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Soil Characteristics and Carbon Storage in Forest Soil of Mae Ya Noi Community Forest, Chom Thong District, Chiang Mai Province

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ABSTRACT

Soil characteristics and carbon storage were studied in the forest soils of Ban Mae Ya Noi community forest, Chom Thong district, Chiang Mai province. Twelve plots (40×40 m) were selected using stratified random sampling along the latitudinal gradient. One soil pit was made in each plot and soil samples were collected down the profile for analysis of physical and chemical properties and to calculate carbon storage. It was found that there were 137 tree species in this forest (106 genera and 52 families). The species diversity using the Shannon-Wiener equation (SWI) was 4.74±0.41. The soil depth was more than two meters. The textures of soil samples were loamy sand and sandy clay loam and the soil reaction was only strongly acid. The organic matter and carbon were very high in the surface soil and high to very low in the deeper soil. Total N was medium to high in the surface soil and low to very low in the deeper soil. Available P was moderately high to very low. Extractable K was very low to low and Ca was very low throughout the soil profile. Extractable Mg was low to medium, but the Na content was very low. The amounts of organic matter, carbon and total nitrogen were 291.00, 168.78 and 14.87 Mg ha^{-1}, respectively. The amounts of available P, extractable K, Ca, Mg and Na were 46.64, 529.00, 321.06, 1876.29 and 55.61 kg ha^{-1}, respectively. Types of vegetation, soil characteristics and carbon storage can be useful in the management of community forest as part of forest restoration for degraded areas, choosing the right plants and the soil suitable for the growth of plants.

Keywords: community forest, soil properties, forest soil, carbon and nutrient in soils

INTRODUCTION

The forests of the world span a vast range of climatic condition and soil properties, and the variations across relatively small landscapes may be almost as large as the variation across hemispheres. This wide range of situations is reflected in the major soil types that are found within major types of forests.

Forest in northern Thailand can be divided into two types, deciduous and evergreen with composed of 5 sub-categories:1) dry dipterocarp (DDF), 2) mixed deciduous

(MDF), 3) dry evergreen (DEF), 4) montane (MF) and 5) pine (PF) forests (Khamyong, 2003). Forest soils are considered to be soils that presently support forest cover. These soils differ in many ways from agronomics. On the forest floor, there is an organic layer that covers the mineral soil and diverse fauna and flora play major roles in their structure and function. Sites are often wet or steep, with the soil ranging from shallow to bedrock or having a high stone content. Soil layers that occur at great depth are important to forests (Fisher and Binkley, 2000).

Carbon can be stored in different compartments of a forest ecosystem including forest biomass (plant, animals and microbes), organic layers on the forest floor and in the mineral soil (Waring and Running, 1998; Negi *et al*., 2003). Carbon begins its cycle through forest ecosystems when plants assimilate atmospheric CO_2 through photosynthesis into reduced sugars. Usually about half the gross photosynthetic products produced (GPP) are expended by plants in autotrophic respiration for the synthesis and maintenance of living cells, releasing CO_2 back into the atmosphere. The remaining carbon products go into net primary production (NPP): foliage, branches, stems, roots and plant reproductive organs. As plants shed leaves and roots, or are killed, the dead organic matter forms detritus, a substrate that supports animals and microbes, which through their heterotrophic metabolism release CO_2 back into the atmosphere. Soil humus represents the major accumulation of carbon in most ecosystems because it remains unoxidized for centuries. It is the most important long-term carbon storage site in ecosystems. However, this study focused only on carbon storage in the soil.

The Mea Ya Noi community forest is located in Ban Luang sub-district, Chom Tong district, Chiang Mai province. The altitude range of the village area is between 1,200 and 1,600 m above mean sea level (m.s.l.). The parent rock in the area is granite. The villagers are the Hmong tribe. This village is situated in the Doi Inthanon National Park. The occupation of most villages is agriculture, and some of them are employed in government offices.

The objectives of this research were study the soil characteristics and carbon storage in the forest soil of upland communities located in the Doi Inthanon National Park of Thailand.

