CHAPTER 3

Soil Characteristics

Abstract

The research on soil characteristics and nutrient storages in the natural pine forest of four subtype communities was carried out at Ban Chan sub-district, Kunlaya Ni Wattana district, Chiang Mai province. Three subtypes were the pine-dry dipterocarp forest of dominated *Dipterocarpus obtusifolius* (P-DDF1), *D. tuberculatus* (P-DDF2) and *Shorea obtusa* (P-DDF3), and the fourth subtype was the pine-lower montane (oak) (P-LMF) forest. Soil pits were made in each subtype, and soil samples were collected along profiles for analysis of physico-chemical properties. Soils under all subtypes were classified into Order Ultisols with the depth of more than one meter, well developed horizons and high clay accumulations in subsoils. Some small differences of physical properties among soils were observed. Bulk density varied from moderately low to medium. The texture of top soils was mainly sandy clay/sandy loam, and soil reaction were strongly acid to slightly acid (pH, 5.4-6.5). The texture in subsoils was clay, and the soil reaction varied from slightly to moderately acid (pH, 5.6-6.1).

Amounts of organic matter, carbon and nitrogen accumulated within 100 cm depth were the highest in P-LMF (146.5, 85.0 and 5.11 Mg ha^{-1}, respectively). The lower amounts were found in the P-DDF3 and P-DDF2, and P-DDF1 had the lowest amount. The differences were implied to their soil fertility. Amounts of extractable phosphorous, calcium and magnesium were the highest in soil under P-DDF1 (29.1, 1,210.1 and 1,287 kg ha^{-1}) whereas potassium was the highest in P-DDF3 (1,328.9 kg ha^{-1}).

3.1 Introduction

Soil develops from parent material by the processes of soil formation. The soil development and associated forest vegetation is a complex and continuing process (Pritchett and Fisher, 1987; Fisher and Binkley, 2000). Many factors are involved in the development of both soils and forests. The process of forming soil from a hard rock such as granite may be divided into two stages, rock weathering and soil formation. Soil forming factors include parent material, climate, topography, living organisms and time. Eventually, a series of horizons form in a typical well developed forest soil: an organic layer (O), an organically enriched mineral layer (A), an eluviated layer (E), an illuviated layer or zone of accumulation (B) and a mineral layer little altered by soil-forming processes (C). The formation of these distinctive soil horizons results from a series of complex reaction and pedogenic processes.

Soils play important roles in the development of forests. They provide water, nutrients and support for forest vegetation. The soils are derived from various rocks of different mineral composition. These differences result in variable soil properties that influence plant species composition, diversity and growth rates.

Forest vegetation also plays the vital roles on soil characteristics. Tree roots grow into fissures and aid in the breakdown of bedrock. They penetrate some compacted layer and improve aeration, soil structure, water infiltration and retention. The above-ground and below-ground litter fall result in annual input of organic matter into soil. The annual amounts of litter fall are different among forests in Thailand (Tsutsumi *et al*., 1983), 4.7-11.3 Mg ha^{-1}. The annual inputs of nutrient such as nitrogen were varied between 56.2-120 kg ha^{-1}. Decomposition of litter releases nutrients into soil. Moreover, different decomposing litter of different tree species affects on chemical properties particularly soil acidity. Khamyong and Seramethakun (2006) found that leaf decomposition of 70 tree species resulted in the different levels of soil pH, varied from ultra acid to strongly base. Most species gave acid properties to soil caused by releasing organic (humic) acids. However, some forests including deciduous and pine forests usually have the forest fire in dry season. The forest fire is one important factors affecting soil properties either physical or chemical properties (Whelan, 1995).

The objective of this research was to investigate differences of soil characteristics under the four subtype communities of a natural pine forest. The soil characteristics involved soil types, physical and chemical properties, and fertility levels.

3.2 Materials and Methods

The soil characteristics were studied in each forest subtype. Three soil pits per subtype were made up to 1.20 m depth. Soil sampling was taken at the depth of 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm. The samples were later analyzed for physical and chemical properties in laboratory.

3.2.1 Physical Properties

(1) Soil texture and analysis for particle size distribution were taken by a hydrometer method.
(2) Bulk density was determined by a core method.

3.2.2 Chemical Properties

Soil chemical properties were evaluated using the criteria used by the National Soil Survey Center (1995, 1996).

(1) Soil reaction by using a pH meter; pH (H_2O) (soil : water = 1 : 1) (Mclean, 1982)
(2) Organic matter and carbon contents were analyzed by the wet oxidation method (Nelson and Sommers,1982)
(3) Total N by using Micro Kjedahl method (Bremner and Mulvaney, 1982)
(4) Extractable phosphorus by using Bray II and colorimetric method and read by atomic absorption spectophotometer (Bray and Kunzt, 1945)
(5) Extractable bases including potassium and sodium were analyzed by using flame photometer (Knudsen and Peterson, 1982), calcium, and magnesium were extracted by ammonium acetate solution 1N, pH 7.0 and read by atomic absorption spectophotometer (Lanyon and Heald, 1982)

(6) Cation exchange capacity (CEC) extracted by ammonium acetate solution 1 N, pH 7.0 (Rhoades, 1982)
(7) Extractable acidity (EA) was extracted by using barium chloride-triethanolamine, pH 8.2 (Thomas, 1982)
(8) Base saturation percentage (BS%) is the amount of basic cations that occupy the cation exchange sites, divided by the total cation exchange capacity (CEC) (Soil Survey Staff, 1972)

$$\text{Base saturation percentage} = \frac{\text{Sum bases}}{\text{Sum bases + EA}} \times 100$$

3.3 Results

3.3.1 Soil Type and Profile Development

(1) Pine with dominant *D. obtusifolius* (P-DDF1)

It was a deep soil with well developed horizons, more than one meter. The surface soil (A/AB/BA) was grey to reddish yellow with sandy clay to sandy clay loam. Bulk density was medium. Soil reaction was moderately to slightly acid. Texture of subsoil (Bt1/Bt2/Bt3) was clay with red to dark red, and had moderately acid.

(2) Pine with dominant *D. tuberculatus* (P-DDF2)

It was also a deep soil with well developed horizons, more than one meter. The surface soil (A/BA) was grey to reddish yellow with sandy clay loam. Soil reaction was strongly to moderately acid. Texture of subsoil (Bt1/Bt2/Bt3) was clay with red to dark red, and had moderately acid.

(3) Pine with dominant *S. obtusa* (P-DDF3)

It was a deep soil with well developed horizons, more than one meter. The surface soil (A/BA) was reddish grey to reddish brown with clay loam to sandy clay. Soil reaction was moderately to slightly acid. Texture of subsoil (Bt1/Bt2/Bt3) was clay with red to dark red, and had moderately to slightly acid.

(4) Pine with oaks (P-LMF)

It was also a deep soil with the well developed horizons, more than one meter. The surface soil (A/BA) was reddish grey to reddish brown with clay loam to sandy clay loam. Soil reaction was moderately acid. Texture of subsoil (Bt1/Bt2/Bt3) was clay with red to dark red, and moderately acid.

The soils under four subtype communities were classified into Order Ultisols, the well developed horizons with high clay accumulation in subsoils and had the low base saturation (<35%).

