# CHAPTER 3

# Methodology

## 3.1 Study site

The study site was located in the field trial plot system, set up to test the framework species method of forest restoration. Plots had been established annually, every rainy season since 1997, ranging in size from 1.4 to 3.2 $hay^{-1}$ and planted with varied combinations of 20 - 30 candidate framework tree species, in the Upper Mae Sa Valley (18’ $52^0$N, 98’ $51^0$E, 1,207 – 1,310 m elevation) of Doi Suthep-Pui National Park (Elliott *et al*., 2012). The forest restoration plots were established near Ban Mae Sa Mai, Mae Rim district Chiang Mai province, Thailand (Figs. 3.1a - b), a Hmong hill tribe community (around 36.3 km. away from Chiang Mai University). In the past, the Hmong farming system consisted of swidden farming, mainly growing maize, opium, and upland rice. During the 1970’s, opium was cultivated as a cash crop, maize for stock feed, and mainly rained rice for subsistence (Irwin, 1976) and then lychee orchards became the main cultivation. Nowadays, the lychee orchard area is declining to accommodate multiple cash crop e.g. cabbage, radish and also high quality vegetables, using green-house chambers, which some of them were supported by Mae Sa Mai Royal Project.

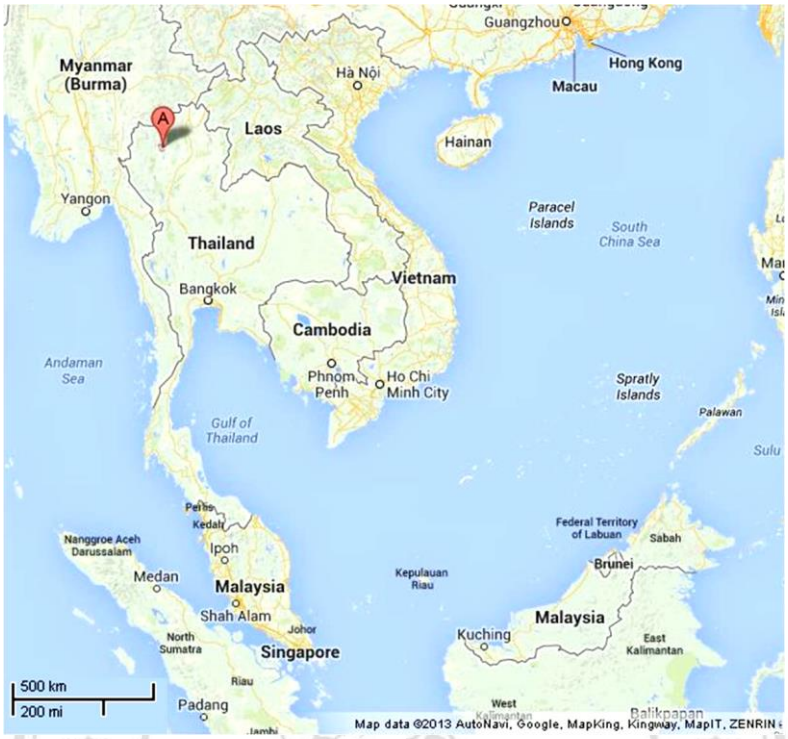



Figure 3.1a Location of Chiang Mai, Thailand (Google, 2013)