MATERIALS AND METHODS

A forest vegetation survey was carried out in the Mea Ya Noi (MYN) community forest during October–December 2013. Plant community analysis was applied for the forest vegetation survey using 12 plots (40x40 m). The plots were arranged in the forest using stratified random sampling. Stem girths at 1.3 m above ground of all tree species of height ≥1.5 m and tree heights (height of dominant trees calculated from an in the study by Seeloy-ounkeaw *et al*, 2014) were measured. Ecological parameters were calculated: (1) plant frequency, (2) plant abundance, (3) plant density, (4) dominance, (5) important value index and (6) species diversity index using the Shannon-Wiener equation (Krebs, 1985). All plots were located using a global positioning system (GPS).

Soil properties were determined from one soil pit within plot with 200 cm depth, and soil samples were collected down the profile at 13 different depths: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80-100, 100-120, 120-140, 140-160, 160-180 and 180-200 cm. Soil composite samples were obtained from the same layers along three soil depths. They were later analyzed for physical and chemical properties in the laboratory.

For soil physical analysis, (1) soil texture and analysis for particle size distribution were taken using the hydrometer method and (2) bulk density was determined using the core method. For chemical analysis, the following were measured: (1) soil reaction using a pH meter; pH (H_2O) (soil : water = 1:1) (Mclean, 1982); (2) total N using the Micro Kjedahl method (Bremner and Mulvaney, 1982); (3) extractable phosphorus using the Bray II and Colorimetric method and read using atomic absorption spectophotometry (Bray and Kunzt, 1945; Olsen and Sommers, 1982); (4) extractable bases (potassium, calcium, magnesium and sodium) extracted by ammonium acetate solution 1N, pH 7.0 and read using atomic absorption spectophotometry (Peech, 1945; Lanyon and Heald, 1982); (5) cation exchange capacity (CEC) extracted using ammonium acetate solution 1 N, pH 7.0 (Summer and Miller, 1996); and (6) base saturation percentage (BS%) defined as the amount of basic cation that occupies the cation exchange sites divided by the total cation exchange capacity (CEC) (Coleman and Thomas, 1964; Soil Survey Staff, 1972).

Amounts of nutrients accumulated in soils for total C and N, extractable P, K, Ca, Mg and Na were calculated from their contents and the soil mass for each layer down the soil profile.

RESULTS AND DISCUSSION

Species composition and richness

Mae Ya Noi community forest is montane forest. In the 12 sample plots, 7,326 tree individuals from 137 species in 106 genera and 52 families were found. *Castanopsis acuminatissima* was the dominant tree species in the forest. The most abundant species was *Castanopsis acuminatissima* (1,053 tree individuals) followed by *Lithocarpus garrettianus, Phoebe paniculata, Styrax benzoides, Garcinia merguensis, Wendlandia tinctoria, Quercus semiserrata* and *Ilex umbellulata* (543, 386, 292, 289, 256, 216, 201 tree individuals, respectively). The species with high numbers influenced the composition of the forest area.

Quantitative characteristics of tree species

1) Tree frequency, tree density and tree dominance

Twelve species had a high frequency of 100%: *Symplocos macrophylla, Helicia nilagirica, Myrica rubra, Anneslea fragrans, Phoebe paniculata, Syzygium albiflorum, Ilex umbellulata, Memecylon celastrinum, Wendlandia tinctoria, Castanopsis acuminatissima* and *Lithocarpus garrettianus*. These species were common being found at every location. Slightly less common species were: *Syzygium cumini, Rapanea porteriana, Eurya nitida, Garcinia merguensis, Millettia pachycarpa, Olea salicifolia, Styrax benzoides, Quercus* *semiserrata* and *Diospyros glandulosa* (91.62%), and nine other species were common too, but had lower frequency.

The average density of all tree species in the forest was 3,839.58 trees/ha. The species with the highest density was *Castanopsis acuminatissima* (548.44 trees/ha), followed by *Lithocarpus garrettianus, Phoebe paniculata, Styrax benzoides, Garcinia merguensis, Wendlandia tinctoria, Helicia nilagirica, Quercus semiserrata, Ilex umbellulata* and *Syzygium albiflorum* with 282.81, 206.25, 151.56, 150.52, 133.33, 117.71, 112.50, 104.69, 102.08 trees/ha, respectively. These species represented the major population of trees in this forest. The numbers of the remaining species were lower.

