Walailak J Sci & Tech 2008; 5(1): 1-15.

Testing the Framework Species Method for Forest Restoration in Chiang Mai, Northern Thailand

Prasit WANGPAKAPATTANAWONG and Stephen ELLIOTT

Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

(E-mail: prasit.w@chiangmai.ac.th)

ABSTRACT

The framework species method of reforestation, developed by FORRU (Forest Restoration Research Unit) has been used successfully to restore evergreen forest on degraded former agricultural sites in Doi Suthep-Pui National Park, Chiang Mai province, Thailand. This paper reports 3 year results of an attempt to duplicate the FORRU reforestation techniques at Ban Toong Yah, Mae Chaem district, at a similar elevation as FORRU's original plots at Ban Mae Sa Mai, Mae Rim district. Twenty species of framework tree seedlings were planted in June 2002. The 2 year results indicate that the seedlings achieved lower survival rates than at the FORRU's original site. Height growth, root collar diameter, and crown width were also lower. Some seedlings died because they were trampled by cows, which also ate some of the seedlings. However, several sapling species, such as *Ficus fistulosa* and *Phyllanthus emblica*, were able to produce new shoots from their axillary buds, after having been browsed by cows. In 2004, 5 well-performed species: *Castanopsis tribuloides*, *Ficus fistulosa*, *Hovenia dulcis*, *Ostodes paniculata* and *Prunus cerasoides*, were selected along with 12 never-planted species to be planted in June. The results indicate that the seedlings achieved lower survival rates than at the FORRU's original site. The seedlings achieved an average survival rate of about 50 % after the first growing season. The exposed, windy environment of the planting site might also account for lower than expected growth and survival rates. The FORRU's recommended methods of site preparation using herbicide and weed suppression using cardboard mulch may be employed to improve seedling survival and growth on this site.

Keywords: Framework species method, FORRU, Mae Chaem watershed, Northern Thailand, seedling performance

INTRODUCTION

Land-use patterns in the highlands of northern Thailand are changing rapidly. Much of the forest that once covered this region has now been replaced with agriculture and infrastructure development, whilst illegal logging and fire continue to degrade remaining forest patches. Despite a government ban on logging since 1989, it has proved impossible to halt deforestation and forest degradation. On the other hand, there are many abandoned agricultural sites, within conservation areas, that are potentially available for reforestation, to meet the statutory objectives of such areas, i.e. to conserve biodiversity and the environment. Therefore, there is an urgent need to develop effective methods of "forest restoration" [1-4], i.e. restoration of "levels of tree species richness, ecosystem structure and ecological functioning, found in the original forest ecosystem" [1] in degraded conservation areas, particularly on former shifting-cultivation sites. There have been numerous attempts by the government to reforest degraded sites using monocultures of common economic trees such as pines and fast-growing non-native species (e.g. *Eucalyptus* species). Such plantations are a poor substitute for the original forest, particularly in terms of biodiversity conservation value; hence the need to develop effective forest restoration methods to provide a viable alternative to such plantations [5].

The Forest Restoration Research Unit (FORRU, http://www.forru.org) at Chiang Mai University has been conducting research on how to restore forest ecosystems on degraded forestland in northern Thailand since 1994 [6,7]. FORRU adapted the framework species method, originally conceived in Australia [8] to successfully restore evergreen forest on abandoned agricultural fields in an upper watershed at 1,300 m elevation in Doi Suthep-Pui National Park, Chiang Mai province. This technique involves planting of 20 - 30 native tree species that can suppress weeds, grow fast and provide shade and food for seed-dispersing wildlife. Tree planting restores basic ecosystem structure and functioning, whilst seed-dispersing mammals and birds, attracted by the planted trees, help to restore species diversity of the vegetation, thus improving wildlife habitats. It is undoubtedly successful in a single watershed within Doi Suthep-Pui National Park, but in order for the method to have broad appeal, it is necessary to show that similar results can be achieved over a range of elevation, soil types, aspects, slopes etc.

Consequently, the study reported here was carried out to test the methods developed by FORRU in a different environment to determine if the results are reproducible. Here we present results on the initial establishment and growth of 32 candidate framework tree species. Results are compared with those of FORRU at a similar time after planting.

Results from this research will help with selecting appropriate forest restoration methods for different sites in northern Thailand. The Chiang Mai Agenda stemmed from the proceedings of a workshop on forest restoration for wildlife conservation held in Chiang Mai province between January 30th and February 4th 2000 which listed 5 main areas of needed research in forest restoration. The areas were 1) plantation design, 2)

seed dispersal, 3) fire ecology and management, 4) species selection, nursery, and plantation techniques, and 5) social and community issues [9,10]. The research corresponded with two of the research agendas, which are #1 plantation design ("1.2 Establishing experimental plots to determine optimum plantation design") and #4 species selection, nursery, and plantation techniques ("4.1 Identification of framework species in different bio-regions") [9].