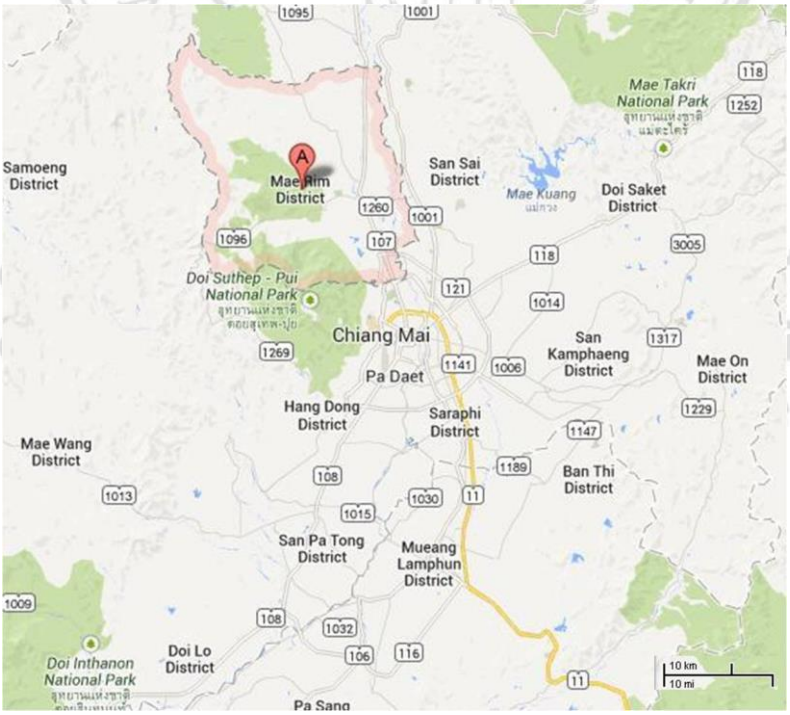



Figure 3.1b Location of Mae Rim District, Chiang Mai, Thailand (Google, 2013)

Fifteen subplots measuring 40 x 40 $m^2$ were set up in forest restoration plots of 3 different ages, since planting: 2, 7, and 11 years old (at the start of this study), planted in 2007, 2002 and 1998 (Figs. 3.4 - 6). The locations of the subplots in restored forest and in control sites (excluding the natural forest site) are shown in Fig 3.2. The plots planted in 1998 (11 years old) were split into 3 locations (1998.1, 1998.2 and 1998.3) and together with adjacent control plots (control 1, control 2 and control 3). The 2002 and 2007 plots were the larger and were split into 3 subplots.

Three control sites (Fig. 3.3), dominated by herbaceous weeds, where no trees had been planted and no restoration treatment applied, were used as an indicators of initial conditions. This site was dominated by the grasses: *Thysanolaena latifolia*, *Phragmites vallatoria* and *Imperata cylindrical* (Toktang, 2005).

Plots had been planted with mixtures of 20–30 selected indigenous framework species (Appendix A).

Secondary forest east of Ban Mae Sa Mai was also included in the study, as the least disturbed forest in the vicinity (Fig. 3.7). Although never clear cut, this area had been disturbed by local villagers, including selective tree felling for construction, fire wood collection and clearance of small patches for opium cultivation about 40-50 years previously. This “community” forest had been protected from disturbance for at least 20 years by local rules, enforced by the village environment committee. Throughout this thesis it is referred to as “natural forest” to distinguish it from “restored forest”. Situated at 1,300 m a.s.l., this natural forest was dominated by trees and seedlings of *Castanopsis diversifolia* (Family Fagaceae) (Jinto, 2009).