The tree with the highest dominance was *Castanopsis acuminatissima* (21.34% of all species) followed by *Schima wallichii, Lithocarpus garrettianus, Syzygium cumini, Pinus kesiya, Castanopsis armata, Quercus semiserrata, Neolitsea cassia, Helicia nilagirica, Styrax benzoides, Anneslea fragrans* and *Myrica rubra rubra* with 8.79, 8.02, 7.06, 4.49, 4.47, 3.88, 3.78, 3.39, 2.66, 2.55 and 2.49%, respectively.

2) Importance value index (IVI)

Castanopsis acuminatissima had the highest IVI (12.45% of all species) in the forest, followed by *Lithocarpus garrettianus, Schima wallichii, Syzygium cumini, Phoebe paniculata, Quercus semiserrata, Styrax benzoides, Helicia nilagirica, Castanopsis armata, Wendlandia tinctoria*, *Anneslea fragrans, Neolitsea cassia* and *Garcinia merguensis*, respectively. The IVI is a composite index based on measures of relative frequency, relative density and relative dominance (Mueller-Dombois and Ellenberg, 1974). It represents the integrated influence of a tree species in the forest.

3) Species Diversity

The Shannon-Wiener equation (SWI) was used as the species diversity index of this community forest to compare species richness and population abundance. The SWI value was 4.74 ± 0.41. The maximum and minimum values were 5.26 and 3.74, respectively.

Khamyong (2009) found that the lower montane forest (LMF) in the Doi Suthep-Pui National Park with 188 species had a higher SWI value of 6.10. Satienperakul (2013) studied plant species diversity in two areas, (1) fragmented forests in Boakaew sub-district, Samoeng district, Chiang Mai province and (2) montane forest in the Doi Inthanon National Park, Chom Tong district, Chiang Mai province. The LMF at location 1 with species richness of 103 species (82 genera and 44 families) had an SWI value of 5.28, whereas at location 2, the species richness of 122 species (112 genera and 49 families) had an SWI value of 5.72.

Khamyong *et al.* (2004) reported on the plant species diversity and structure of UMF at the summit of Mt. Inthanon and found 47 tree species in 39 genera and 26 families in the forest. There was lower species richness than in lower montane forest. Species and family richness as well as their diversity decreased at higher altitude. Data on forest vegetation and the ecosystem of montane forest have been collected by many researchers (Ohsawa, 1991; Robbins and Smitinand, 1966: Santisuk, 1988; Sri-Ngernyuang *et al*., 2003; Seeloy-ounkeaw *et al*., 2012).

Table 1 Quantitative data of tree species.