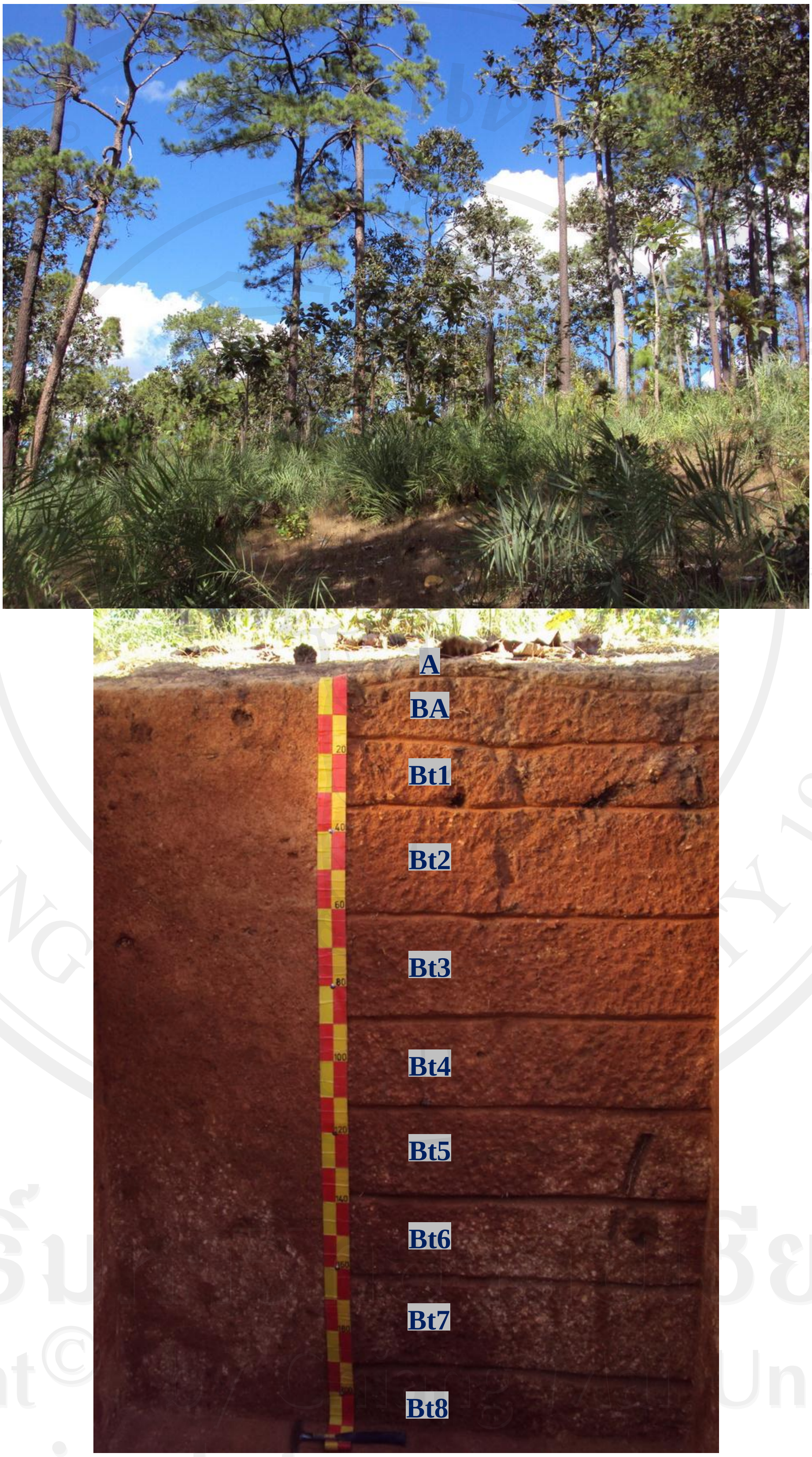

Figure 3-1 Study site and soil profile of P-DDF1

P-DDF1

I Information on the Site

Profile symbol	: P-DDF1
Soil name	: Wat Chun series 1 (tentative)
Classification	: Typic Paleustlt
Date of examination	: December 23,2010
Described by	: Niwat Anongrak Soontorn Khamyong and Trin Serамethakun
Location	: Approximately 90 km north from Chiang Mai City. Tumbon Ban Chun, Kunlaya Ni Wattana District. Chiang Mai Province. Grid Reference: 47Q 2105737 N, 0428927 E (Sheet: 4647 II)
Elevation	: 950 m (MSL)
Land form	
1. Physiographic position	
2. Surrounding land form	: Mountainous
3. Slope on which profile site	: Steep (25%), S 80 ^{0} W aspect
Vegetation and land use	: Under Pine forest. The dominant tree is *Pinus merrkusii*, *P. kesiya* and *Dipterocarpus obtusifolius*
Annual rainfall	: Approximately 1,200 mm/yr
Mean temperature	: Approximately 22.0 ^{0}C
Other	: Nil

II General Information on the Soil

Parent material	: Derived “insitu” granitic rocks in Triassic period
Drainage	: Well drained
Moisture condition in profile	: Dry throughout
Depth of ground water table	: Nil
Surface stones and rock outcrops	: No stones and no rocks
Evidence of erosion	: Moderate sheet erosion
Human influence	: Nil

III Profile Description :

No	Horizon	Depth (cm)	Description
1	A	0-3/5	Very dusky red (2.5YR2.5/2) moist and dark reddish gray (2.5YR4/0) dry; sandy clay loam; moderate fine and weak medium subangular blocky structure; many fine and medium, few coarse pores; common fine, medium and coarse roots; moderately acid (pH 5.7); clear and smooth boundary to BA
2	BA	3/5-16/19	Dark gray (2.5YR4/0) moist and weak red (2.5YR5/2) dry; sandy clay loam; moderate fine and weak medium subangular blocky structure; common fine and medium pores; common fine, medium and coarse roots; moderately acid (pH 5.8); clear and smooth boundary to Bt1
3	Bt1	16/19-27/29	Red (2.5YR4/6) moist and light red (2.5YR5/8) dry; sandy clay; moderate medium and strong medium subangular blocky structure; common fine and medium pores; few fine, medium roots; moderately acid (pH 5.7); clear and smooth boundary to Bt2
4	Bt2	27/29-56/61	Red (2.5YR4/6) moist and red (2.5YR5/8) dry; clay; strong medium subanular blocky structure; few fine and medium pores; few fine, common medium and few coarse roots; moderately acid (pH 5.9); clear and smooth boundary to Bt3
5	Bt3	56/61-79/84	Red (2.5YR4/6) moist and red (2.5YR5/8) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 5.8); clear and smooth boundary to Bt4

No	Horizon	Depth (cm)	Description
6	Bt4	79/84-110/118	Red (2.5YR5/6) moist and red (2.5YR4/8) dry; sandy clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; slightly acid (pH 6.1); gradual and wavy boundary to Bt5
7	Bt5	110/118-137/140	Red (2.5RY4/6) moist and red (2.5YR4/8) dry; sandy clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; ; slightly acid (pH 6.1); clear and smooth boundary to Bt6
8	Bt6	137/140-163/172	Dark red (2.5YR3/6) moist and red (2.5YR4/8) dry; sandy clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine and medium roots; slightly acid (pH 6.1); gradual and wavy boundary to Bt7
9	Bt7	163/172-197/202	Dark red (2.5YR3/6) moist and red (2.5YR4/8) dry; sandy clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; slightly acid (pH 6.2); clear and smooth boundary to Bt8
10	Bt8	197/202-210/215	Red (2.5YR4/6) moist and light red (2.5YR6/8) dry; sandy clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; slightly acid (pH 6.2)

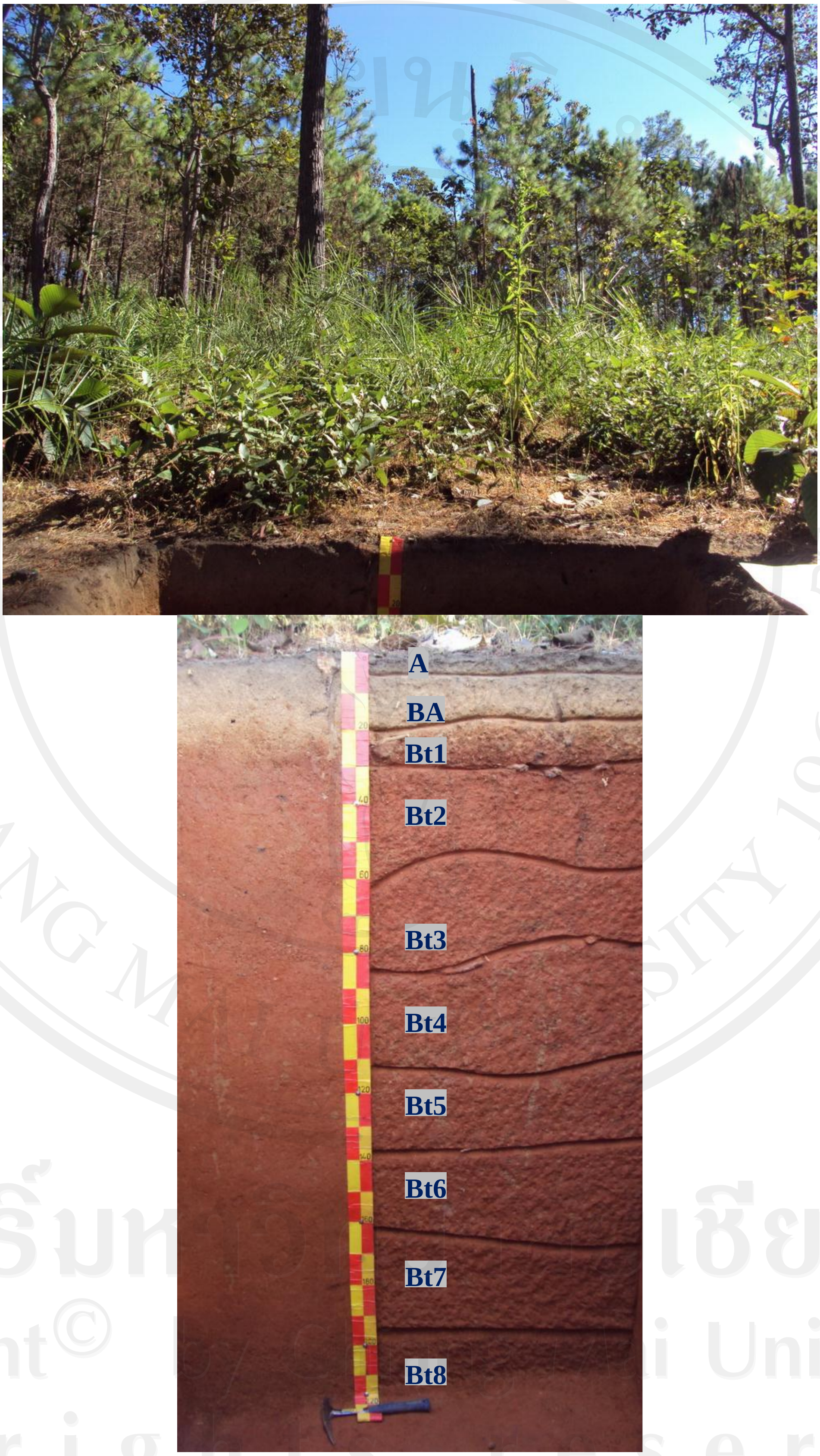

Figure 3-2 Study site and soil profile of P-DDF2

P-DDF2

I <u>Information on the Site</u>

Profile symbol	**: P-DDF2**
Soil name	: Wat Chun series 2 (tentative)
Classification	: Typic Paleustlt
Date of examination	: December 24,2010
Described by	: Niwat Anongrak Soontorn Khamyong and Trin Seramethakun
Location	:Approximately 90 km north from Chiang Mai City. Tumbon Ban Chun, Kunlaya Ni Wattana District. Chiang Mai Province. Grid Reference: 47Q 2111484 N, 0431143 E (Sheet: 4647 II)
Elevation	:1,040 m (MSL)
Land form	
1. Physiographic position	
2. Surrounding land form	: Mountainous
3. Slope on which profile site	: Steep (24%), S 5 ^{0} E aspect
Vegetation and land use	: Under Pine forest. The dominant tree is *Pinus merrkusii, P. kesiya* and *Dipterocarpus tuberculatus*
Annual rainfall	: Approximately 1,200 mm/yr
Mean temperature	: Approximately 22.0 ^{0}C
Other	: Nil

