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FERTILITY STATUS OF SOME FORESTED SOILS OF CHITTAGONG HILL TRACTS, BANGLADESH

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Abstract-* *The study was conducted in forested soils of three hilly districts of Chittagong Hill Tracts (CHT), Bangladesh to evaluate their fertility status. There were 17 sites; each site was an individual hill with variable slopes, elevation and forest type. A total number of 102 soil samples were collected from surface & subsurface from three positions of each hill i.e. hill top, mid-slope and foot hill and analyzed for various physical, chemical and nutritional properties. There were four forest tree species such as teak (Tectona grandis), gamar (Gmelina arborea), jarul (Lagerstroemia speciosa) and mahagony (Swietenia mahagony) species planted in different sites. The results showed that soil organic carbon, cation exchange capacity, exchangeable magnesium, and total nitrogen differed among the sites due to the variation in slope, elevation, aspect, texture, moisture & temperature regimes and clay content. The contents of organic matter, total nitrogen, available phosphorus and available potassium also varied due to the variation in land use. Soil pH varied within a narrow range between 5.1 and 5.7. But variation in organic matter content of these forested hilly soils was considerable between 1.0 and 2.44 percent. The soils were categorized into low and medium categories. The ranges of total N, and available P, K, Ca and Mg were 0.05% to 0.18%, 1.38 mg kg^{-1} to 7.32 mg kg^{-1}, 62 mg kg^{-1} to 206 mg kg^{-1}, 279 mg kg^{-1} to 928 mg kg^{-1} and 74 mg kg^{-1} to 371 mg kg^{-1} respectively. Teak sites were considerably more severely eroded. Teak should be selected in some valley sites where the soils are deep, fertile and well drained. It should not be planted in steep slopes susceptible to erosion.

Keywords - Forest soil, Bangladesh, fertility, Chittagong, Hill Tracts,

I. INTRODUCTION

Bangladesh has a total land area of 147,570 km² including 17,342 km² hilly areas. Chittagong Hill Tracts (CHT) is the only wide-ranging hilly area in the southeastern part of the country which occurs between 21° 25' N and 23° 45' N latitude and 91° 54' E to 92° 50' E longitude (MOCHTA 2011). The hills range in height from several meters to 1,000 meter above the mean sea level and are steep to very steep sloped having a rather youthful soil mantle ranging from a few centimeters to several meters in thickness over bedrocks. The soils of Hill Tracts are mainly yellowish brown to reddish brown loams which grade into broken shale or sandstone as well as mottled sand at a variable depth.

The region was covered by humid tropical rainforests with rich and diverse flora and fauna just some decades ago. Due to increased human population pressure the area has largely been deforested. The main causes of forest disturbance and deforestation in Bangladesh are encroachment (ADB 2002, Ali 2003, Rasul *et al.*. 2004, PCB 2005), illegal logging and fuel wood collection (Rasheed 1995, ADB 2002), grazing, fire, uncontrolled and wasteful commercial logging (Khan 2001), internal armed conflict (FAO 2005) and unplanned development activities (ADB 1998, Ahamed 1998). Tribal people and their way of life i.e. shifting cultivation are often considered responsible for forest degradation (Salam *et al.*. 1999). Some government development activities also had detrimental effects on the forests (Ahamed 1998). The impact of high intensity rainfall (>3000 mm in some years) followed by run-off over steep and very steep slopes results in tremendous soil erosion in many parts of Chittagong Hill Tracts. Land degradation has become a common phenomenon in the hilly and undulated areas of Bangladesh (Khisha 1982) like degradation of natural resources in many parts of the world, particularly in developing countries where vast majority of the rural people depend largely on these resources for sustenance (FAO 1999).

Most areas of CHT have now been degraded and converted to denuded hills. Some lands have been artificially regenerated replacing the natural forests of the region by high value timber species like teak in the past, and recently by fast growing indigenous gamar and exotic tree species Acacia and Eucalyptus. The wide variability in parent materials, topography and vegetation should bring about variation in fertility status of these highly disturbed soils which has not been sufficiently investigated in the past.

Therefore, the study was conducted in forested soils of three hilly districts of Chittagong Hill Tracts (CHT), Bangladesh to evaluate their fertility status.