No	Species name	Frequency (%)	Density (trees ha^{-1})	Basal area (cm^2 ha^{-1})	Relative (%) Frequency	Density	Dominance	IVI 300.00	%
1	*Castanopsis acuminatissima*	100.00	548.44	82,658.37	1.72	14.28	21.34	37.34	12.45
2	*Lithocarpus garrettianus*	100.00	282.81	31,053.48	1.72	7.37	8.02	17.10	5.70
3	*Schima wallichii*	100.00	64.06	34,050.83	1.72	1.67	8.79	12.18	4.06
4	*Syzygium cumini*	91.67	13.54	27,334.42	1.57	0.35	7.06	8.98	2.99
5	*Phoebe paniculata*	100.00	206.25	6,377.36	1.72	5.37	1.65	8.74	2.91
6	*Quercus semiserrata*	91.67	112.50	15,038.76	1.57	2.93	3.88	8.39	2.80
7	*Styrax benzoides*	91.67	151.56	10,292.48	1.57	3.95	2.66	8.18	2.73
8	*Helicia nilagirica*	100.00	117.71	13,125.50	1.72	3.07	3.39	8.17	2.72
9	*Castanopsis armata*	83.33	36.98	17,306.36	1.43	0.96	4.47	6.86	2.29
10	*Wendlandia tinctoria*	100.00	133.33	5,472.51	1.72	3.47	1.41	6.60	2.20
11	*Anneslea fragrans*	100.00	86.46	9,880.29	1.72	2.25	2.55	6.52	2.17
12	*Neolitsea cassia*	75.00	47.40	14,647.51	1.29	1.23	3.78	6.30	2.10
13	*Garcinia merguensis*	91.67	150.52	2,844.67	1.57	3.92	0.73	6.23	2.08
14	*Pinus kesiya*	25.00	31.25	17,385.83	0.43	0.81	4.49	5.73	1.91
15	*Myrica rubra*	100.00	49.48	9,627.24	1.72	1.29	2.49	5.49	1.83
16	*Symplocos macrophylla*	100.00	97.40	4,492.25	1.72	2.54	1.16	5.41	1.80
17	*Syzygium albiflorum*	100.00	102.08	3,617.59	1.72	2.66	0.93	5.31	1.77
18	*Ilex umbellulata*	100.00	104.69	1,397.51	1.72	2.73	0.36	4.80	1.60
19	*Rapanea porteriana*	91.67	96.35	1,731.10	1.57	2.51	0.45	4.53	1.51
20	*Millettia pachycarpa*	91.67	96.88	584.18	1.57	2.52	0.15	4.25	1.42
	Total 1-20 species	1,833.33	2,529.69	308,918.23	31.47	65.88	79.76	177.12	59.04
	Total 21-138 species	3,991.67	1,309.90	78,374.25	68.53	34.12	20.24	122.88	40.96
	Total	5,825.00	3,839.58	387,292.48	100	100	100	300	100

Soil Properties

The development of soil and associated forest vegetation is a complex and continuing process. Soils play vital roles in the development of forests, and forest likewise play vital roles in the development of soils.

1. Soil Physical Properties

Soil physical properties profoundly influence the growth and distribution of trees through their effects on soil moisture regimes, aeration, temperature profiles, soil chemistry, and even the accumulation of organic matter.

1.1) Bulk density

Bulk density is the dry mass (of <2 mm material) of a given volume of intact soil in mega-grams per cubic meter (which also equals kilograms per liter) (Fisher and Binkley, 2000). The soil densities were normally low in the surface soils and increased with soil depth.

The densities in soil at 0-40 cm depth were very low (0.45-0.90 Mg m^{-3}) and low to moderately low in deeper soil (40-200 cm; 1.01-1.32 Mg m^{-3}). The lower densities in surface soils were caused by the high contents of organic matter.

1.2) Gravel contents by weight

The gravel contents in the soil profile at 0-10 cm depth varied between 7.97 and 9.43% and ranged from 2.52 to 9.37% in deeper soil (10-200 cm).

The gravel content in the soils of this community forest was relatively low since they were well developed soils (Ultisols). Most gravel had been weathered to soil particles.

1.3) Soil particle distribution and textures

The percentages of sand particles in the soil pits at 0-20 cm depth varied between 78.40 and 82.40% and decreased with soil depth (51.40-66.40%). The percentages of silt particles in the soil at 0-20 cm were in a range 13.20-17.20% and increased in deeper soil (18.00-32.00%). The percentages of clay particles in the soil at 0-40 cm depth were between 4.40 and 6.60% and varied in deeper soil (15.60-29.60%).

The soil at 0-20 cm depth was coarse-textured, loamy sand. The deeper soil had different textures: at 20-60 cm, moderately coarse-textured, sandy loam; at 60-120 cm, moderately fine-textured, sandy clay loam; at 120-180 cm, moderately coarse-textured, sandy loam, and at 180-200 cm, moderately fine-textured, sandy clay loam.

2. Soil Chemical Properties

The chemistry of soils is complex, involving inorganic reactions between the solid phase (including minerals, mineral surfaces and organic matter), the liquid phase (near surfaces and in the bulk soil solution), and an incredible diversity of soil organisms.