II <u>General Information on the Soil</u>

Parent material	: Derived "insitu" granitic rocks in Triassic period
Drainage	: Well drained
Moisture condition in profile	: Dry throughout
Depth of ground water table	: Nil
Surface stones and rock outcrops	: No stones and no rocks
Evidence of erosion	: Moderate sheet erosion
Human influence	: Nil

III <u>Profile Description</u> :

No	Horizon	Depth (cm)	Description
1	A	0-3/5	Weak red (2.5Y5/2) moist and pale red (2.5Y6/2) dry; sandy clay loam; moderate fine and weak medium subangular blocky structure; many fine and medium, few coarse pores; common fine, medium and coarse roots; moderately acid (pH 5.7); clear and smooth boundary to BA
2	BA	3/5-14/18	Red (2.5YR5/8) moist and light red (2.5YR6/8) dry; sandy clay loam; moderate fine and weak medium subangular blocky structure; common fine and medium pores; common fine, medium and coarse roots; strongly acid (pH 5.5); clear and wavy boundary to Bt1
3	Bt1	14/18-31/35	Red (2.5YR4/8) moist and light red (2.5YR6/6) dry; sandy clay loam; moderate medium and strong medium subangular blocky structure; common fine and medium pores; few fine, medium roots; strongly acid (pH 5.6); clear and wavy boundary to Bt2
4	Bt2	31/35-53/61	Red (2.5YR5/8) moist and light red (2.5YR6/6) dry; clay; strong medium subangular blocky structure; few fine and medium pores; few fine, common medium and few coarse roots; moderately acid (pH 5.8); gradual and wavy boundary to Bt3
5	Bt3	53/61-74/84	Red (2.5YR5/8) moist and light red (2.5YR6/8) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 5.8); gradual and wavy boundary to Bt4

No	Horizon	Depth (cm)	Description
6	Bt4	74/84-112/118	Red (2.5YR5/8) moist and light red (2.5YR6/8) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 6.0); gradual and wavy boundary to Bt5
7	Bt5	112/118-36/139	Red (2.5YR5/8) moist and light red (2.5YR6/6) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; slightly acid (pH 6.1); clear and smooth boundary to Bt6
8	Bt6	136/139-63/170	Light red (2.5YR6/8) moist and light red (2.5YR6/6) dry; clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine and medium roots; slightly acid (pH 6.1); gradual and wavy boundary to Bt7
9	Bt7	163/170-93/197	Light red (2.5YR6/8) moist and light red (2.5YR6/6) dry; clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; slightly acid (pH 6.1); clear and smooth boundary to Bt8
10	Bt8	193/197-209+	Red (2.5YR5/8) moist and light red (2.5YR6/8) dry; clay; strong fine and medium subangular blocky structure; few very fine and fine pores; slightly acid (pH 6.1)

Figure 3-3 Study site and soil profile of P-DDF3

P-DDF3

I Information on the Site

Profile symbol	**:P-DDF3**
Soil name	:Wat Chun series 3 (tentative)
Classification	:Typic Haplustult
Date of examination	:December 25,2010
Described by	: Niwat Anongrak Soontorn Khamyong and Trin Seramethakun
Location	**:**Approximately 90 km north from Chiang Mai City.Tumbon Ban Chun, Kunlaya Ni Wattana District. Chiang Mai Province. Grid Reference: 47Q 2109851 N, 0423682 E (Sheet: 4647 II)
Elevation	:1,100 m (MSL)
Land form	
1. Physiographic position	
2. Surrounding land form	: Mountainous
3. Slope on which profile site	: Steep (24%), S 5 ^{0} E aspect
Vegetation and land use	: Under Pine forest. The dominant tree is *Pinus merrkusii*, *P. kesiya* and *Shorea obtusa*
Annual rainfall	: Approximately 1,200 mm/yr
Mean temperature	: Approximately 22.0 ^{0}C
Other	: Nil

II General Information on the Soil

Parent material	: Derived "insitu" granitic rocks in Triassic period
Drainage	: Well drained
Moisture condition in profile	: Dry throughout
Depth of ground water table	: Nil
Surface stones and rock outcrops	: No stones and no rocks
Evidence of erosion	: Moderate sheet erosion
Human influence	: Nil

III Profile Description :

No	Horizon	Depth (cm)	Description
1	A	0-3/5	Dark reddish brown (5YR3/2) moist and pink (5YR7/3) dry; sandy clay loam; moderate fine and weak medium granular structure; many fine and medium, few coarse pores; common fine, medium and coarse roots; slightly acid (pH 6.5); clear and smooth boundary to BA
2	BA	3/5-12/16	Reddish brown (5YR4/4) moist and light reddish brown (5YR6/4) dry; sandy clay loam; moderate fine and weak medium subangular blocky structure; common fine and medium pores; common fine, medium and coarse roots; moderately acid (pH 5.7); clear and smooth boundary to Bt1
3	Bt1	12/16-28	Yellowish red (5YR4/6) moist and yellowish red (5YR5/6) dry; clay loam; moderate medium and strong medium subangular blocky structure; common fine and medium pores; few fine and medium roots; neutral (pH 6.8); clear and smooth boundary to Bt2
4	Bt2	28-54/58	Yellowish red (5YR5/6) moist and reddish yellow (5YR7/6) dry; clay; strong medium subangular blocky structure; few fine and medium pores; few fine, common medium and few coarse roots; moderately acid (pH 6.0); clear and wavy boundary to Bt3or Bc3
5	Bt3	54/58-86/99	Yellowish red (5YR4/6) moist and reddish yellow (5YR6/6) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 6.0); gradual and wavy boundary to 2Bt4

No	Horizon	Depth (cm)	Description
6	2Bt4	86/99-112/127	Reddish yellow (5YR6/6) moist and pink (5YR7/4) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 6.0); gradual and wavy boundary to 2Bt5
7	2Bt5	112/127-131/160	Reddish yellow (5YR6/6) moist and pink (5YR7/4) dry; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 6.0); diffuse and wavy boundary to 2BC
8	2BC	131/160-145/187	Reddish yellow (5YR6/6) moist and pink (5YR8/3) dry; clay loam; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine and medium roots; common sub-angular stones of granite and weathered diorite; moderately acid (pH 6.0); diffuse and wavy boundary to 2C1
9	2C1	145/187-160/200	Reddish yellow (7.5YR7/6) moist and yellowish red (7.5YR8/3) dry; clay loam; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; many sub-angular boulders of granite and weathered diorite; moderately acid (pH 6.0); diffuse and wavy boundary to 2C2
10	2C2	160/200-210+	Pink (7.5YR8/4) moist and pinkish gray (7.5YR7/2) dry; clay loam; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; many sub-angular boulders of granite and weathered diorite; moderately acid (pH 6.0)

Figure 3-4 Study site and soil profile of P-LMF

P-LMF

I Information on the Site

Profile symbol	**: P-LMF**
Soil name	:Wat Chun Series 4 (tentative)
Classification	:Typic Paleudult
Date of examination	August 03, 2011
Described by	: Niwat Anongrak Soontorn Khamyong and Trin Seramethakun
Location	**:**Approximately 90 km north from Chiang Mai City. Tumbon Ban Chun, Kunlaya Ni Wattana District. Chiang Mai Province. Grid Reference: 47Q 2112086 N, 0420167 E, (Sheet: 4647 II)
Elevation	:1,100 m (MSL)
Land form	
1. Physiographic position	
2. Surrounding land form	: Mountainous
3. Slope on which profile site	: Steep (35%), S 20^0 E aspect
Vegetation and land use	: Under Pine forest. The dominant tree is *Pinus merrkusii*, *P. kesiya* and aok
Annual rainfall	: Approximately 1,200 mm/yr
Mean temperature	: Approximately 22.0 ^{0}C
Other	: Nil