MATERIALS AND METHODS

1. Study site

The Mae Chaem watershed is about 49 km wide (east-west) and 113 km long (north-south), with a total area of about 400,000 hectares (**Figure 1**) [11]. The watershed has about 96 % of its area (354, 200 hectares), in the Mae Chaem district, and the rest in Hod district, Chiang Mai province. The watershed can be geologically divided into 3 main parts: 1) the new sediment valley at 190 - 500 m asl., with 0 - 4 % slopes, 2) the old sediment hills at 500 - 650 m asl., with 4 - 16 % slopes up to 35 % slope at some points, and 3) the highlands at 700 - 2,000 m asl., with more than 35 % slope. The Mae Chaem watershed is characterized by 5 major forest types: 1) hill-evergreen (*Castanopsis* spp., *Quercus* spp.) at approximately 1,000 - 1,800 m asl., 2) hill-evergreen and pine (*Pinus kesiya* Royle *ex* Gordon, *P. merkusii* Jungh. & de Vriese) at approximately 1,000 - 1,400 m asl., 3) dry dipterocarp and pine, 4) dry dipterocarp (*Dipterocarpus* spp., *Shorea siamensis* Miq.) at approximately 100 - 1,200 m asl., and 5) mixed deciduous forests (*Tectona grandis* L.f. or teak tree, *Gmelina arborea* Roxb.) at approximately 800 m asl. Generally, soils are slightly acidic (pH 4 - 6). Their texture is sandy clay loam in the hill evergreen forests and sandy clay loam to sandy clay in the dry dipterocarp and mixed deciduous forests [12].

Seedlings were planted in an area that had been designated by the Royal Forestry Department (RFD) for reforestation, near Toong Yah village, Mae Chaem district, Chiang Mai province (18° 33′ N latitude, 98° 14′ E longitude, at about 1,400 m asl.). The surrounding area included cultivated areas, with cash crops like cabbages and carrots, of the village. The plot was about 160 km south of the FORRU's original site in Mae Sa Mai village (18° 52′ N latitude, 98° 51′ E longitude, at about 1,300 m asl.), Chiang Mai province. The area has a monsoon climate like the rest of northern Thailand. From 1985 - 2001, the mean monthly temperature recorded at the RFD's research station, at about 1,200 m asl., about 10 km from the site was 21 °C, and the mean annual rainfall was 1,210 mm [13]. The wet season starts from May to October, and the dry season starts from November to April. Part of the area was still grazed by cattle. The RFD had planted parts of the area surrounding the selected plots with some tree species such as *Acacia auriculaeformis* A.Cunn. *ex* Benth., *Docynia indica* (Andr.) Decne., *Prunus cerasoides* D.Don and *Pinus kesiya* for several years. Records of seedling ages could not be found. At the start of this study, there were some sparse seedlings of *Docynia indica* and *Pinus kesiya* about 50 cm tall. These seedlings were

not growing well, possibly due to fire, cattle grazing and unsuitable silvicultural treatments.

The area planted for the experiments reported here was 0.96 ha in size, and was divided into 3 treatments and 3 control plots of 0.16 ha each. This is the standard land measurement used in Thailand of 1 rai, 1 ha = 6.25 rai. A barb-wire fence was set up surrounding the plot to prevent cattle from entering the site.

To collect baseline data on the condition of the vegetation in the areas to be planted with trees, 4 circular sample units of 10 m in diameter were laid in each area of 1 rai. All plants found in the sample units were identified by a plant taxonomist of Chiang Mai University (CMU) Herbarium to species level. Some trees that had been previously planted by the RFD were present, including *Acacia auriculaeformis*, *Docynia indica*, *Prunus cerasoides* and *Pinus kesiya*. Trees in a nearby less-disturbed patch of evergreen forest, which was about 2 km away, were also identified for comparison.

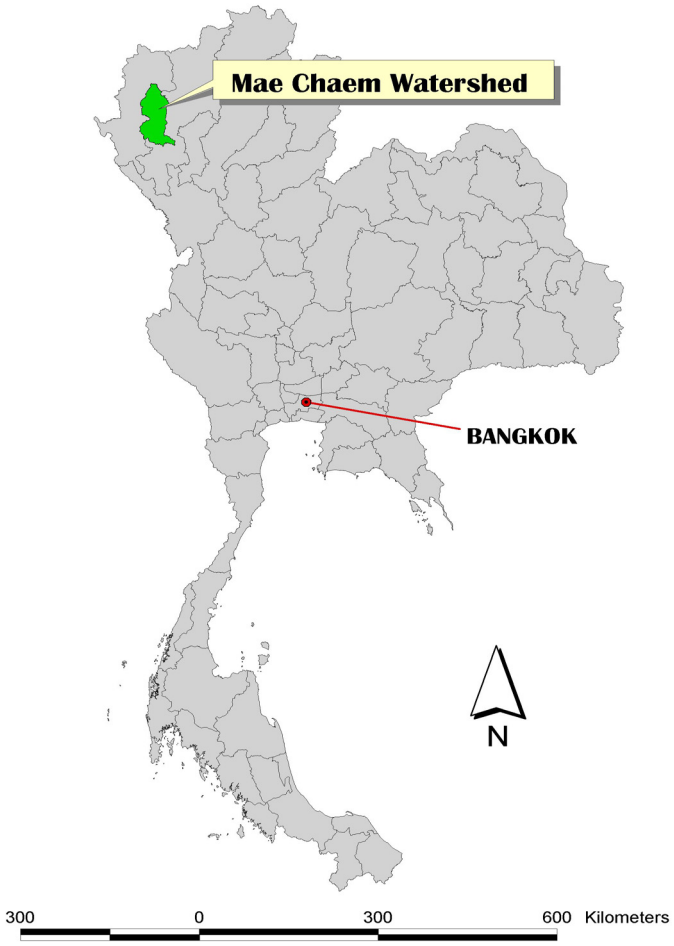

Figure 1 Map of Thailand showing the Mae Cheam watershed, Chiang Mai province [11].

