CHAPTER 3

Methodology

3.1 Site Description

Four different forest restoration plots with varying ages were selected for this study. The youngest plot (1-year-old) was in Mon Long (ML) area and the second plots (2-, 14- and 17-year-old plots) were near Ban Mae Sa Mai and Ban Mae Sa Noi (BMSs). All plots were in the Mae Rim district, in the north of Chiang Mai province, in northern Thailand (Figure 3.1 and Table 3.1). Mon Long (ML) is the highest mountain in the Mae Rim district at about 1,450 m a.s.l. The ML plot was located slightly below the highest point between 1,350 - 1,380 m a.s.l. Ban Mae Sa Mai/Ban Mae Sa Noi (BMS) are Hmong villages located at about 1,200 m a.s.l. BMSs plots are situated about 3 km further from the villages between 1,260 - 1,320 m a.s.l. Annual mean temperature during this study (2015) was between 22 - 23 degree Celsius, average rainfall was between 1,350 - 2,500 mm/year and relative humidity was 70 - 80% (Mae SA Mai Royal project, 2016 - unpublished information).

Before the 1960s the land in northern Thailand was covered with montane forest. Dominant tree families in this forest ecosystem sites were Magnoliaceae, Theaceae, Lauraceae and Fagaceae (Werner and Santisuk, 1993). Such forests have been extensively cleared and replaced with cash crops e.g. cabbages, maize, carrots, lettuces, etc. Intensive maintenance and heavy chemical inputs are required continuingly for these crops. Before restoration activity began in 1997, the abandoned fields were previously dominated by herbaceous weeds such as Pteridium *aquilinum* (L.) Kuhn (Dennstaedtiaceae), *Bidens pilosa* L., *Ageratum conyzoides* (L.) L., *Eupatorium odoratum* L. (all Compositae), *Commelina diffusa* Burm.f. (Commelinaceae) and grasses e.g. *Phragmites vallatoria* (Benth.) Mabille, *Imperata cylindrical* (L.) Raeusch and *Thysanolaena latifolia* (Roxb. Ex Hornem.) Honda (both Gramineae).

Forest fires are common during the dry season in northern Thailand. Although fire breaks were created around all restoration plots in both ML and BMSs sites, some plots were partially burned due to various factors; topography (e.g. fire can easily cross a fire break strip in an area with steep slopes), location in the landscape (e.g. the plots are surrounded with agricultural activities which usually use fire to clear away weeds), and lacking a holistic plan of fire management. Fire entered BMSs plots in mid-April 2015. An 80,000 m2 area was burned. Later in early May 2015, the same thing happened over an area of 960 m2 in ML plot.

Table 3.1 GPS coordinates of all studied restoration plots

Site	**Planting year**	**Plot age (year)**	**Planted area (m2)**	**GPS coordinates**	**Elevation (m)**
ML	2014	1	960	N 18° 55’ 22.50’’ E 98° 50’ 27.90’’	1350 - 1380
MSMs	2013	2	3,200	N 18° 51’ 19.80’’ E 98° 50’ 53.29’’	1260 - 1290
MSMs	2001	14	1,600	N 18° 51’ 25.26’’ E 98° 50’ 57.60’’	1280 - 1310
MSMs	1998	17	1,600	N 18° 51’ 27.24’’ E 98° 50’ 53.29’’	1280 - 1320