II. MATERIALS AND METHODS

Study sites

Site characteristics are summarized in table 1. There were 10 sites in Rangamati (sites 1 to 10), 3 sites in Bandarban (sites 11 to 13) and 4 sites in Khagrachari districts (sites 14 to 17). The names of the sites were actually the names of villages where the hills were located. There were 8 sites (sites 1, 6, 7, 10, 11, 12, 14, 17) planted with teak (*Tectona grandis*), 5 sites (site 2, 3, 13, 15, 16) planted with gamar (*Gmelina arborea*), 3 sites (sites 4, 5, 8) with jarul (*Lagerstroemia speciosa*) and 1 site (site 9) planted with mahagoni (Swietenia *mahagoni*). Latitude varied from 22°

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12’ 102” N to 23° 05’ 152” N and longitude from 91° 57’ 323” E to 92° 15’ 606” E. The elevation ranged from 13 to 294 m above mean sea level. The area enjoys a tropical monsoon climate, the rainfall varies from 2500 to 3500 mm, mainly concentrating in May to August. Temperature generally varies from 10 to 30°C. The parent materials of the soils belong to tertiary sediments to sandstones, occasionally shales or shale fragments. The weathering is intense with high oxidation, leaching and surface runoff. The soils are predominantly coarse textured with sporadic distribution of fine textured clay soils.

Soil sampling and analysis

Soil Sampling was done from 17 sites listed in Table 1, each site being an individual hill. Soil samples were collected from there sampling spots in each site: hill top, mid hill and foot hill and from two depths of soil: 0-15 cm and 15-30 cm. There were 102 soil samples. Latitude and longitude of the studied sites were measured by a GARMIN GPS device and degree of slope recorded with an Abney level. All soil samples were air-dried, ground and sieved through a 2 mm sieve. The mechanical composition of soil was determined by hydrometer method (Bouyocos 1962, Piper 2005). Water holding capacity was estimated using standard soil cores. Soil pH was measured by an electronic pH meter from a soil-water suspension at a ratio of 1:2.5. Organic carbon was determined by wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by micro-Kjeldahl digestion and distillation method (Jackson 1973) after digestion with a mixture of concentrated H_2SO_4 + H_2O_2 + $LiSO_4$ (Allen et al. 1986)

Cation exchange capacity was determined by saturation with 1N NH_4OAc at pH 7.0. Available phosphorus was extracted by Bray & Kurtz-1 extractant (0.025N HCl in 0.03N NH_4F). Available calcium (Ca), magnesium (Mg) and potassium (K) were extracted with 1N NH_4OAc. Calcium and magnesium were determined by an atomic absorption spectrophotometer and potassium by a flame photometer. Results of the spots and depths of a site were averaged to represent a site.

TABLE 1: SOIL SAMPLING SITES IN STUDIED AREAS

Region	Site	Name of site	Tree	Latitude	Longitude	Elev. (m.)	Degree of Slope		
							Hill Top	Mid Hill	Foot Hill
Rangamati	1	Manik Chari	Teak	22° 39’ 024” N	92° 08’ 006” E	130	10°	39°	15°
	2	Betar, Vedvedi	Gamar	22° 39’ 183” N	92° 08’ 821” E	75	26°	37°	41°
	3	Vedvedi	Gamar	22° 39’ 452” N	92° 09’ 120” E	65	24°	33°	28°
	4	Mohismara	Jarul	22° 37’ 763” N	92° 06’ 732” E	90	34°	25°	18°
	5	Bang Chari	Jarul	22° 30’ 146” N	92° 11’ 541” E	55	20°	14°	24°
	6	Bang Chari	Teak	22° 30’ 146” N	92° 11’ 541” E	68	15°	29°	27°
	7	Chawduri Chara	Teak	22° 29’ 130” N	92° 12’ 885” E	17	8°	17°	26°
	8	Chawduri Chara	Jarul	22° 28’ 716” N	92° 12’ 849” E	13	15°	18°	14°
	9	Khaler Mukh	Mahogani	22° 28’ 552” N	92° 13’ 014” E	29	7°	13°	26°
	10	Chawduri Chara	Teak	22° 29’ 245” N	92° 12’ 955” E	17	15°	26°	20°
Bandarban	11	Khansama Para	Teak	22° 12’ 435” N	92° 15’ 773” E	53	25°	37°	28°
	12	Khansama Para	Teak	22° 12’ 152” N	92° 15’ 606” E	15	26°	30°	30°
	13	Tarasa Mouza	Gamar	22° 12’ 102” N	92° 15’ 366” E	91	16°	30°	25°
Kihagrachari	14	Headman Para	Teak	23° 04’ 687” N	91° 56’ 700” E	17	15°	19°	17°
	15	Campu	Gamar	23° 05’ 026” N	91° 56’ 890” E	134	22°	21°	25°
	16	Alutila Bridge	Gamar	23° 05’ 541” N	91° 57’ 477” E	127	37°	35°	05°
	17	Alutila Tourism Centre	Teak	23° 05’ 152” N	91° 57’ 323” E	294	30°	26°	16°