2.1) Soil reaction

The pH of soils is important for a variety of reasons, including the solubility of aluminum (which is toxic to many plants and organisms), the weathering of minerals and the distribution of cations on the exchange complex. The soil reaction is considered using pH values. The soil reaction throughout the 2 m soil profile in the MYN forest was only strongly acid (pH= 5.05-5.43) which reflected a similar trend to the conservation forest of the Ban Nong Tao community forest (pH=5.23-6.04) according to Seeloy-ounkeaw *et al.* (2014).

2.2) Soil organic matter and carbon

The content of organic matter was very high in the surface soil at 0-10 cm depth (6.11-7.46%), medium to high at 10-60 cm (0.64-4.24%) and very low in the deeper soil (0.12-0.48%).

The carbon contents in soils of the community forests varied with the same trend as soil organic matter since it is calculated from the assumption that the organic matter consists of 58% organic carbon on average.

2.3) Total nitrogen and C/N ratios

The nitrogen content was high in the surface soil at 0-5 cm depth (0.5%), medium (0.22-0.30%) at 5-20 cm, low (0.11%) at 20-30 cm and very low in the deeper soil (0.01-0.08%). The C/N ratios in soil varied from 6.96 to 37.12.

2.4) Available phosphorus (P)

The concentration of available P in the surface soil (0-5 cm depth) was moderately high (22.80 mg kg^{-1}) and very low in deeper soils (0.60-2.80 mg kg^{-1}).

2.5) Extractable potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na)

The concentrations of extractable K in the 2 m soil depth of Pedon 1 were very low to low (10.88-57.75 mg kg^{-1}).

The concentration of extractable Ca were very low throughout soil profile varying from 11.43 to 190.48 mg kg^{-1}.

The concentration of extractable Mg was medium (126.95 mg kg^{-1}) at 0.5 cm soil depth, was low (69.18-110.55 mg kg^{-1}) at 5-40 cm soil depth, was medium (100.55-169.73 mg kg^{-1}) at 40-100 cm soil depth and was very low to low in deeper soils.

The concentration of extractable Na in the 2 m soil profiles of all community forests was low to very low.

2.6) Cation exchange capacity (CEC) and base saturation (BS)

The CEC in the soil at 0-10 cm depth was moderately low (6.21 cmol kg^{-1}), at 10-40 was low (2.50-4.02 cmol kg^{-1}) and was low to moderately low (3.53-11.07 cmol kg^{-1}) in the deeper soil.

The base saturation was low throughout the soil profiles being between 5.38 and 23.74%.

Amount of Soil Carbon

This study considered only the amount of carbon storage in the soil. Decomposition of organic layers on the forest floor resulted in the accumulation of organic matter in the soil profile and, on average, 58% of the organic matter was converted into organic carbon. Table 5 shows the amounts of soil organic matter and carbon down the soil profile.

The amounts of carbon storage in the 2 m soil profiles in these community forests were studied. The amount of carbon was high in the surface soil and decreased in the subsoil. The amount of carbon in the 2 m soil profile was 168.78 Mg ha^{-1}. In the 1 m soil depth, the amount of carbon was 121.40 Mg ha^{-1} (93.68% of the total amount in the 2 m soil depth). The forest had a lot of organic matter on the soil surface, which might be high in carbon too. Generally carbon will be accumulating in the topsoil and decreasing in deeper soil. The soil organic matter in montane forest is higher than in pine-montane forest. In other locations in Thailand, the montane forest (altitude, 1,700 m) in the Doi Inthanon National Park had 124.87 Mg ha^{-1} soil carbon (Satienperakul, 2013). Thus, this forest could store more carbon than the montane forest at Doi Inthanon at an altitude of 1,700 m.

Pornleesangsuwan *et al*. (2011) reported the amounts of organic matter, carbon and nitrogen within 160 cm soil depth in a fragmented lower montane forest at the Boa Kaew watershed station were 164.0-476.6, 95.1-276.5 and 9.05-19.85 Mg ha^{-1}, respectively. The soil within 100 cm soil depth in a pine-oak forest in Ban Chan sub-district, Kanlayaniwattana contained 146.5, 85.0 and 5.11 Mg ha^{-1} of organic matter, carbon and nitrogen, respectively (Seramethakun *et al*., 2012). *Pinus kesiya* plantation forest at the Boa Kaew watershed management station, Chiang Mai could store 80.4-177.7 Mg ha^{-1} of carbon (Nongnuang *et al*., 2012).