II General Information on the Soil

Parent material	: Derived "insitu" granitic rocks in Triassic period
Drainage	: Well drained
Moisture condition in profile	: Moist throughout
Depth of ground water table	: Nil
Surface stones and rock outcrops	: No stones and no rocks.
Evidence of erosion	: Slight sheet erosion
Human influence	: Nil

III Profile Description :

No	Horizon	Depth (cm)	Description
1	A	0-9	Dark reddish brown (2.5Y3/4) moist; sandy clay loam; moderate fine and weak medium subangular blocky structure; many fine, medium and few coarse pores; many fine, medium and few coarse roots; moderately acid (pH 5.8); clear and smooth boundary to BA
2	BA	9-27	Dark reddish brown (2.5Y3/4) moist; clay loam; moderate fine and weak medium subangular blocky structure; common fine, medium and few coarse pores; common fine, medium and few coarse roots; moderately acid (pH 5.6); clear and smooth boundary to Bt1
3	Bt1	27-47	Red (2.5YR4/6) moist; clay; moderate medium and strong medium subangular blocky structure; common fine and medium pores; few fine, medium roots; moderately acid (pH 5.8); clear and smooth boundary to Bt2
4	Bt2	47-66	Red (2.5YR4/6) moist; clay; strong medium subangular blocky structure; few fine and medium pores; few fine, common medium and few coarse roots; moderately acid (pH 5.8); clear and smooth boundary to Bt3
5	Bt3	66-92	Red (2.5YR4/6) moist; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 5.7); clear and smooth boundary to Bt4
6	Bt4	92-121	Red (2.5YR5/8) moist; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 5.9); clear and smooth boundary to Bt5

No	Horizon	Depth (cm)	Description
7	Bt5	121-150	Red (2.5RY5/8) moist; clay; strong fine and medium subangular blocky structure; few fine and medium pores; few fine and medium roots; moderately acid (pH 6.0); clear and smooth boundary to Bt6
8	Bt6	150-179	Red (2.5RY5/6) moist; clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine and medium roots; moderately acid (pH 5.9); clear and smooth boundary to Bt7
9	Bt7	179-210+	Red (2.5RY5/6) moist; clay; strong fine and medium subangular blocky structure; few very fine and fine pores; few fine roots; moderately acid (pH 6.0)

Table 3-1 Some physical properties in soil profiles under four subtypes of pine forest

Forest subtyps		Soil depth (cm)	Bulk density (Mg.m^{-3})	*	Gravel (%)	Soil particle %	Sand	Silt	Clay	Soil texture
P-DDF1	A	0-3/5	1.5	M	3.9	96.1	64.4	6.6	29.0	Sandy
	E or	3/5-16/19	1.4	M	2.1	97.9	56.9	8.3	34.8	Sandy
	Bt1	16/19-27/29	1.4	M	9.9	90.1	43.9	7.7	48.4	Sandy
	Bt1	27/29-54/61	1.4	ML	7.2	92.8	38.5	9.8	51.7	Clay
	Bt2	54/61-79/84	1.4	ML	8.7	91.3	40.5	11.8	47.6	Clay
	Bt3	79/84-110/118	1.4	ML	12.8	87.2	40.7	11.1	48.2	Sandy
	Bt4	110/118-	1.4	ML	15.7	84.3	41.0	11.0	48.0	Sandy
	Bt5	137/140-	1.4	ML	17.4	82.6	40.4	11.6	48.0	Sandy
	Bt6	163/172-	1.4	ML	18.5	81.5	40.0	12.0	48.0	Sandy
	Bt7	197/202-	1.4	ML	18.5	81.5	40.0	12.0	48.0	Sandy
P-DDF2	A	0-3/5	1.5	M	7.2	92.8	64.4	6.6	29.0	Sandy
	Bt1	3/5-16	1.5	M	8.8	91.2	54.0	13.4	32.5	Sandy
	Bt1	16-33	1.5	M	8.2	91.8	46.0	13.0	40.9	Sandy
	Bt2	33-61	1.5	M	18.0	82.0	44.4	12.9	42.7	Clay
	Bt3	61-89	1.4	ML	15.1	84.9	43.9	13.5	42.6	Clay
	Bt4	89-113	1.4	ML	21.6	78.4	42.9	14.8	42.3	Clay
	Bt5	113-139	1.4	ML	22.8	77.2	43.0	15.0	42.0	Clay
	BC1	139-163	1.4	ML	26.3	73.7	43.5	15.5	40.9	Clay
	BC2	163-193	1.4	ML	29.3	70.7	44.0	16.0	40.0	Clay
	BC3	193-209+	1.4	ML	29.3	70.7	44.0	16.0	40.0	Clay
P-DDF3	A	0-3/5	1.2	ML	3.9	96.1	58.6	16.6	24.8	Sandy
	BA	3/5-14	1.3	ML	10.4	89.6	43.8	21.9	34.3	Sandy
	Bt1	14-28	1.5	M	6.3	93.7	41.5	29.6	28.9	Clay loam
	Bt2	28-54/58	1.3	ML	3.6	96.4	31.4	12.9	55.7	Clay
	Bt3	54/58-86/99	1.4	ML	16.2	83.8	29.2	18.3	52.5	Clay
	2Bt4	86/99-112/127	1.4	M	15.3	84.7	30.4	24.8	44.8	Clay
	2Bt5	112/127-	1.5	M	18.8	81.2	33.0	24.5	42.5	Clay
	2BC	131/160-	1.5	M	31.1	68.9	36.9	23.5	39.6	Clay loam
	2C	145/187-	1.5	M	34.6	65.4	38.0	23.2	38.8	Clay loam
	2R	160/200-210+	1.5	M	34.6	65.4	38.0	23.2	38.8	Clay loam
P-LMF	A	0-9	1.3	ML	4.3	95.7	50.6	24.2	25.2	Sandy
	BA	9-27	1.4	M	3.9	96.1	37.3	26.8	35.9	Clay loam
	Bt1	27-47	1.5	M	4.0	96.0	36.7	22.4	40.9	Clay
	Bt2	47-66	1.5	M	3.2	96.8	37.2	20.5	42.3	Clay
	Bt3	66-92	1.5	M	11.4	88.6	37.9	20.8	41.4	Clay
	Bt4	92-121	1.5	M	24.5	75.5	36.8	20.6	42.6	Clay
	Bt5	121-150	1.5	M	25.4	74.6	37.0	20.0	43.0	Clay
	Bt6	150-179	1.5	M	23.8	76.2	38.0	21.0	41.0	Clay
	Bt7	179-210+	1.5	M	23.8	76.2	38.0	21.0	41.0	Clay

Table 3-2 Some chemical properties in soil profiles under four subtypes of pine forest