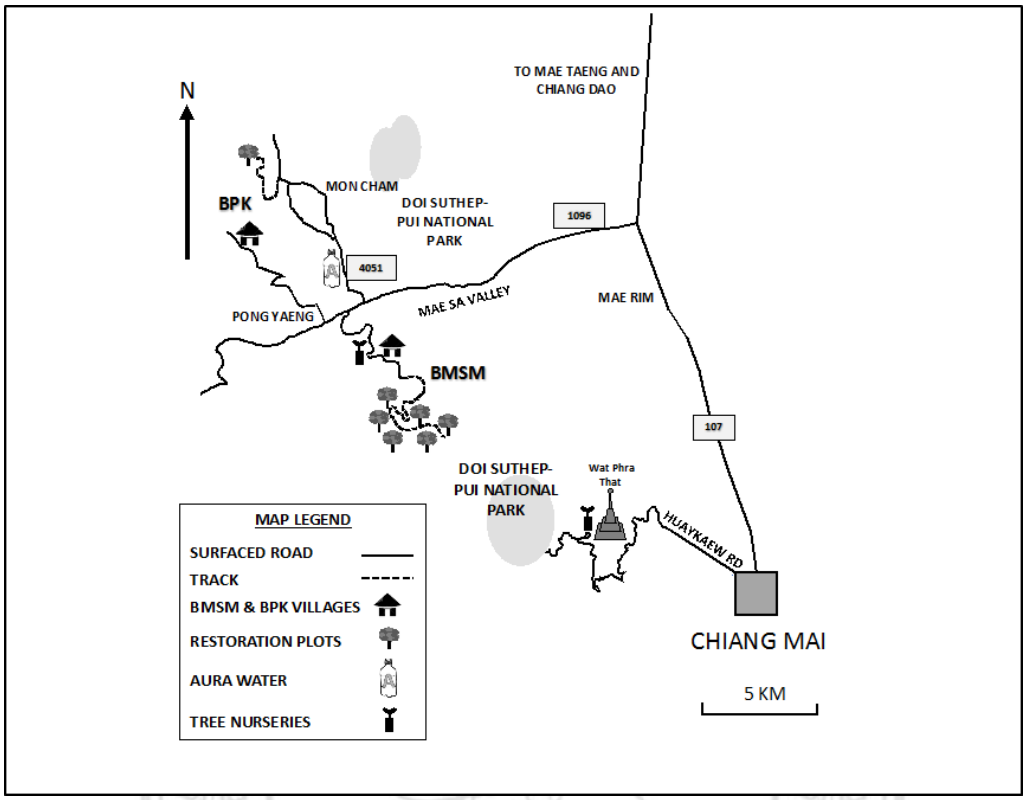

Figure 3.1: Map BMSs and ML restoration sites

3.2 Studied species

A total of 39 native tree species were studied because they had a minimum of five surviving trees after the fire in the summer of 2015. The list of all studied species is presented in Table 3.2, only Prunus cerasoides existed in all plots. There were 6, 23, 14 and 18 species presented in 1-, 2-, 14- and 17-year-old plot (planted in 2014, 2013, 2001 and 1998 respectively).

Table 3.2 The number of surviving trees in all studied plots

Scientific name	Family	Number of trees			
		1-y	2-y	14-y	17-y
Acrocarpus fraxinifolius Arn.	Leguminosae	5			
Alangium kurzii Craib	Cornaceae	6			
Artocarpus nitidus Trécul	Moraceae		18	18	
Bischofia javanica Blume	Phyllanthaceae		37	6	41
Castanopsis acuminatissima (Blume) A.DC.	Fagaceae		25	8	
Castanopsis calathiformis (Skan) Rehder & E.H.Wilson	Fagaceae				7
Castanopsis diversifolia (Kurz) King ex Hook.f.	Fagaceae			6	
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	8	16		
Choerospondias axillaris (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae		18	7	20
Cinnamomum iners Reinw. ex Blume	Lauraceae		30		7
Cinnamomum longipetiolatum H.W.Li	Lauraceae	6			
Diospyros glandulosa Lace	Ebenaceae		27		8
Duabanga grandiflora (*DC.*) Walp.	Lythraceae		8		
Ficus altissima Blume	Moraceae				9
Ficus auriculata Lour.	Moraceae		40		
Ficus callosa Willd.	Moraceae		34		
Ficus hispida L.f.	Moraceae		29		

Table 3.2 The number of surviving trees in all studied plots (Continued)

Scientific name	Family	Number of trees			
		1-y	2-y	14-y	17-y
Ficus subulata Blume	Moraceae			6	
Garcinia mckeaniana Craib	Clusiaceae				6
Gmelina arborea Roxb.	Lamiaceae				6
Helicia nilagirica Bedd.	Proteaceae				13
Heynea trijuga Roxb. ex Sims	Meliaceae		30	6	
Hovenia dulcis Thunb.	Rhamnaceae		37		8
Magnolia baillonii Pierre	Magnoliaceae		27	15	
Magnolia garrettii (Craib) V.S.Kumar	Magnoliaceae		24		10
Markhamia stipulata (*Wall*.) Seem.	Bignoniaceae			5	
Melia azedarach L.	Meliaceae				11
Ocotea lancifolia (*Schott*) Mez	Lauraceae				7
Podocarpus neriifolius D. Don	Podocarpaceae		25		
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae		26		
Prunus cerasoides Buch. -Ham. ex D.Don	Rosaceae	6	22	56	14
Pterospermum grandiflorum Craib	Malvaceae		34		
Quercus semiserrata Roxb.	Fagaceae	7		5	10
Sapindus rarak DC.	Sapindaceae				16
Sarcosperma arboreum Hook.f.	Sapotaceae		23	10	19

Table 3.2 The number of surviving trees in all studied plots (Continued)

Scientific name	Family	Number of trees			
		1-y	2-y	14-y	17-y
Scleropyrum pentandrum (Dennst.) Mabb.	Santalaceae		14		
Styrax benzoides W. G. Craib	Styracaceae		10		
Syzygium albiflorum (Duthie ex Kurz) Bahadur & R.C.Gaur	Myrtaceae			6	8
Syzygium tetragonum (Wight) Wall. ex Walp.	Myrtaceae		21	14	
Total species		**6**	**23**	**14**	**18**

3.3 Data collection and data analysis

A 40 x 40 m sampling plot was established in each restoration plot that had been burnt in 2015 (planted in 1998, 2001 and 2013 at BMSs), except the plot planted in 2014 at ML where two sampling plots were laid out due to the size of burned area. The distance between each plot in BMSs was about 200 m, whereas only one plot was located in the ML site.