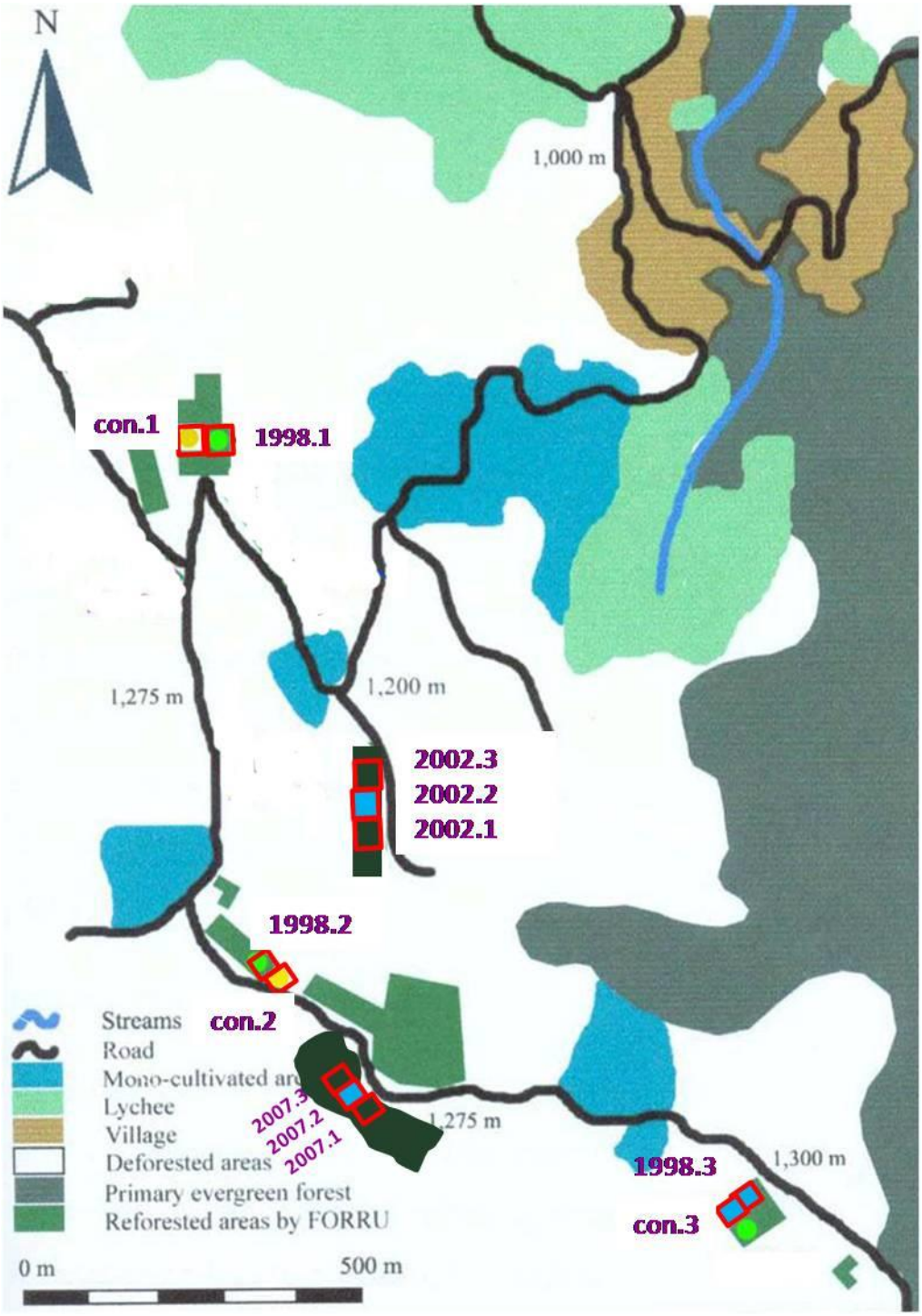



Figure 3.2 Map of forest restoration study plots and the position of soil pedon (subplot with blue color) at Ban Mae Sa Mai, Mae Rim district, Chiang Mai

Figure 3.3 Control site

Figure 3.4 2-year-old site (2007 site)

Figure 3.5 7-year-old site (2002 site)

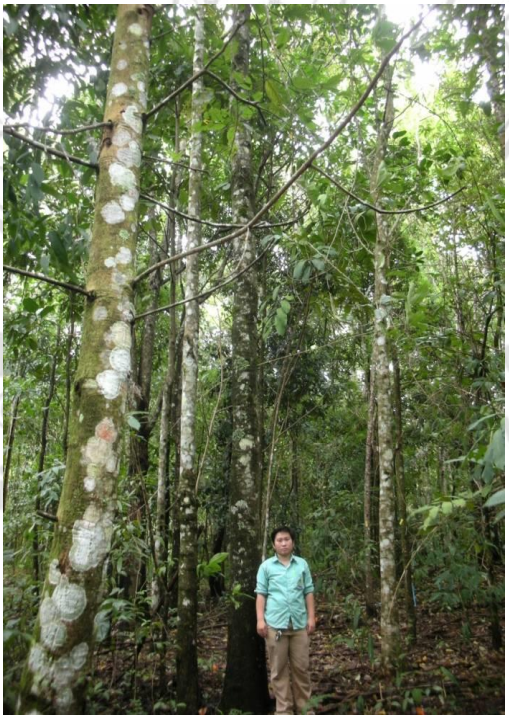


Figure 3.6  11-year-old site (1998 site)