Statistical Analysis

The mean values and standard deviations for each parameter of a site were estimated. The nutrient levels were categorized into low (mean - $\frac{1}{2}SD$), medium (between low and high) and high (mean + $\frac{1}{2}SD$) categories. Statistical analysis was done with Microsoft Office Excel 2007 and MINITAB software.

III. RESULTS AND DISCUSSION

Physical Properties

Among the physical properties, mechanical composition and water holding capacity were determined. The mean percentages of sand, silt and clay and the textural class names are shown in Table-2. The mean (mean of all topographic positions and depths) percentage of sand, silt and clay varied considerably among the sites. The percentage of sand, silt and clay ranged from 37 to 67%, 7 to 36% and 20 to 33%, respectively. The maximum percentages of sand, silt and clay were found in site No.2, 16 and 10. From the mean values of soil mechanical compositions, there were three soil textural classes such as- loam (sites 5, 8, 12, 13, 14, 16), sandy clay loam (sites 1, 2, 3, 6, 7, 9, 11, 15 and 17) and clay loam (sites 4 and 10). Soil texture is one of the inherent soil physical properties less affected by management (Tilahun 2007). Variation in the mechanical composition among the sites might have inherited from the parent materials. Some variation could be due to the sorting effects of runoff. In the monsoon, the surface run off is low to severe depending on slope characteristics. Banglapedia (2012) states that the Eastern Hills of Bangladesh are underlain by sandstone, siltstone and shale of Tertiary and Quaternary ages. The soils developed on these parent materials are brown in colour, usually loamy in texture and very strongly acidic in reaction. Landscape is steep and soils were mainly developed on steep slopes and some occur on more gentle slopes. The nature of parent materials strongly determines the texture of the soils. Soils subject to erosion have topsoil with less clay content.

Maximum water holding capacity (MWHC) values, also presented in table 2, varied between 41.17 and 51 percent (w/w). The water holding capacity was apparently closely related to the mechanical composition of soils. The clay loam soils tended to have higher water holding capacity than other textural classes. The surface drainage classes as observed in field were all good; the internal drainage could be moderate to good. Huq and Shoaib (2013) characterized these soils as yellow-brown to strong brown , permeable, friable, loamy, very strongly acid and low in moisture holding capacity.

TABLE 2: PHYSICAL PROPERTIES OF SOILS IN DIFFERENT SITES.

Site No.	%Sand	%Silt	%Clay	USDA Textural class	MWHC*
1	58 ±5.96	21 ±4.12	21 ±2.06	Sandy clay loam	45 ±1.70
2	67 ±1.46	7 ±0.48	26 ±1.54	Sandy clay loam	45 ±0.76
3	64 ±2.18	8 ±0.75	28 ±2.05	Sandy clay loam	45 ±0.84
4	37 ±2.39	31 ±0.88	32 ±2.12	Clay loam	51 ±1.36
5	49 ±2.26	31 ±2.12	20 ±0.42	Loam	41 ±0.95
6	64 ±2.23	15 ±0.65	21 ±2.14	Sandy clay loam	44 ±1.25
7	50 ±1.82	19 ±1.69	31 ±1.06	Sandy clay loam	46 ±1.74
8	51 ±3.45	28 ±1.74	21 ±1.77	Loam	42 ±1.30
9	49 ±3.66	23 ±2.98	28 ±2.62	Sandy clay loam	45 ±1.78
10	40 ±1.36	27 ±1.94	33 ±1.09	Clay loam	51 ±0.89
11	64 ±6.44	15 ±3.66	21 ±2.85	Sandy clay loam	43 ±2.04
12	45 ±2.82	30 ±2.69	25 ±1.44	Loam	46 ±1.51
13	42 ±1.19	32 ±1.03	26 ±2.01	Loam	48 ±1.52
14	43 ±1.81	33 ±1.33	24 ±0.75	Loam	46 ±1.36
15	50 ±1.87	22 ±1.03	28 ±1.48	Sandy clay loam	49 ±1.11
16	44 ±1.99	36 ±1.52	20 ±1.85	Loam	43 ±1.23
17	53 ±2.17	24 ±1.09	23 ±1.63	Sandy clay loam	44 ±1.74