3.3.1 Tree size and survival after a fire disturbance

The plots were surveyed 3 times during this study; 2 weeks (end of dry season), 18 weeks (beginning of rainy season) and 30 weeks (end of rainy season) after the plots had been burned (during April and May 2015). Girth at breast height (GBH) of all trees that survived was measured unless they were smaller than 10 cm, then their root collar diameters (RCD) were measured instead. GBH was then converted to diameter at breast height (DBH) for data analysis.

According to DBH measured from the last monitoring (30 weeks after fire), the trees were grouped into 13 classes (40 mm interval in each class), then calculated

their survival percentage. Trees sizes with stem diameter between 1 - 40 mm were analyzed by Chi-square test at 95% confidence interval. This test was conducted to assess the survival of burnt tree at 30 weeks after fire, response in difference size of tree. Trees with DBH ≤ 40 mm were grouped into 8 classes (5 mm interval), and grouped into bigger group if not significant for testing Chi-square.

Simple linear regression used to explore relations between stem diameter (only tree that DBH ≤ 40 mm) and survival after fire. The survival at 30 weeks after fire disturbance was response variable and stem diameter was explanatory variable. R2 was interesting in figure out the correlation of this relation.

Only small trees (DBH between 1 - 50 mm) were analyzed by a generalized linear mixed models (GLMMs) with a binomial family test in the R program version 3.3.1, to determine the effects of tree size on their survival after fire. Trees were categorized as dead (0) or alive (1) and then used as a dependent variable. Tree stem diameter (DBH or RCD) was used as an independent variable (fixed effect). For 1- and 2-year-old plot, the size monitored from before the fire in the summer 2015 (November 2014 and December 2014 respectively) was used. Unfortunately, this data is not available for the old plots, so the size of surviving trees monitored at 2 weeks after burning was used for the 14- and 17-year-plot. In addition, planting plots were carried out as another independent variable (random effect) to reduce the variance of size on survival ability in GLMMs analysis.

3.3.2 Tree size and resprouting ability

In addition to tree survival from 3.3.1, the number of resprouting shoots were recorded from all plots. For all trees that survived during the last monitoring (30 weeks after a fire event), they were grouped into 17 classes (30 mm range in each class) to represent the ability of resprouting.

Only trees with a stem diameters between 1 to 210 mm were subsequently analyzed using generalized linear mixed models (GLMMs) with a Poisson family test in the R program version 3.3.1. To determine the effects of tree size on its resprouting ability, stem diameter (same data used in 3.3.1) was used as an independent variable (fixed effect), while the planting plot was assigned as a random effect.

3.3.3 Suitability index

A suitability index was calculated from the data of the young plots (1- and 2-year-old plots). This index aims to select suitable native tree species for restoring forest ecosystem in fire-prone sites. Three different variables were selected; (i) survival percentage (ii) relative growth rate (RGR) of stem diameter and (iii) resprouting ability (number of resprouting shoots after fire) of each native tree species.

(i) Survival percentage of each native tree species was calculated as a proportion of the number of trees survived before fire disturbance and during the last monitoring (30 weeks after the fire).

$$\text{Percent survival } (\%) = \frac{Number\ of\ survived\ trees}{Total\ number\ of\ trees} \times 100$$

(ii) RGR was presented as a percentage of growth in one year (365 days).

$$\text{Relative Growth Rate (RGR)} = \frac{\ln(G2)-\ln(G1)}{T2-T1} \times 365 \times 100$$

Where; G1 = Stem diameter (mm) at 1st monitoring (2 weeks after fire)

G2 = Stem diameter (mm) at 3rd monitoring (30 weeks after fire)

T1 = Date of 1st monitoring (2 weeks after fire)

T2 = Date of 3rd monitoring (30 weeks after fire)

(iii) Resprouting ability was presented for each species as a proportion of the number of resprouting shoots and the number of all burned trees.

$$\text{Resprouting ability} = \frac{No.\ of\ resprouting\ shoot}{Every\ trees\ that\ burnt}$$

The highest value from all three parameters was then selected and then converted into a score, ranging from 0 to 100. The survival percentage was multiplied by two after converting due to their importance to fire resilience. All scores were summed for each species and they were again ranked from 0 to 100.