Figure 3.7 Natural forest nearby Ban Mae Sa Mai, Mae Rim district, Chiang Mai province

According to the geological map of Northern Thailand (German Geological Mission, 1979), the petrography of Mae Sa Mai consists of 87% migmatites from Palaeozoic granites and 13% Precambrain paragneiss. Schuler (2008) found that the soils of the Mae Sa Mai area are dominated by Acrisols and Cambisols based on soil mapping.



### 3.2 Climate data

The data of rainfall (mm), minimum and maximum temperature ($^0$C) were taken from the nearest meteorogical station, Ban Mae Sa Mai Royal Project to the study around 3 km., during June 2009 – January 2012 (Fig. 3.8). Minimum and maximum temperature ranged from 14.68 – 20.52 and 16.14 – 36.79 $^0$C, respectively. Annual rainfall in year 1 (June 2009 – May 2010) and year 2 (June 2010 – May 2011) of this study was 764 and 1,336 mm, respectively.

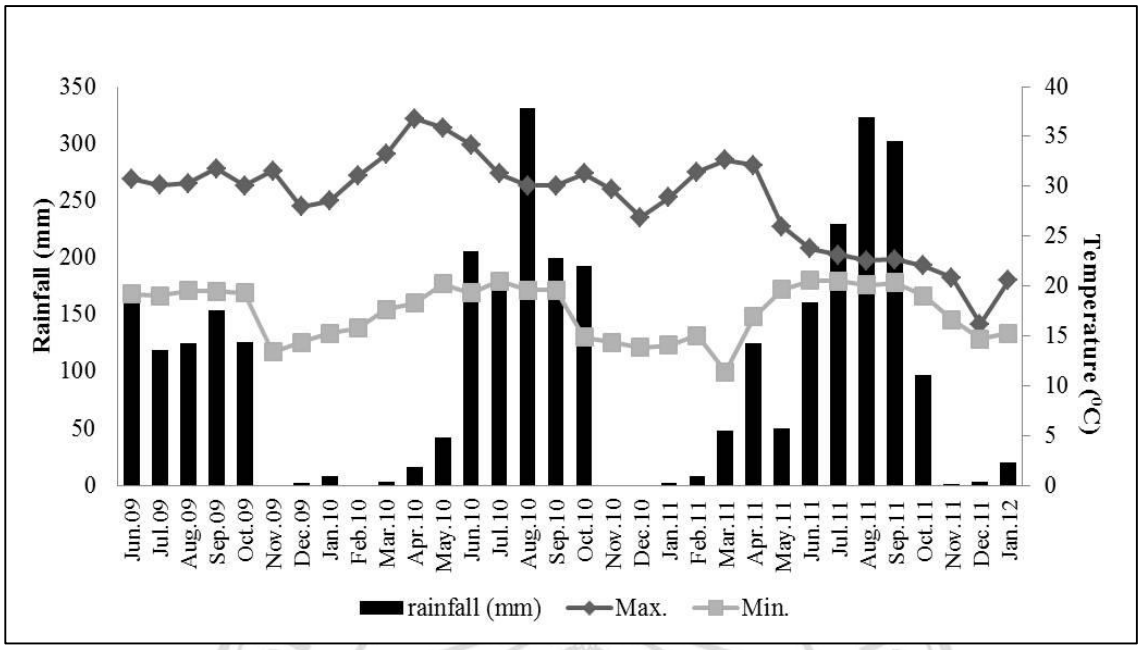



Figure 3.8 Rainfall, minimum and maximum temperatures from the nearest meteorogical station of Ban Mae Sa Mai Royal project. (Ban Mae Sa Mai meteorogical station, 2009 -2012)