Forest subtype	Soil (cm)	pH		O.M. (g.kg^{-1})	*	C (g.kg^{-1})	*	Total N (g.kg^{-1})	*	C/N ratio	Available P (mg.kg^{-1})	*	Extractable (mg.kg^{-1}) K	*	Ca	*	Mg	*	Na	*	CEC (cmol.kg^{-1})	*
P-DDF1	0-5	5.7	moderately acid	26.6	MH	15.4	MH	0.8	VL	19.3	14.0	M	82.0	M	300.0	VL	112.7	L	2	VL	11.0	M
	5-10	6.2	slightly acid	12.1	ML	7.0	ML	0.4	VL	17.5	19.0	MH	72.5	M	170.0	VL	108.1	L	1.25	VL	9.2	ML
	10-20	5.6	moderately acid	13.3	ML	7.7	ML	0.4	VL	19.3	4.2	L	101.0	H	142.0	VL	148.4	ML	1.75	VL	12.2	M
	20-30	5.7	moderately acid	6.9	L	4.0	L	0.2	VL	20.0	0.1	VL	80.0	M	76.0	VL	117.3	ML	1.25	VL	12.8	M
	30-40	5.8	moderately acid	4.5	VL	2.6	VL	0.2	VL	13.1	nd.	VL	79.5	M	56.0	VL	40.3	L	1.63	VL	12.4	M
	40-60	6.0	moderately acid	4.7	VL	2.7	VL	0.2	VL	13.6	nd.	VL	72.5	M	64.0	VL	103.5	L	2.13	VL	11.2	M
	60-80	5.2	moderately acid	2.2	VL	1.3	VL	0.2	VL	6.4	0.1	VL	57.5	L	68.0	VL	97.8	L	1.75	VL	10.3	M
	80-100	6.1	slightly acid	1.8	VL	1.0	VL	0.2	VL	5.2	nd.	VL	53.0	L	76.0	VL	90.9	L	0.63	VL	11.6	M
P-DDF2	0-5	5.7	moderately acid	34.4	MH	20.0	MH	1.1	L	18.1	6.7	ML	112.5	H	98.0	VL	101.2	L	2.25	VL	14.8	M
	5-10	5.6	moderately acid	25.2	MH	14.6	MH	0.5	VL	29.2	3.4	L	105.0	H	40.0	VL	64.4	L	2.38	VL	10.9	M
	10-20	5.4	strongly acid	16.5	M	9.6	M	0.5	VL	19.1	0.9	VL	93.5	H	32.0	VL	55.2	L	8.5	VL	9.0	ML
	20-30	5.6	moderately acid	11.6	ML	6.7	ML	0.4	VL	16.8	nd.	VL	114.5	H	20.0	VL	40.3	L	2.75	VL	9.3	ML
	30-40	5.8	moderately acid	6.2	L	3.6	L	0.4	VL	9.0	nd.	VL	109.0	H	12.0	VL	33.4	VL	2.15	VL	8.8	ML
	40-60	5.8	moderately acid	3.3	L	1.9	L	0.3	VL	6.4	nd.	VL	88.5	M	14.0	VL	29.9	VL	0.75	VL	10.3	M
	60-80	5.8	moderately acid	5.1	L	3.0	L	0.2	VL	14.8	nd.	VL	78.5	M	30.0	VL	35.7	L	1.63	VL	8.7	ML
	80-100	6.0	moderately acid	3.4	VL	2.0	VL	0.2	VL	9.9	nd.	VL	76.5	M	46.0	VL	40.3	L	0.5	VL	6.2	ML
P-DDF3	0-5	6.5	slightly acid	53.5	VH	31.0	VH	1.2	L	25.9	8.3	ML	187.5	VH	674.0	L	261.1	M	1.75	L	16.1	MH
	5-10	5.4	strongly acid	35.6	H	20.6	H	0.8	VL	25.8	nd.	VL	158.0	VH	78.0	VL	69.0	L	1.63	VL	12.2	M
	10-20	5.8	moderately acid	20.2	M	11.7	M	0.6	VL	19.5	nd.	VL	199.5	VH	54.0	VL	70.2	L	1.63	VL	13.0	M
	20-30	6.1	moderately acid	12.9	ML	7.5	ML	0.5	VL	15.0	nd.	VL	154.5	VH	46.0	VL	108.1	L	2.13	VL	13.1	M
	30-40	6.2	moderately acid	5.9	L	3.4	L	0.4	VL	8.6	nd.	VL	131.5	VH	60.0	VL	108.1	L	2.13	VL	13.1	M
	40-60	6.0	moderately acid	1.6	VL	0.9	VL	0.3	VL	3.1	nd.	VL	73.5	M	52.0	VL	81.7	L	1.63	VL	13.1	M
	60-80	6.0	moderately acid	2.6	VL	1.5	VL	0.2	VL	7.5	nd.	VL	61.5	M	48.0	VL	72.5	L	1.5	VL	10.1	M
	80-100	6.0	moderately acid	0.6	VL	0.3	VL	0.2	VL	1.7	nd.	VL	65.5	M	46.0	VL	69.0	L	2.13	VL	10.2	M
P-LMF	0-5	5.9	moderately acid	58.5	VH	33.9	VH	1.3	L	26.1	5.8	L	45.5	L	328.0	VL	95.5	L	3.25	VL	12.0	M
	5-10	5.6	moderately acid	28.1	MH	16.3	MH	0.6	VL	27.2	5.0	L	26.5	VL	44.0	VL	28.8	L	4.13	VL	9.1	ML
	10-20	5.5	moderately acid	21.0	M	12.2	M	0.5	VL	24.4	0.9	VL	18.0	VL	32.0	VL	20.7	L	3.75	VL	10.2	M
	20-30	5.6	moderately acid	13.4	ML	7.8	ML	0.4	VL	19.4	nd.	VL	13.5	VL	36.0	VL	21.9	L	3.25	VL	10.4	M
	30-40	5.7	moderately acid	7.5	L	4.4	L	0.3	VL	14.5	nd.	VL	16.0	VL	54.0	VL	27.6	L	3.25	VL	9.6	ML
	40-60	5.9	moderately acid	5.6	L	3.2	L	0.3	VL	10.8	nd.	VL	13.5	VL	72.0	VL	34.5	L	1.88	VL	11.0	M
	60-80	5.6	moderately acid	3.8	VL	2.2	VL	0.3	VL	7.3	nd.	VL	69.0	M	22.0	VL	16.1	L	2.63	VL	9.6	ML
	80-100	5.8	moderately acid	2.9	VL	1.7	VL	0.2	VL	8.4	nd.	VL	4.5	VL	26.0	VL	20.7	L	2.13	VL	7.8	ML

Note: * 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)

3.3.2 Soil Physical Properties

Some soil physical properties including bulk density, amounts of gravel, soil particle distribution and soil texture were given in **Table 3-1**.

(1) Bulk density

The bulk densities in soils under the four subtype communities were slightly low to medium in surface soils, and subsoils.

P-DDF1 : The bulk densities in surface soil at 0-30 cm depth were medium (1.41-1.45 Mg m^{-3}), and slightly low (1.36-1.39 Mg m^{-3}) in subsoil (30-100 cm depth).

P-DDF2 : The densities in surface soil at 0-60 cm depth were medium (1.41-1.54 Mg m^{-3}), and slightly low (1.37-1.38 Mg m^{-3}) in subsoil (60-100 cm depth).

P-DDF3 : The densities in surface soil at 0-60 cm depth were slightly low (1.24-1.39 Mg m^{-3}) nearly throughout soil profile (0-80 cm depth).

P-LMF : The densities in surface soil at 0-10 cm depth were slightly low (1.22-1.36 Mg m^{-3}), and medium (1.42-1.55 Mg m^{-3}) in the deeper soil (10-100 cm depth).

(2) Gravel contents

The gravel contents in soils under the four subtype communities were low in surface soils, and some increases were occurred in the subsoils.

P-DDF1 : The gravel content was low in surface soil (2.1-9.9% by weight) and slightly increased (12.8-18.5%) in the subsoil.

P-DDF2 : It was low in the surface soil (7.2-8.8% by weight) and increased (15.1-29.3%) in the subsoil.

P-DDF3 : It was low in the surface soil (3.6-10.4% by weight) and increased (15.3-34.6%) in the subsoil.

P-LMF : It was low in the surface soil (3.3-3.9% by weight) and increased (11.4-23.8%) in the subsoil.

(3) Soil particle distribution

The sand particle in soils under the four subtype communities was high in surface soils (0-20 cm depth) and decreased in subsoils. The silt particle had small proportions throughout their soil profiles. The clay contents in these soil profiles varied between 20-40% in surface soils, and increased to 40-60% in the subsoils.

P-DDF1 : The sand, silt and clay contents in soil profile varied between 38.5-64.4, 6.6-12.0 and 29.0-51.7% by weight, respectively.

P-DDF2 : The sand, silt and clay contents in soil profile varied between 42.9-64.4, 6.6-16.0 and 29.0-42.7% by weight, respectively.

P-DDF3 : The sand, silt and clay contents in soil profile varied between 29.2-58.6, 12.9-29.6 and 24.8-55.7% by weight, respectively.

P-LMF : The sand, silt and clay contents in soil profile varied between 36.7-50.6, 20.0-26.8 and 25.2-42.6% by weight, respectively.

(4) Soil texture

The soil texture refers to the relative proportion of sand, silt and clay particles. These soils were the fine-textured soil.

P-DDF1 : In surface soil, the texture was sandy clay whereas those in the subsoil were sandy clay to clay.

P-DDF2 : The texture in surface soil was sandy clay while that in the subsoil was clay.

P-DDF3 : The texture in surface soil was sandy clay whereas those in the subsoil were clay to clay loam.

P-LMF : The texture in surface soil was sandy clay or clay loam whereas that in the subsoil was mainly clay.

3.4.3 Soil Chemical Properties

Soil reaction (pH), contents of organic matter, carbon, nitrogen, and extractable minerals were investigated as soil chemical properties. The data were given in **Table 3-2**.

(1) Soil reaction

The soil reaction was considered by pH values.

P-DDF1 : The reaction of surface soil (0-10 cm depth) was moderately acid (pH, 5.7) and slightly to moderately in the deeper soil (pH, 5.2-6.1).

P-DDF2 : The reaction of surface soil (0-10 cm depth) was moderately acid (pH, 5.6-5.7), strongly acid (pH, 5.4) at 10-20 cm depth, and moderately acid in the deeper soil (pH, 5.6-6.0).

P-DDF3 : The reaction of surface soil (0-5 cm depth) was slightly acid (pH, 6.5), strongly acid (pH, 5.4) at 5-10 cm depth and moderately acid in the deeper soil (pH, 5.5-6.2).

P-LMF : The soil reaction was moderately acid throughout the soil profile (pH, 5.5-5.9).

(2) Soil organic matter (SOM) and carbon

P-DDF1 : The SOM content was moderately high at 0-5 cm depth, moderately low at 5-20 cm depth, and low to very low in the deeper soil.

P-DDF2 : The content was moderately high at 0-10 cm depth, medium at 10-20 cm, moderately low at 20-30 cm and low to very low in the deeper soil.

P-DDF3 : The content was very high at 0-5 cm depth, high at 5-10 cm, medium at 10-20 cm, moderately low at 20-30 cm and low to very low in the deeper soil.

P-LMF : The content was very high at 0-5 cm depth, moderately high at 5-10 cm, medium at 10-20 cm, moderately low at 20-30 cm and low to very low in the deeper soil.

The carbon contents in soils were the same trends as the organic matter since it was 58% of SOM in average.

(3) Total nitrogen and C/N ratios

P-DDF1 : The contents of total nitrogen were very low throughout the soil profile. C/N ratios in the surface soil varied between 17.5-20.0, and decreased to 5.2-13.1 in the subsoil.