The amounts of N, P, K, Ca, Mg and Na were 14870.00, 46.64, 529.00, 321.06 and 1876.29 kg ha^{-1}, respectively. The amount of nutrients stored varied with the soil profile, soil order and parent rock in each area.

Table 2 Some physical properties in soil profiles.

Soil depth (cm)	Bulk density (Mg m^{-3})	*	Gravel (%)	Soil particle distribution (%) Sand	Silt	Clay	Soil texture
0-5	0.45	VL	9.43	82.40	13.20	4.40	loamy sand
5-10	0.62	VL	7.97	78.40	17.20	4.40	loamy sand
10-20	0.67	VL	6.95	80.40	15.30	4.30	loamy sand
20-30	0.78	VL	6.63	66.40	27.00	6.60	sandy loam
30-40	0.90	VL	8.23	61.40	32.00	6.60	sandy loam
40-60	1.01	L	8.89	62.40	21.00	16.60	sandy loam
60-80	1.11	L	9.37	52.40	18.00	29.60	sandy clay loam
80-100	1.23	ML	3.65	55.40	21.00	23.60	sandy clay loam
100-120	1.31	ML	3.02	51.40	27.00	21.60	sandy clay loam
120-140	1.30	ML	3.99	59.40	25.00	15.60	sandy loam
140-160	1.30	ML	3.13	60.40	22.00	17.60	sandy loam
160-180	1.28	ML	2.52	66.40	18.00	15.60	sandy loam
180-200	1.32	ML	3.31	60.40	18.00	21.60	sandy clay loam

Notes: VL = very low, L = low, ML = moderately low, M = medium, MH = moderately high

Table 3 Chemical properties of pH, OM, OC, N, C/N and P in soil profiles.

Depth (cm)	pH		OM %	*	OC %	*	Total N %	*	C/N Ratio	Available P (mg kg^{-1})	*
0-5	5.05	strongly acid	7.46±0.93	VH	4.33	VH	0.50	H	8.74	22.80	MH
5-10	5.38	strongly acid	6.11±0.26	VH	3.54	VH	0.30	M	11.77	2.80	VL
10-20	5.10	strongly acid	4.24±0.40	H	2.46	H	0.22	M	11.18	2.79	VL
20-30	5.43	strongly acid	2.12±0.27	H	1.23	VL	0.11	L	11.39	1.20	VL
30-40	5.42	strongly acid	1.95±0.25	M	1.13	VL	0.08	VL	13.63	1.10	VL
40-60	5.24	strongly acid	0.64±0.25	M	0.37	L	0.01	VL	37.12	1.20	VL
60-80	5.35	strongly acid	0.47±0.33	VL	0.27	VL	0.01	VL	27.26	1.20	VL
80-100	5.36	strongly acid	0.44±0.22	VL	0.26	VL	0.01	VL	25.52	1.00	VL
100-120	5.35	strongly acid	0.48±0.24	VL	0.28	VL	0.01	VL	27.84	0.92	VL
120-140	5.26	strongly acid	0.28±0.21	VL	0.16	VL	0.01	VL	16.24	0.80	VL
140-160	5.31	strongly acid	0.18±0.05	VL	0.10	VL	0.01	VL	10.44	0.79	VL
160-180	5.29	strongly acid	0.14±0.10	VL	0.08	VL	0.01	VL	8.12	0.77	VL
180-200	5.39	strongly acid	0.12±0.12	VL	0.07	VL	0.01	VL	6.96	0.60	VL

Notes: VL = very low, L = low, ML = moderately low, M = medium, MH = moderately high, H = high, VH = very high (Land Classification and FAO Project Staff, 1973; Soil Survey Division Staff, 1993; Land Use Planning Division, 1993)

Table 4 Chemical properties of K, Ca, Mg, Na, CEC and BS in soil profiles.