## 3.3 Method

### 3.3.1 Litterfall

Six 1 x 1 $m^2$ litter traps were set up in each subplot (Fig. 3.9) (total litter traps = 6 traps x 15 subplots = 90 traps) for collecting litter monthly for 32 months (June 2009 – January 2012). The collected litter was oven-dried at $80^0$C to constant weight and sorted into 4 major parts (leaves, wood, reproductive organ and other parts) before weighing (Weerakkody and Parkinson, 2006).

The dry litter in each study site was analyzed for organic carbon concentration in a laboratory and carbon in the litter was estimated using formula:

Carbon in litter (tC/ha) = dry mass (t/ha) x C concentration (%)/100

% carbon concentration in litter from lab analysis was compared with the 50 % value mass, suggested by many previous research (Jina *et al*., 2008 and Lewis *et al*., 2009).

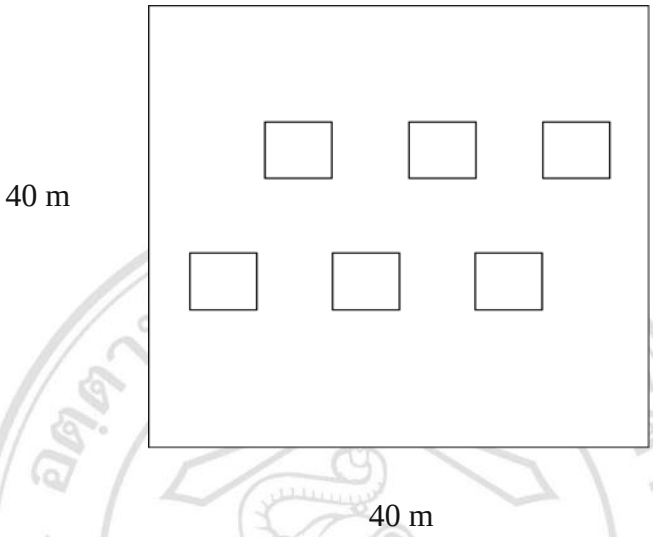



Figure 3.9 Diagram of litter traps in each subplot (40 x 40 $m^2$)

### 3.3.2 Litter accumulation

At all nine points, forest floor without soil was collected within a ring of 30 cm diameter (Fig. 3.10) and dry weight was also determined.

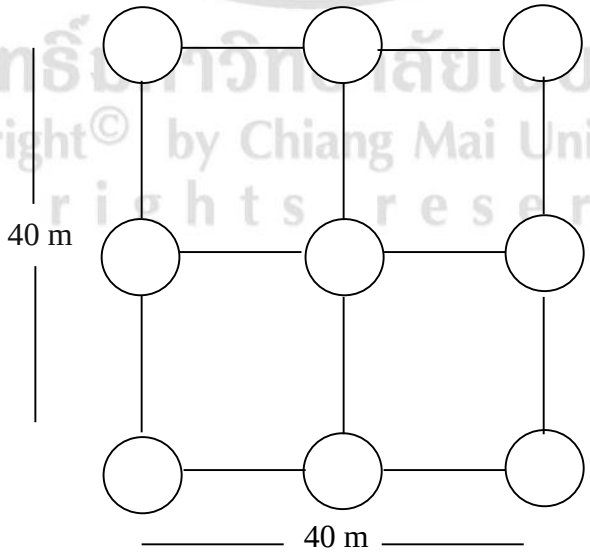



Figure 3.10 Diagram of sampling plot for soil and litter sampled in each site

### 3.3.3 Litter decomposition of three species

Senescent leaves of 3 important framework tree species *Erythrina subumbrans*, *Ficus subinsica* and *Castanopsis diversifolia* were collected and air-dried. Because the characteristics of *Erythrina subumbrans* (Family Leguminosae (Papilionoideae) and *Ficus subinsica* (Family Moraceae) provided (nectar rich and flowers, fruits respective that attract seed dispersers, from an early age (within 4 years). *Castanopsis diversifolia* (Family Fagaceae) is a common species characteristic of natural forest with edible fruites. Therefore, it was also selected for litter decomposition study.

