due to illuviation or vertical migration of clay (Ram *et al.,* 2013; Ram *et al.,* 2010; Rao *et al.,* 2008; Hegde *et al.,* 2008; Taha and Nanda, 2003; Sarkar *et al.,* 2002). 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 (Ray and Mukhopadhyay, 2012; Singh *et al.,* 2011; Maurya *et al.*, 2005; Sahu and Ghosh, 1982). 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 (www.sikkimagrisnet.org).

B. Chemical characteristics and nutrients availability of soils of Kalimpong hills: While comparing the nutrients availability among the research farms and farmers' fields, it was observed that, the pH of the soils of RSRSA farm was quite low and grouped under strong to moderate acidic whereas it was almost equal in the soils of RSRS research farm and progressive farmers' field and grouped under moderate acidity. Likewise, the OC content in the soils of RSRSA farm was also quite low than RSRS research farm and progressive farmers' field. Beside, the OC content also varied highly from terrace to terrace and plot to plot and its availability significantly correlated with the soil pH. In general, soils of Kalimpong hills have medium to high organic carbon content except farmers' field of Khani village and few terraces of RSRSA research farm. The acidic condition and variation in the availability of OC content within the soils of Kalimpong hills might be due to cultural practices, slope, nature of terrace, soil pH, leaf litter and application of manures, fertilizers and lime etc.

Nitrogen is an essential macronutrient needed by all plants to thrive. The availability of nitrogen in entire Kalimpong hills is highly variable. Considering the range <272 kg ha^{-1} 'low', 272-544 kg ha^{-1} 'medium' and >544 kg ha^{-1} 'high' (Baruah and Barthakur, 1997), the soils of both research farms and farmers' fields have medium to high available nitrogen content, which highly differ from plot to plot and terrace to terrace. Very high nitrogen content was also recorded in few terraces of farms and farmers' field, among them most of the terraces were fallow. High nitrogen content might be due to forest leaf litter, application of farm yard manures and seri compost, which helps to improve the physical, chemical and microbial properties of soils.

Next to nitrogen, phosphorus is very important essential nutrients for plant growth and is found in every living plant cell. Considering the range <22.5 kg ha^{-1} 'low', 22.5-56.0 kg ha^{-1} 'medium' and >56.0 kg ha^{-1} 'high' (Baruah and Barthakur, 1997) for available phosphorus (P_2O_5), the soils of both research farms and farmers' field have low to medium available phosphorus content, which significantly varied from plot to plot and terrace to terrace. The availability of phosphorus were significantly correlates with soil pH, slope

TABLE 8: Comparative statements of the overall mean of available nutrients status and LR ($CaCO_3$) in the soils of RSRS research farm, RSRSA research farm and progressive farmers' field

Location	pH (1:2.5)	EC (dSm)	OC (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulphur (kg ha^{-1})	LR (mt ha^{-1}) @ 60% BS
RSRS farm	6.0	0.20	1.8	586.4	17.9	183.6	15.3	1.50
RSRSA farm	5.0	0.10	1.3	474.1	14.4	164.7	9.6	2.30
Farmers' Field	6.0	0.10	1.5	590.5	19.5	284.6	12.7	1.16

and size of terraces, hence, soils of RSRSA found highly deficient of phosphorus followed by RSRS farm and farmers' field.

Potassium is third essential macronutrients. Like nitrogen, potassium is absorbed by plants in significantly larger quantities than any other nutrient. Considering the range <136.0 kg ha^{-1} 'low', 136.0-338.0 kg ha^{-1} 'medium' and >338.0 kg ha^{-1} 'high' (Baruah and Barthakur, 1997), the soils of the both research farms and farmers' fields have low to medium available potassium content, which significantly varied from plot to plot and terrace to terrace. The availability of potassium was significantly correlates with slope and size of terraces etc. and its mean range almost similar among entire area. Sulphur is also one of the essential secondary plant nutrients. Considering the range <22.4 kg ha^{-1} 'low', (Baruah and Barthakur, 1997), the soils of RSRS farms and farmers' fields have low available sulphur content, which significantly varied from plot to plot and terrace to terrace. The availability of sulphur was significantly correlates soil pH, slope and size of terraces etc. In general, soils of RSRSA farm found low available sulphur content followed by RSRS farm and farmers' field.