P-DDF2 : The content of total nitrogen was low at 0-5 cm depth, and very low in the deeper soil. The C/N ratios in surface soil varied between 16.8-29.2, and declined to 6.4-14.8 in the subsoil.

P-DDF3 : The content of total nitrogen was low at 0-5 cm depth, and very low in the deeper soil. The C/N ratios in surface soil varied between 15.0-25.9, and declined to 1.7-8.6 in the subsoil.

P-LMF : The content of total nitrogen was low at 0-5 cm depth, and very low in the deeper soil. The C/N ratios in surface soil varied between 19.4-27.2, and declined to 7.3-14.5 in the subsoil.

(4) Available phosphorus

P-DDF1 : The content of available P was medium at 0-5 cm depth, moderately high at 5-10 cm, and low to very low in the deeper soil.

P-DDF2 : The content of available P was moderately low at 0-5 cm depth and low to very low in the deeper soil.

P-DDF3 : The content of available P was moderately low at 0-5 cm depth and very low in the deeper soil.

P-LMF : The content of available P was low at 0-10 cm depth and very low in the deeper soil.

(5) Extractable potassium

P-DDF1 : The content of extractable K was medium at 0-10 cm depth, high at 10-20 cm, medium at 20-60 cm and low in the deeper soil.

P-DDF2 : The content of extractable K was high at 0-40 cm depth and medium in the deeper soil.

P-DDF3 : The content of extractable K was very high at 0-40 cm depth and medium in the deeper soil.

P-LMF : The content of extractable K was low at 0-5 cm depth and almost very low in the deeper soil.

(6) Extractable calcium

P-DDF1 : The contents of extractable Ca were very low throughout soil profile.

P-DDF2 : The contents of extractable Ca were very low throughout soil profile.

P-DDF3 : The content of extractable Ca was low at 0-5 cm depth and was very low throughout soil profile.

P-LMF : The contents of extractable Ca were very low throughout soil profile.

(7) Extractable magnesium

P-DDF1 : The content of extractable Mg was low at 0-10 cm depth, moderately low at 10-30 cm and was low in the deeper soil.

P-DDF2 : The content of extractable Mg was low in surface soil and very low in the deeper soil.

P-DDF3 : The content of extractable Mg was medium at 0-5 cm depth and low in the deeper soil.

P-LMF : The contents of extractable Mg were low throughout soil profile.

(8) Cation exchange capacity (CEC)

P-DDF1 : The CEC was medium at 0-5 cm depth, moderately low at 5-10 cm and medium in the deeper soil.

P-DDF2 : The CEC was medium at 0-10 cm depth, moderately low at 10-40 cm and medium to moderately low in the deeper soil.

P-DDF3 : The CEC was moderately high at 0-5 cm depth and medium in the deeper soil.

P-LMF : The CEC values were medium to moderately low throughout the soil profile.

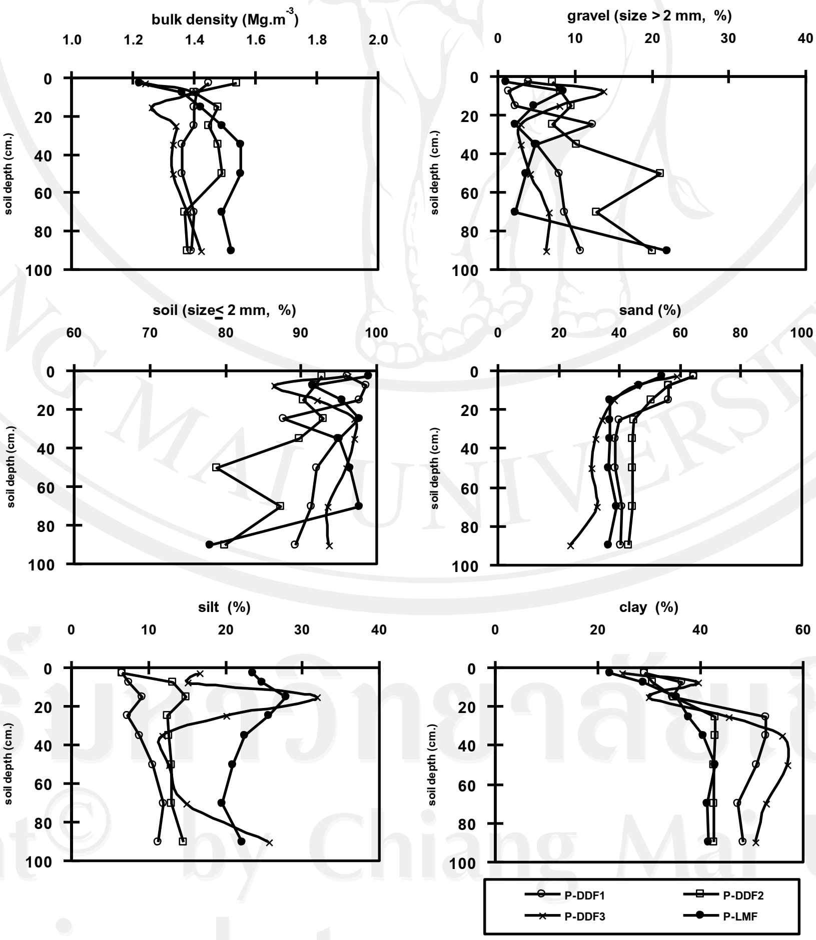

Figure 3-5 Physical properties in one-meter soil profiles under different subtypes of pine forest

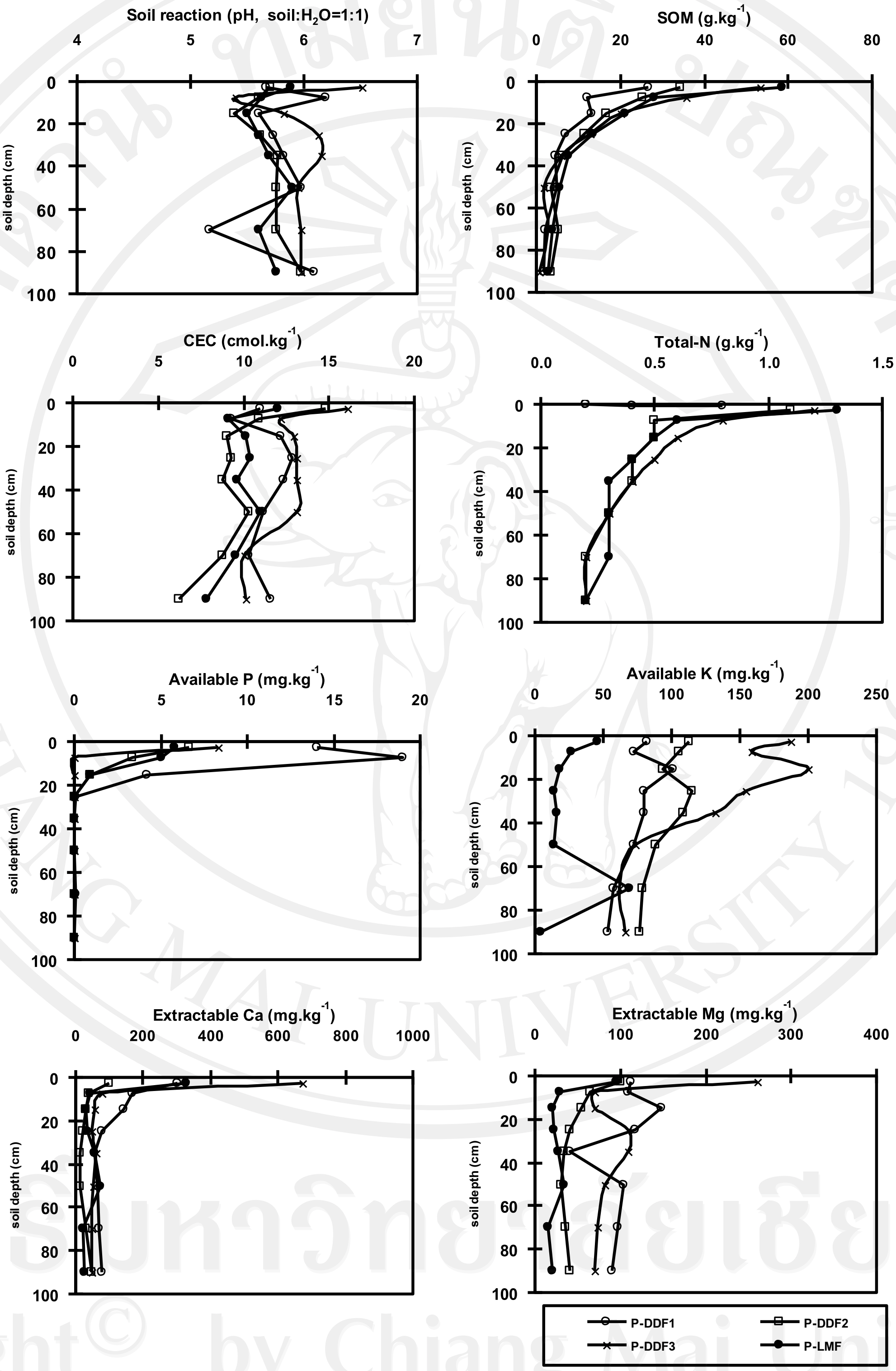

Figure 3-6 Chemical properties in one-meter soil profiles under different subtypes of pine forest

3.3.4 Amounts of Soil Carbon and Nutrient Storages

Amounts of organic matter, carbon and nutrient accumulated in soils under four subtype communities of the pine forest were given in **Table 3-3** (**Figure 3-7** to **3-9).**

(1) Organic matter and carbon

More than 50% of organic matter in soils under the four subtypes of pine forest were stored at the depth of 0-20 cm, and the mounts were decreased in deeper horizons. The amount was the highest in P-LMF, and followed by P-DDF3, P-DDF2 and P-DDF1, respectively.