This experiment was conducted from October 2010 – March 2011. Two grams of dried leaves of each species was placed in nylon litterbags (2-mm mesh size) (Berg *et al*., 1993). Three hundred and sixty bags for all the species, were placed *in situ* in all the study sites (October 2010). Twenty-four bags were placed in each subplot. Four litterbags were collected after 2 weeks (October 2010), 1 (November 2010), 2 (December 2010), 3 (January 2011), 4 (February 2011) and 5 months (March 2011). Then, washed and oven-dried at $70^0$C to constant weight.

Percentage remaining mass of each of the species and the total remaining mass of each species and mixed-three species were calculated using formula:

$$\% \text{ mass loss} = \frac{(W1 - W2)}{W1} \times 100$$

where W1 is the original dry mass of litter,

W2 is dry mass of litter after time t

% mass remaining = 100 - % mass loss

Freshly senescent leaves of the three species: *Erythrina subumbrans*, *Ficus subinsica* and *Castanopsis diversifolia* at the beginning phase (October 2010), decomposed litter at middle after 3 months (December 2010) and late phase after 5 months (March 2011) were analyzed for organic carbon by Walkley-Black

method and total nitrogen by micro-Kjeldahl digestion technique (Cromack and Monk, 1975) at Central laboratory, Faculty of Agriculture.

Decay rate of three species, i.e., *k* values (units = year$^{-1}$) after 5 months were calculated (Olson, 1963) using the formula:

$$\ln \frac{Xt}{X_0} = -kt$$

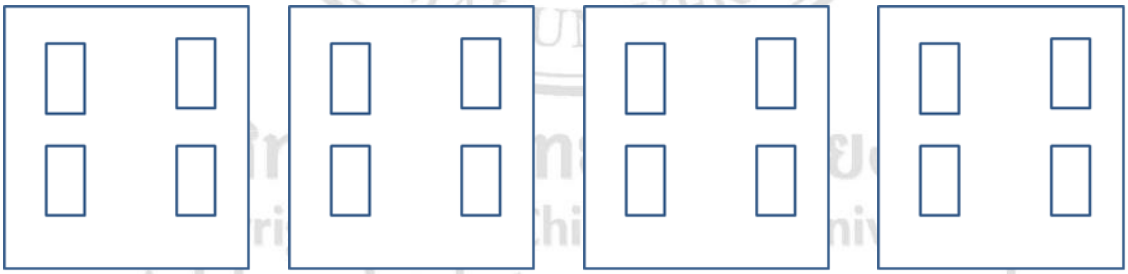
where $X_0$ is the original mass of litter,

Xt is the amount of litter remaining after time t,

t is the time (year) and *k* is the decomposition rate (year$^{-1}$)

### 3.3.4 Decomposition of natural litter using big bag

Mixed litter of each study site in natural condition was used for this experiment. Mixed framework species was used in restored forest, grass in control site and mixed plant species in natural forest site. Around 500 g (wet weight) of material in natural condition was placed in each big bag (50 x 50 cm$^2$) (Fig.3.11).



| Setting point | 1 collection | 2 collection | 3 collection |
|---|---|---|---|
| April 2011 | August 2011 (rainy season) | November 2011 (cool season) | February 2012 (cool dry season) |

Figure 3.11 Diagram of litter bags containing mixed species

Setting (Apr.11)

- wet weight 500g was put in each litterbag and 10% of the whole sample was collected

1st and 2nd collection

- collected 10% of sample

3rd collection

- collected whole sample

Each period, measure wet weight (mass loss during time), carbon content, decomposition rate and C:N ratio. 10% (subsample) of litter in litterbag was collected at the setting point (April 2011), rainy season (August 2011), cool season (November 2011) and cool dry season (February 2011). The subsamples were used to measured moisture content and calculated for percentage of mass remaining and analyzed for organic carbon by Walkley-Black method and total nitrogen by micro-Kjeldahl digestion technique (Cromack and Monk, 1975). Decay rate was also determined.