Depth (cm)	Extractable ($mg\ kg^{-1}$)								CEC		B.S.	
	K	*	Ca	*	Mg	*	Na	*	($cmol\ kg^{-1}$)	*	(%)	*
0-5	57.75	L	226.35	VL	126.95	M	3.68	VL	6.21	ML	19.13	L
5-10	38.73	L	3.53	VL	101.10	L	4.70	VL	6.21	ML	13.80	L
10-20	44.83	L	8.58	VL	96.10	L	2.95	VL	4.02	L	20.35	L
20-30	16.98	VL	0.13	VL	69.18	L	2.98	VL	2.50	L	23.28	L
30-40	33.30	L	3.85	VL	110.55	L	2.73	VL	3.93	L	23.74	L
40-60	14.28	VL	1.83	VL	143.90	M	2.50	VL	8.04	ML	14.99	L
60-80	22.43	VL	4.53	VL	169.73	M	2.90	VL	9.64	ML	14.76	L
80-100	22.43	VL	7.58	VL	122.50	M	2.85	VL	8.39	ML	12.29	L
100-120	10.88	VL	7.23	VL	100.55	L	3.20	VL	11.07	M	7.64	L
120-140	21.05	VL	3.18	VL	59.45	L	1.98	VL	7.99	ML	6.30	L
140-160	36.68	L	3.18	VL	33.05	VL	2.33	VL	3.53	L	8.15	L
160-180	12.23	VL	4.53	VL	40.00	L	4.70	VL	6.34	ML	5.38	L
180-200	48.93	L	0.95	VL	39.73	L	0.88	VL	3.75	L	9.18	L

Notes: VL = very low, L = low, ML = moderately low, M = medium, MH = moderately high, H = high, VH = very high (Land Classification and FAO Project Staff, 1973; Soil Survey Division Staff, 1993; Land Use Planning Division, 1993)

Table 5 Storage of carbon and nutrients in soils.

Soil depth (cm)	OM	C	Total N	Available P ($kg\ ha^{-1}$)	Extractable ($kg\ ha^{-1}$)			
	($Mg\ ha^{-1}$)				K	Ca	Mg	Na
0-5	82.89	48.08	5.56	25.33	62.51	244.99	137.40	3.98
5-10	49.27	28.58	2.42	2.26	35.69	3.25	93.19	4.33
10-20	63.28	36.70	3.28	4.16	62.19	11.90	133.33	4.09
20-30	27.18	15.76	1.41	1.54	22.58	0.17	92.00	3.96
30-40	21.67	12.57	0.89	1.22	44.60	5.16	148.07	3.65
40-60	12.67	7.35	0.20	2.38	30.30	3.87	305.44	5.31
60-80	8.47	4.91	0.18	2.16	43.06	8.69	325.89	5.57
80-100	7.15	4.15	0.16	1.63	42.44	14.33	231.81	5.39
100-120	7.33	4.25	0.15	1.40	17.34	11.52	160.31	5.10
120-140	4.31	2.50	0.15	1.23	32.33	4.88	91.31	3.03
140-160	2.77	1.61	0.15	1.22	54.08	4.68	48.73	3.43
160-180	2.19	1.27	0.16	1.20	17.20	6.37	56.27	6.61
180-200	1.82	1.05	0.15	0.91	64.69	1.26	52.53	1.16
Total	**291.00**	**168.78**	**14.87**	**46.64**	**529.00**	**321.06**	**1,876.29**	**55.61**

CONCLUSION

Mae Ya Noi village is a Hmong tribe. Legally, the villagers have to manage the community forest with the cooperation of government officers. Most conservation forest is an old and new graveyard and therefore, the forest is still abundant. Utilization is a little removed from the village, mainly in the pine-montane forest. Expansion of the village and cultivated land is restricted. Carbon storage in this forest varied with location and soil profile; it was high in the surface soil and low in deeper soils. Nowadays, forest fire is critical in mountainous areas, caused mainly by human activities. It is also a problem in the management of community forests. The villagers protect against forest fire by constructing fire lines surrounding the community forest areas. The effects of forest fire on this forest ecosystem included the reduction of species richness and diversity, carbon and nutrient storage.

There are many aspects for the application of this research data including forest management, particularly with regard to highland community forests, watershed management and forest fire protection.

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