P-DDF1 : The total amount of soil organic matter and carbon within 100 cm depth was 81.3 and 47.1 Mg ha^{-1}, respectively.
P-DDF2 : The total amount of soil organic matter and carbon within 100 cm depth was 108.9 and 63.2 Mg ha^{-1}, respectively.
P-DDF3 : The total amount of soil organic matter and carbon within 100 cm depth was 113.4 and 65.8 Mg ha^{-1}, respectively.
P-LMF : The total amount of soil organic matter and carbon within 100 cm depth was 146.5 and 85.0 Mg ha^{-1}, respectively.

(3) Nitrogen

P-DDF1 : The total amount of soil nitrogen within 100 cm depth was 3,395.8 kg ha^{-1}.
P-DDF2 : The total amount of soil nitrogen within 100 cm depth was 4,302.6 kg ha^{-1}.
P-DDF3 : The total amount of soil nitrogen within 100 cm depth was 4,870.8 kg ha^{-1}.
P-LMF : The total amount of soil nitrogen within 100 cm depth was 5,105.1 kg ha^{-1}.

The amount of total nitrogen in soil under P-LMF was the highest, and followed by P-DDF3, P-DDF2 and P-DDF1, respectively.

(4) Available Phosphorus

P-DDF1 : The total amount of available phosphorus in soil within 100 cm depth was 29.1 kg ha^{-1}.
P-DDF2 : The total amount of available phosphorus in soil within 100 cm depth was 7.1 kg ha^{-1}.
P-DDF3 : The total amount of available phosphorus in soil within 100 cm depth was 4.9 kg ha^{-1}.
P-LMF : The total amount of available phosphorus in soil within 100 cm depth was 7.9 kg ha^{-1}.

The amount of available phosphorus in soil under P-DDF1 was the highest, and followed by P-LMF, P-DDF2 and P-DDF3, respectively.

(5) Extractable Potassium

P-DDF1 : The total amount of extractable potassium in soil within 100 cm depth was 906.9 kg ha^{-1}.
P-DDF2 : The total amount of extractable potassium in soil within 100 cm depth was 1,119.4 kg ha^{-1}.
P-DDF3 : The total amount of extractable potassium in soil within 100 cm depth was 1,328.9 kg ha^{-1}.
P-LMF : The total amount of extractable potassium in soil within 100 cm depth was 363 kg ha^{-1}.

The amount of extractable potassium in soil under P-DDF3 was the highest, and followed by P-DDF2, P-DDF1 and P-LMF, respectively.

(6) Extractable Calcium

P-DDF1 : The total amount of extractable calcium in soil within 100 cm depth was 1,210.1 kg ha^{-1}.
P-DDF2 : The total amount of extractable calcium in soil within 100 cm depth was 372.4 kg ha^{-1}.
P-DDF3 : The total amount of extractable calcium in soil within 100 cm depth was 1,027.3 kg ha^{-1}.
P-LMF : The total amount of extractable calcium in soil within 100 cm depth was 741.7 kg ha^{-1}.

The amount of extractable calcium in soil under P-DDF1 was the highest, and followed by P-DDF3, P-LMF and P-DDF2, respectively.

(7) Extractable Magnesium

P-DDF1 : The total amount of extractable magnesium in soil within 100 cm depth was 1,287.5 kg ha^{-1}.
P-DDF2 : The total amount of extractable magnesium calcium in soil within 100 cm depth was 514.9 kg ha^{-1}.
P-DDF3 : The total amount of extractable c magnesium in soil within 100 cm depth was 1,137.2 kg ha^{-1}.
P-LMF : The total amount of extractable magnesium in soil within 100 cm depth was 375.1 kg ha^{-1}.

The amount of extractable magnesium in soil under P-DDF1 was the highest, and followed by P-DDF3, P-DDF2 and P-LMF, respectively.

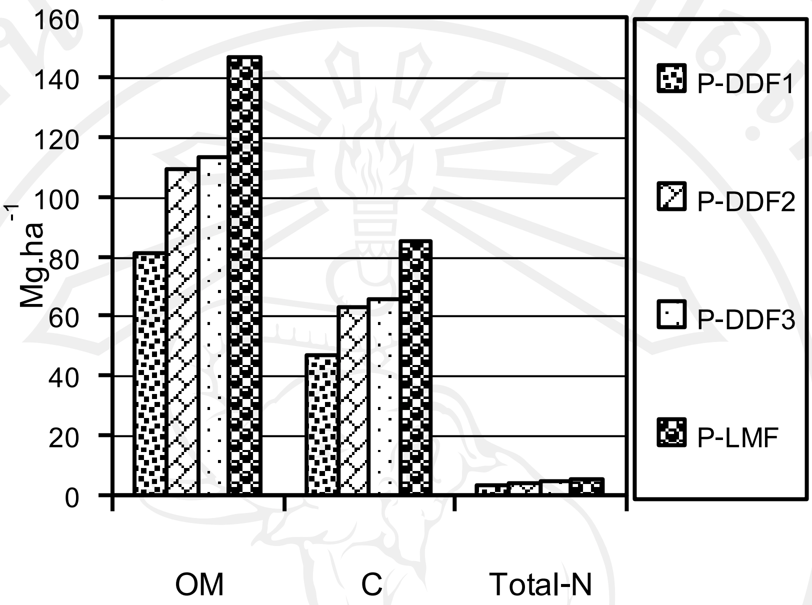

Figure 3-7 Amounts of soil organic matter, carbon and nitrogen in one-meter soil profiles under different subtypes of pine forest

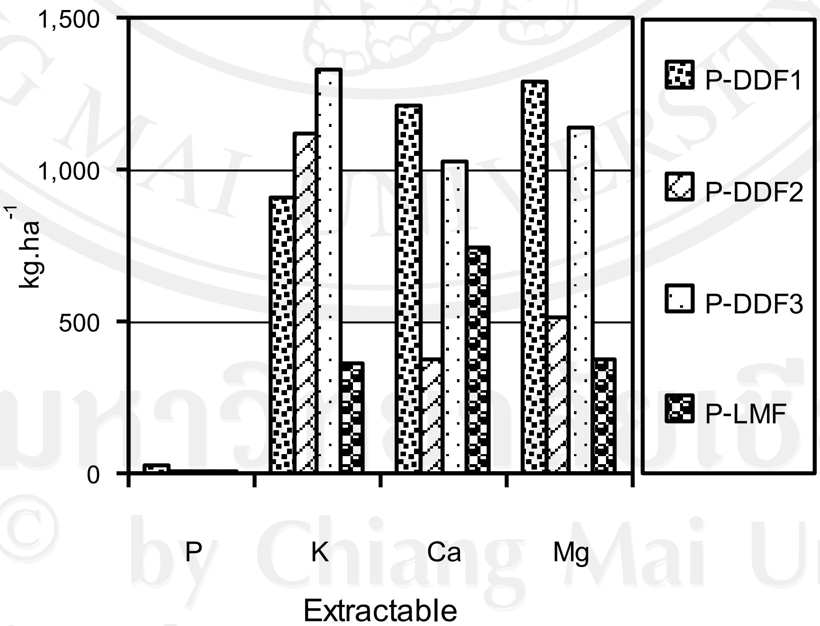

Figure 3-8 Amounts of available P, extractable K, Ca and Mg in one-meter soil profiles under different subtypes of pine forest