### 3.3.5 Soil sampling

#### 3.3.5.1 Soil moisture

Top soil samples were collected 0 – 10 cm in depth monthly from June 2009 – January 2012 at six random points in each site. The wet weight and dry weight (after oven-drying at $80^0$C to constant weight) were determined for each sample.



#### 3.3.5.2 Soil investigation and description

A soil pit was dug (in each study site) down to 2 m depth (Fig. 3.12). Soil descriptions were written according to the "Field Book for Describing and Sampling Soils" (USDA-NRCS, 2002). The soil type was assigned using "Soil Taxonomy USDA 11th Edition" (USDA, 2010). Study site topography of each soil pit was recorded, e.g. elevation, slope and position. Then, the soil samples from each layer: 0 -5, 5-10, 10 – 20, 20 – 30, 30 – 40, 40 – 60, 60 – 80, 80 – 100,

100 -150 and 150 -200 cm. in depth were collected for analysis at Central Laboratory, Faculty of Agriculture, CMU (Fig. 3.13)

Figure 3.12 Soil pit

Figure 3.13 Soil sample collection

### 3.3.5.3 Soil analysis in laboratory

**Soil physical properties**

- Soil color using Munsell color system
- Soil texture using hydrometer method (Gee and Bauder, 1986)
- Bulk density using core method (Blake and Hartge, 1986)

**Soil chemical properties**

- pH (soil : $H_2O$ = 1:1) (Mclean, 1982)
- Organic matter (O.M.) using Wet Oxidation Walkley and Black (Nelson and Sommers, 1996)
- Total nitrogen using Micro Kjeldahl method (Bremner and Mulvaney, 1982)
- Extractable P using Bray II and Colorimetric method (Olsen and Sommer, 1982)
- Extractable K and Na using Ammonium acetate (1 N, pH 7.0) and Flame photometer (Knudsen *et al.*, 1982)
- Extractable Ca and Mg using Ammonium acetate (1 N, pH 7.0) and Atomic absorption (Lanyon and Heald, 1982)
- Cation exchange capacity (CEC) extracted by 1 M Ammonium acetate (pH 7.0) (Rhoader, 1982).

### 3.3.5.4 Soil sampling and soil organic carbon

Soil samples from depth ranging from 0 to 200 cm were collected at 4 points from each study site (which have soil pit) using a soil auger. Four points in each layer was mixed and sub-sampled into 3 replicates. Soil properties (pH, N, P, K and CEC) were also determined (Figs. 3.14 - 15). Organic matter and bulk density were determined using the Walkley-Black method (Nelson and Sommers, 1996) and core method (Black and Hartge, 1986), respectively.