*MWHC- denotes Maximum water holding capacity

Chemical Properties

Soil pH varied between 4.6 (site 7 and 11) and 6.5 (site 12) among these sites. According to the USDA classification (Soil Survey Division Staff 1993), mean pH of the presently studied soils can be placed in the following categories: strongly acid pH 5.1 – 5.5 and moderately acid pH 5.6 – 6.0. In this classification 13 sites (2, 3, 4, 7, 8, 9, 10, 11, 12, 14, 15, 16 and 17) fall in strongly acid category. On the other hand, only 4 sites (1, 5, 6 and 13) fall in moderately acid category respectively.

Organic matter content of the soil varied between 0.15% (site 11) and 3.32% (site 13). Bangladesh soils are generally low in organic matter content; most soils having less than 1.5 % organic matter in surface 0-15 cm (BARC 2005). Based on organic matter content, BARC (1989) classified Bangladesh agricultural soils into very low (<1.0%), low (1.0 - 1.7), medium (1.7 - 3.4%), high (3.4 - 5.5) and very high (>5.5%).

Forest soils generally contain higher organic matter than agricultural soils (Osman 2013). Yet, according to this scheme, the presently studies sites 1, 5, 6, 7, 8 & 11 fall in low and sites 2, 3, 4, 9, 10, 12, 13, 14, 15, 16 & 17 fall in medium categories. According to Huq and Shoaib (2013), the soils of the northern and eastern hills are low in organic matter and poor in general fertility. However, there is no standard value of organic matter for forested hilly soils. We separated the presently studied seventeen sites into low, medium and high categories by defining low as (mean - $\frac{1}{2}SD$), medium (between low and high) and high as (mean + $\frac{1}{2}SD$) categories. In this scheme sites 1, 5, 6, 7, 8 and 11 fall in low (<1.5 %), sites 2, 9, 10, 12 and16 fall in medium (between 1.5 % and 2.04%), and sites 3, 4, 13, 14, 15 and 17 (>2.04%) fall in the high category.

Cation exchange capacity (CEC) ranged between 2.12 $cmol_c\ kg^{-1}$ (site 11) and 12.50 $cmol_c\ kg^{-1}$ (site 4). According to BARC (1989), CEC of agricultural soils in Bangladesh are classified as: very high (>30 $cmol_c\ kg^{-1}$); high (15-30 $cmol_c\ kg^{-1}$); medium (7.5-15 $cmol_c\ kg^{-1}$), low (3-7.5 $cmol_c\ kg^{-1}$) and very low (<3 $cmol_c\ kg^{-1}$). Based on this statement the presently studied soil of site 1, 5, 6, 8, 11 and 16 fall in low and site 2, 3, 4, 7, 9, 10, 12, 13, 14, 1 and 17 fall in medium category. According to our categorization the presently studied 5 sites of the seventeen sites fall into low (<7.32 $cmol_c\ kg^{-1}$) (1, 5, 6, 11 and 16), 6 sites (2, 7, 8, 9, 10 and 12) fall into medium (between 7.32 $cmol_c\ kg^{-1}$ and 8.79 $cmol_c\ kg^{-1}$), and the remaining 5 sites (3, 4, 13, 14, 15 and 17) fall into the high category (>8.79 $cmol_c\ kg^{-1}$). The low, medium and high categories of CEC corresponded well with the respective categories of organic matter with few exceptions. It indicated a close association between organic matter and CEC.