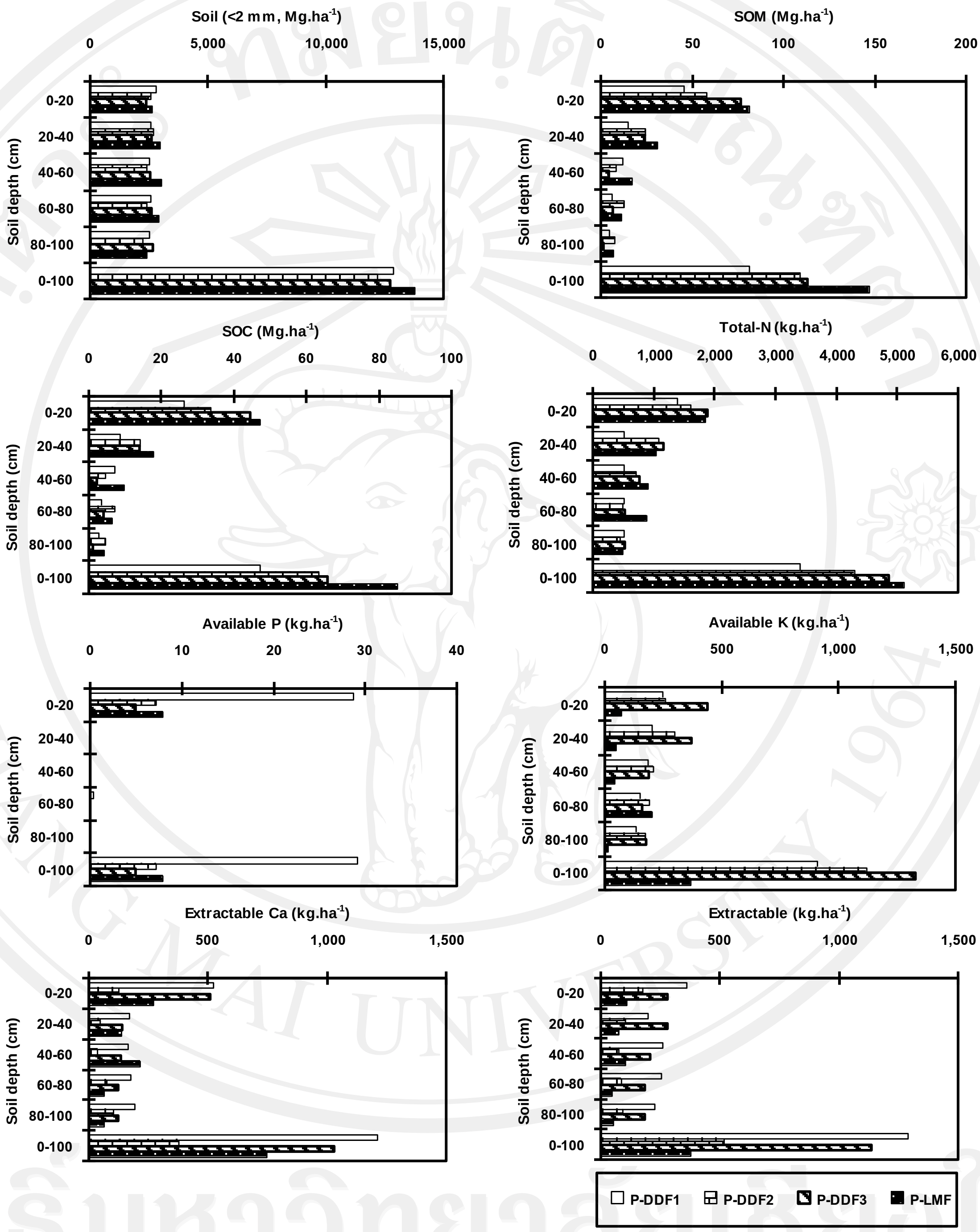

Figure 3-9 Variations with soil depth of the nutrient amounts in soil profiles under different subtypes of pine forest

Table 3-3 Soil organic matter, carbon and nutrient amounts in four-subtype pine forest

Forest type	Soil depth	Soil	SOM	SOC	Total-N	Avai. P	Avai. K	Extr. Ca	Extr. Mg
	(cm)	(Mg.ha^{-1})			(kg.ha^{-1})				
P-DDF1	0-5	696.7	18.5	10.7	557.4	9.8	57.1	209.0	78.5
	5-10	695.3	8.4	4.9	278.1	13.2	50.4	118.2	75.2
	10-20	1,367.7	18.2	10.6	547.1	5.7	138.1	194.2	202.9
	20-30	1,227.5	8.5	4.9	245.5	0.1	98.2	93.3	144.0
	30-40	1,291.6	5.8	3.4	258.3	-	102.7	72.3	52.0
	40-60	2,505.4	11.8	6.8	501.1	-	181.6	160.3	259.3
	60-80	2,558.1	5.6	3.3	511.6	-	147.1	173.9	250.1
	80-100	2,483.4	4.5	2.6	496.7	-	131.6	188.7	225.6
	0-100	12,825.7	81.3	47.1	3,395.8	29.1	906.9	1,210.1	1,287.5
P-DDF2	0-5	560.7	19.3	11.2	616.8	3.7	63.1	54.9	56.7
	5-10	642.9	16.2	9.4	321.4	2.2	67.5	25.7	41.4
	10-20	1,337.8	22.1	12.8	668.9	1.2	125.1	42.8	73.8
	20-30	1,347.3	15.6	9.1	538.9	-	154.3	26.9	54.2
	30-40	1,329.6	8.2	4.8	531.9	-	144.9	16.0	44.3
	40-60	2,352.1	7.8	4.5	705.6	-	208.2	32.9	70.3
	60-80	2,391.2	12.2	7.1	478.2	-	187.7	71.7	85.2
	80-100	2,204.4	7.5	4.3	440.9	-	168.6	101.4	88.7
	0-100	12,166.0	108.9	63.2	4,302.6	7.1	1,119.4	372.4	514.9
P-DDF3	0-5	596.0	31.9	18.5	715.2	4.9	111.8	401.7	155.6
	5-10	600.1	21.4	12.4	480.1	-	94.8	46.8	41.4
	10-20	1,159.6	23.4	13.6	695.7	-	231.3	62.6	81.3
	20-30	1,300.2	16.8	9.7	650.1	-	200.9	59.8	140.6
	30-40	1,290.2	7.6	4.4	516.1	-	169.7	77.4	139.5
	40-60	2,551.2	4.1	2.4	765.4	-	187.5	132.7	208.3
	60-80	2,580.0	6.7	3.9	516.0	-	158.7	123.8	186.9
	80-100	2,661.1	1.6	0.9	532.2	-	174.3	122.4	183.6
	0-100	12,738.5	113.4	65.8	4,870.8	4.9	1,328.9	1,027.3	1,137.2
P-LMF	0-5	603.9	35.3	20.5	785.1	3.5	27.5	198.1	57.6
	5-10	622.8	17.5	10.2	373.7	3.1	16.5	27.4	17.9
	10-20	1,354.7	28.4	16.5	677.3	1.2	24.4	43.3	28.0
	20-30	1,457.1	19.5	11.3	582.8	-	19.7	52.5	31.8
	30-40	1,473.6	11.1	6.4	442.1	-	23.6	79.6	40.7
	40-60	2,989.3	16.7	9.7	896.8	-	40.4	215.2	103.1
	60-80	2,911.8	11.1	6.4	873.5	-	200.9	64.1	46.9
	80-100	2,369.1	6.9	4.0	473.8	-	10.7	61.6	49.0
	0-100	13,782.2	146.5	85.0	5,105.1	7.9	363.5	741.7	375.1

3.4 Discussion

Many factors have influenced on soil characteristics particularly soil forming factors including parent rocks, climate, living organisms, topography and time. Human activities affect on the soil such as timber harvesting, forest fire, etc. Plant species composition and diversity of forest play the vital roles on soil physical, chemical and biological properties. The roots penetrate into soil and alter physical properties whereas litter fall provides organic matter to soil as nutrient recycling as well as habitat of soil fauna and flora (Pritchett and Fisher,1987)

In Thailand, the natural pine forest is divided into the pine-dry dipterocarp (pine-DDF) and pine-montane forests (pine-LMF)(Bunyavejchewin, 1983). The forest site of pine-DDF was usually dry, and surface fire was occurred in dry season. In contrast, the pine-LMF covered the relatively moist area with occasional fire in some years. Therefore, the soil fertility was better. Khamyong and Seramethakun (2006) studied on the effects of leaf litter decomposition on soil properties. They found that grinded leaf litter of *P. merkusii*, *P. kesiya*, *S. obtusa*, *D. obtusifolius*, *D. tuberculatus*, *C. accuminatissima* and *C. diversifolia* had the pH values of 3.66, 3.37, 4.11, 4.48, 5.18, 4.17 and 4.38, respectively. The decomposition of their leaves might increase soil acidity at different levels by releasing organic acids. However, forest fire altered the effects on soil pH in the field since soil organic matter was burned and remaining the ash. Differences of soil characteristics among subtypes of pine-DDF were thought to be influenced by the dominant tree species and other composition species in each subtype.

Since forest fire was occurred in all subtypes of the pine-DDF, some losses of organic matter, carbon and other nutrients into atmosphere might be happened. In rainy season, soil erosion was the major factor of these losses. The subsoils in these subtypes had fine-textured soil, sandy clay to clay, which was difficult to water infiltration, and accelerated surface runoff and soil erosion. However, some differences of texture in surface soils as sandy clay or clay loam influenced on water infiltration and movement of organic matter into soil. Thus, the amounts of soil organic matter and carbon were different among the three subtypes.

Khamyong (2009) studied on soils in different forests at the Doi Suthep-Pui national park. He found that amounts of soil organic matter, carbon and nitrogen within 100 cm depth under the pine-oak forest were 190.0, 110.2 and 7.31 Mg ha^{-1}. These data were higher than P-LMF (this study), since it was the abundant forest. The amounts of soil available P, extractable K, Ca and Mg in this abundant forest were 16.0, 423.2, 164.8 and 65.45 kg ha^{-1}. The available P and extractable K were higher than the present study, but the extractable Ca and Mg were adversely lower. The parent rock in the Doi-Suthep-Pui national park and present study was granite. However, mineral composition in the rock might have some differences.