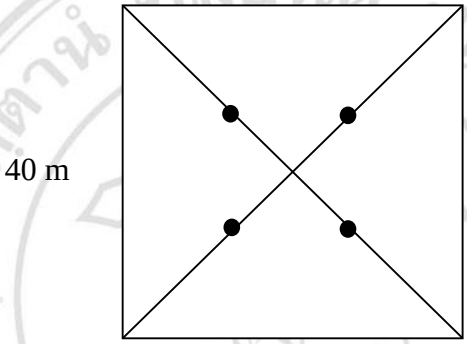



Figure 3.14 Diagram of point for collecting soil samples by soil auger

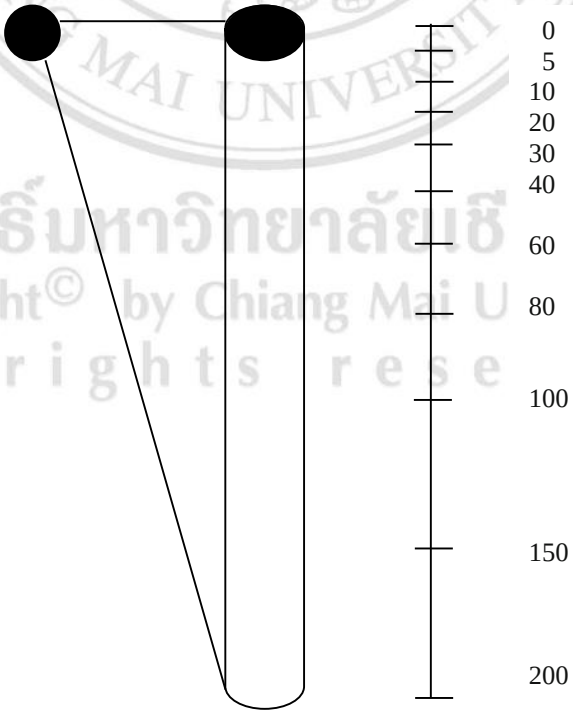



Figure 3.15 10 layers of soil depth

Soil organic carbon stock at depths ranging from 0 to 200 cm was calculated by the formula:

Soil organic carbon stock = OC (g/100g) x soil bulk density(g $cm^{-3}$) x soil depth (cm) (tC/ha)

### 3.3.6 Statistic analysis

#### 3.3.6.1 Litterfall and carbon content in litter

The amounts of the litterfall in 32 months (June 2009 – January 2012) and their fractions were analyzed for differences among the study sites using one-way ANOVA (Guo *et al*., 2004). Tukey's test was used in conjunction with an ANOVA to figure out which study site means were significantly different from one another, amounts of litterfall and carbon content in litter among the study sites. The relationships between total litter (t/ha) and age since planting and between total litterC (tC/ha) and age since planting were determined, using correlation analysis.

#### 3.3.6.2 Litter decomposition of mixed three species and mixed species using big bag

Tukey's test was used to determine differences in decay rate among study sites and in different periods. Mass remaining (%) and carbon remaining (%) in different periods were also determined. Linear regression equation and $R^2$ of all study sites used for calculating predicted mass remaining (%) in 1 year.

#### 3.3.6.3 Soil analysis

Differences in soil pH, N, P, K CEC and OM among study sites were tested. Pearson correlation was used for determined among parameters. Regression analysis was used to detect a relationship between organic carbon (%).

### 3.3.7 Model

**FullCAM model tool** (Richards *et al*., 2005)

FullCAM model 3.13.8 (Research version) was used for estimating soil carbon mass of each study site (control, 2-year-old, 7-year-old, 11-year-old and natural site). Some climate data were derived from Ban Mae Sa Mai Royal Project meteorogical station e.g. rainfall (mm), evaporation (mm) and average air temperature ($^0$C). Measured specify data e.g. plant residues (tC/ha), clay percentage were collected from our study sites from January 2010 – December 2011. Each plot was described and used the following criteria and assumptions for all of sites:

Table 3.1 Input data for simulating soil carbon mass in each study site

| Parameter | Data | Resources |
|---|---|---|
| Plot type | Forest soil | |
| Simulate | Carbon | |
| Simulation steps | Yearly | |
| Year | 2010 – 2020 (next 10 years) | |
| Climate data | Rainfall (mm), open-pan evaporation (mm) and average air temperature ($^0$C) | Climate data from the nearest meteorogical station that called Ban Mae Sa Mai Royal Project during January 2010 – December 2011x |
| Specify data | Plant residues | Measured litterC in each study sites 2010 -2011 (tC/ha) |
| | DPM to RPM 0.25 | Typical value of forest type |
| | HUM encapsulation: 0.005 | Typical value |
| | Depth of soil sampling: 200 cm | Maximum soil depth of our study |
| | Clay percentage | Clay percentage from soil texture analysis |
| | Carbon masses (tC/ha) | Assumption 20% DPM and 80%RPM of litterC of each site |