TABLE 3: CHEMICAL PROPERTIES OF STUDIED SOILS IN DIFFERENT SITES (MEAN ±SE)

Site	pH	pH-range	%OM	%OM-range	CEC	CEC-range
					$cmol_c\ kg^{-1}$	
1	5.68 ±0.17	4.90-6.00	1.41 ±0.14	0.76-1.72	6.37 ±0.59	3.70-7.58
2	5.43 ±0.12	5.00-5.80	1.97 ±0.10	1.58-2.27	7.81 ±0.67	4.80-9.52
3	5.48 ±0.15	4.80-5.90	2.21 ±0.05	2.06-2.37	9.44 ±0.27	8.50-10.16
4	5.17 ±0.06	5.00-5.40	2.09 ±0.22	1.38-2.92	9.23 ±0.72	7.54-12.50
5	5.57 ±0.07	5.30-5.80	1.31 ±0.05	1.17-1.48	7.09 ±0.49	5.83-8.76
6	5.58 ±0.15	5.10-6.10	1.20 ±0.16	0.64-1.84	5.72 ±0.45	4.06-7.21
7	5.13 ±0.15	4.60-5.50	1.49 ±0.08	1.27-1.81	7.52 ±0.24	6.92-8.35
8	5.27 ±0.10	5.00-5.70	1.04 ±0.06	0.83-1.27	7.39 ±0.49	5.77-8.44
9	5.28 ±0.16	4.90-6.00	1.88 ±0.23	1.10-2.67	8.46 ±0.53	6.26-10.20
10	5.30 ±0.09	4.90-5.50	1.80 ±0.14	1.50-2.37	8.75 ±0.34	8.07-10.30
11	5.45 ±0.28	4.60-6.30	1.00 ±0.33	0.15-2.30	5.10 ±1.17	2.12-9.11
12	5.48 ±0.29	4.80-6.50	2.00 ±0.21	1.07-2.67	8.49 ±0.67	5.62-10.71
13	5.58 ±0.06	5.40-5.80	2.41 ±0.27	1.75-3.32	9.84 ±0.64	8.47-12.16
14	5.48 ±0.07	5.30-5.70	2.18 ±0.24	1.51-3.01	8.94 ±0.72	6.96-11.50
15	5.27 ±0.04	5.20-5.40	2.43 ±0.19	1.89-3.15	10.07 ±0.50	8.85-12.13
16	5.40 ±0.08	5.10-5.70	1.71 ±0.30	0.88-3.03	7.13 ±0.73	5.32-10.49
17	5.28 ±0.06	5.00-5.40	2.44 ±0.26	1.34-3.27	9.59 ±0.71	6.71-11.75

Nutritional properties

Total nitrogen contents varied between 0.03% (site 1) and 0.24 % (site 15) (Table 4) and the variation among the sites was statistically significant. Total nitrogen closely followed the trend of variation of organic matter. Generally, a site low in organic matter was also low in total nitrogen. The C/N ratio (not given in table) varied within a narrow range of 8 to 12.

Most terrestrial ecosystems are considered nitrogen (N) and/or phosphorus (P) limited (Aerts and Chapin 2000). Usually, N limitation is alleviated in agricultural systems by N fertilization (Jiao *et. al.* 2010). The forest soils in most under developed countries are not fertilized and nutrient demands of forest trees are mainly met by nutrient recycling (Vitousek and Sanford 1986). Available P (Bray and Kurtz 1 extractable) in the presently studied sites varied between 0.59 mg kg^{-1} (site 11) and 8.78 mg kg^{-1} (site 8). Six sites (2, 6, 7, 11, 13 and 14) fall in low (<2.66 mg kg^{-1}), seven sites (1, 3, 4, 9, 10, 12 and 17) fall in the medium (between 2.66 mg kg^{-1} and 4.22 mg kg^{-1}), and the remaining four sites (13, 8, 15 and 16) (>4.22 mg kg^{-1}) fall in the high category. There was a