Various workers of the country have reported that the leaching of bases, intensive weathering and sloping landforms was major factors in the variation of pH with depths (Ram *et al.,* 2013; Ram *et al.,* 2010; Nayak *et al.,* 2002; Patagundi *et al.,* 1996, Bhadrapur and Seshagiri Rao, 1979). Brady and Weil, (1999) defined, soil organic matter as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances, whereas, Woomer *et al.,* (1994) opined that, the OC regulates the soil properties. Albrecht *et al.,* (1997) also stated that, the soil pH, cultural practices and application of manures and fertilizers have had long term effects on soil organic matter by breaking up the organic residues which helps to stimulate the microbial activity and increasing soil organic matter decomposition. He further described that the fertilizer applications can also result in an increase in soil organic matter levels due to greater yields creating a larger return of crop residues to the soil.

The combined application of organic manures and inorganic fertilizers increased the organic carbon content in Darjeeling tea soils over the initial values (Singh *et al.,* 2011; Hegde, 1996). Maurya *et al.,* (2005) reported that the soils of higher altitude of Darjeeling hills contain medium to high available N and P content which ranged from 445 to 829 kg ha^{-1} and 12.3 to 37.2 kg ha^{-1} respectively. Banerjee *et al.,* (1985) studied the chemical properties of forest soils of Kalimpong hills and he reported that the, maximum organic carbon and cation exchange capacity were found under B. populanea plant but pH and total exchangeable bases were minimum.

C. Exchangeable bases and LR in the soils of Kalimpong hills: The exchangeable bases and 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 RSRSA research farm found low exchangeable bases and CEC as compared to RSRS research farm and farmers' field. Mondal *et al.,* (2002) reported that the soils of Tarai region of West Bengal are acidic with high organic carbon and medium to high nutrients contents and exchangeable bases. Their result also correlates with the findings. LR of the RSRSA research farm was quite high than RSRS research farm and progressive farmers' field. Liming is an effective and dominant practice to raise soil pH and reduce acidity related constraints to improve crop yields (Fageria and Baligar, 2008). The quantity of lime required depends on the soil type, quality of liming material, costs and crop species or cultivars (Fageria and Baligar, 2008). Patiram (1994) also reported that the furrow application of small doses of limestone every year achieved optimum productivity than a relatively higher dose once in three to four years.

D. Effect of long term terrace cultivation on nutrient status and LR in soils of kalimpong hills: It is cleared from the data that, the long term cultivation practices under mulberry farming in acid soils of entire Kalimpong hills, significantly affects the nutrients availability and LR. These nutrients availability under long term cultivation was quite high than short term cultivation or fallow lands. The LR under long term terrace cultivation in the RSRS research farm and farmers' field was low as compared with RSRSA research farm. High LR in RSRSA farm was due to low soil pH . The terraces in the Kalimpong hills were bench terraces type by a series of nearly level to very gently sloping strips constructed on or near the contour. These terraces were supported by a barrier of stones or rocks by cutting and filling. The size and shape of these terraces were not in similar type. Their width and length were varied according to slope and rocky phase. Based on the terrace wise data analyzed, it was found that, the chemical characteristics and nutrients availability within the same plots were highly variable. They differ according to their shape, size, slope and position. Generally, the chemical characteristics and nutrients availability in terraces with 3-4 m width were very less as compare with the terraces with more than 4 m width. Besides, slopes also affected the nutrients availability. The various agencies across the world also opined that, the availability of these nutrients in the soils was significantly affected by the shape, size and slope of the terraces, surface runoff and water erosion (USDA, 1980; AAFC, 1999; FAO, 2000).

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