considerable variation in available P among the different slopes, sites and locations. Nitrogen might be the primary limiting nutrient in many forests, but there is a relative importance of potassium (K) as a co-limiting nutrient in some cases. Available potassium (1N NH_4OAC at pH 7.0 extractable) varied between 21mg kg^{-1} (site 11) and 375 mg kg^{-1} (site 13). There were low values of K (<94 mg k^{-1}) in six sites (1, 5, 6, 8, 11 and 17), medium values in seven sites (2, 3, 4, 7, 12, 14 and 16), and high values (>132 mg kg^{-1}) in four sites (9, 10, 13 and 15). Available calcium content in the studied soils ranged from 58 mg kg^{-1} (site 6) to 1674 mg kg^{-1} (site 12). Available calcium was low (<420 mg kg^{-1}) in sites 6, 7, 11, 13 and 15, medium in sites 2, 3, 4, 5, 8, 9, 14 and 17 and high (>567 mg kg^{-1}) in sites 1, 10, 12 and 16. Available magnesium varied between 31 mg kg^{-1} (site 6) and 756 mg kg^{-1} (site 1). Available magnesium content in sites 2, 3, 6, 7 and 11 fall in low (<141 mg kg^{-1}), sites 4, 5, 8, 9, 10, 14, 15 and 17 fall in medium (between 141 mg kg^{-1} and 219 mg kg^{-}

^{1}), and sites 1, 12, 13 and 16 (>219 mg kg^{-1}) fall in the high category. The variation in nutrient status of the presently studied soils is believed to be due to differences in parent material and losses due to erosion. Despite some inconsistencies in data, it can be said the soils are poor in base status. The high value of Ca, 567 mg kg^{-1}, is equivalent to only 2.84 $cmol_c$ kg^{-1} and the highest CEC was only 10.07 $cmol_c$ kg^{-1}. Earlier works have also indicated that exchangeable Ca and Mg cations constitute the major proportion of total exchangeable cations, and contribute to the base saturation of most soils (Mesfin 1998, Eyelachew 2001). Tilahun (2007) analyzed several hundred forests and agricultural soil samples and observed the highest average mean values of exchangeable Ca (10.75 $cmol_c$ kg^{-1}), exchangeable Mg (5.02 $cmol_c$ kg^{-1}) and CEC (28.17 $cmol_c$ kg^{-1}). Soils of the forest plantations of Chittagong Hill Tracts appear to be relatively low.

TABLE 4: MEAN OF EVALUATED SOIL NUTRITIONAL PROPERTIES (MEAN ±SE)

Site No.	Total N (%)	Available nutrients (mg kg^{-1})			
		P	K	Ca	Mg
1	0.07 ±0.01	3.77 ±0.23	62 ±10	590 ±156	237 ±104
2	0.11 ±0.01	2.34 ±0.19	107 ±17	428 ±44	121 ±19
3	0.12 ±0.01	3.40 ±0.27	114 ±9	441 ±70	87 ±20
4	0.11 ±0.01	3.90 ±0.11	118 ±17	535 ±34	174 ±9
5	0.07 ±0.00	4.52 ±0.34	86 ±15	498 ±59	173 ±24
6	0.07 ±0.01	1.79 ±0.21	77 ±13	279 ±60	74 ±17
7	0.09 ±0.01	2.23 ±0.35	121 ±11	367 ±51	85 ±14
8	0.06 ±0.01	7.32 ±0.35	87 ±13	458 ±25	166 ±13
9	0.12 ±0.02	3.92 ±0.21	175 ±29	558 ±73	160 ±15
10	0.11 ±0.01	2.82 ±0.27	140 ±29	585 ±71	199 ±16
11	0.05 ±0.02	1.38 ±0.36	71 ±15	399 ±107	123 ±33
12	0.11 ±0.01	3.46 ±0.49	109 ±21	928 ±178	371 ±92
13	0.14 ±0.01	2.04 ±0.57	206 ±45	289 ±58	314 ±49
14	0.12 ±0.01	1.78 ±0.40	104 ±14	498 ±50	188 ±24
15	0.18 ±0.02	4.59 ±0.15	153 ±28	419 ±49	172 ±21
16	0.11 ±0.02	5.87 ±0.27	104 ±22	583 ±58	241 ±47
17	0.16 ±0.02	3.31 ±0.33	90 ±7	534 ±59	172 ±20

IV. CONCLUSION

The results of this study revealed significant differences in physical, chemical and nutritional properties among seventeen forested soils of three Hill Districts of Chittagong Hill Tracts. The variation was mainly carried out by parent materials, topography and land use. The general fertility of the soils was low as indicated by low base status, although some sites contained satisfactory levels of organic matter. Forest plantations are not fertilized in general in this area. Fertilized plantations can be established on an experimental basis.

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