Soils from the planting site were collected for analyses of pH, organic matter, nitrogen, phosphorus and potassium contents (**Table 1**). The soil analyses were done at the Faculty of Agriculture, Chiang Mai University. The average bulk density of the soils is 0.93 g/cm^3.

Table 1 Soil properties at the planting plots at Toong Yah Village, Mae Chaem district, Chiang Mai province.

Soil property	Depth from the ground		
	0 - 5 cm	5 - 15 cm	15 - 30 cm
pH	4.97	4.97	5.00
Organic matter (g/100 g soil)	7.77	6.40	4.39
Total nitrogen (g/100 g soil)	0.34	0.27	0.21
Available phosphorus (mg/kg)	6.91	1.72	1.10
Extractable iron (mg/kg)	3.55	5.24	2.64
Extractable aluminum (mg/kg)	80.70	75.20	69.20
CEC ($cmol^+$/kg)	15.90	13.50	11.20
Sand (%)	69.10	74.20	68.20
Silt (%)	20.40	14.40	16.50
Clay (%)	10.50	11.40	15.40

2. Seedling preparation and planting

Twenty tree species were selected based on their performances at the FORRU's original site at Mae Sa Mai village [6]. Twenty five trees of each species were planted in each of the 3 replicated plots, totaling 75 individuals per species. The planting density was equivalent to 3,125 trees/ha with an average spacing between the trees of 1.8 m. The young trees had been grown at FORRU's research nursery following methods already described [6]. The trees were planted in late June 2002. Silvicultural treatments, except site preparation, during the growing season followed the FORRU methods [1], but herbicide was not used to clear the site. An 8 m firebreak strip was created in February 2003 along the fence. In 2004, 5 well-performed species after 2 growing seasons: *Castanopsis tribuloides* (Sm.) A. DC., *Ficus fistulosa* Reinw. *ex* Blume, *Hovenia dulcis* Thunb., *Ostodes paniculata* Blume, and *Prunus cerasoides* D.Don, were selected along with 12 never-planted species, as they were found to perform well at the FORRU's original site [5], for additional planting in June.

3. Post planting care of trees

The basic pre- and post-planting silvicultural treatments developed by FORRU were carried out [6], and circular-shaped weed-suppressing corrugated cardboards, which are normally put surrounding the planted seedlings as mulch, were not used.

FORRU's weeding method involves 3 weeding times during the growing reason. At each weeding time, 50 g of chemical fertilizer (15-15-15) is spread in a circle at least 20 cm away from the stem of each planted tree. During the growing season, weed growth was particularly vigorous at this planting site. Consequently, an additional weeding was carried out at the end of each rainy season, but no fertilizer was applied after the fourth weeding.

4. Tree monitoring

Growth and survival data for all planted trees were collected 2 weeks after planting and at the end of the rainy season when growth slows down or stops. Data recorded included height (root-collar to highest meristem) measured with a tape measure, root collar diameter, measured with vernier calipers. The health of the trees was scored on a scale of 0 (dead) to 3 (perfect health). Crown breadth at the widest point and weed cover in a circle of 1 m diameter around the base of the tree were also recorded to assess the weed suppression capability of each species. They were then monitored again at the end of the growing season.

RESULTS AND DISCUSSION

1. Pre-planting vegetation

Predominant ground flora species were *Setaria geniculata* (Lam.) P.Beauv. (Poaceae), and *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (J.Agardh) R.M.Tryon (Dennstaedtiaceae), which covered on average about 90 % of the area. Some other scattered plant species included grasses (Poaceae) and various herbs of the families Asteraceae, and Fabaceae. Tree species found in the less-disturbed forest patch, using 4 circular sample units of 10 m in diameter in an area of 1 rai, are listed in **Table 2**. Some of the tree species found in the less-disturbed forest patch that might be used in restoration of degraded hill evergreen forests, according to FORRU [5], were *Castonopsis tribuloides*, *Chionanthus ramiflorus*, *Diospyros glandulosa*, *Engelhardtia serrata*, *Engelhardtia spicata*, and *Lithocarpus elegans*.

2. Tree survival

Immediate post-planting mortality of the trees, due to damage during transportation and planting and transplantation shock was low. Two weeks after planting, nearly all species had survival rates of close to 100 %, with just 1 species (*Erythrina subumbrans* (Hassk.) Merr.) suffering 29 % mortality, due to rough handling (**Table 3**).

Table 2 Twenty-seven tree species naturally established found in a less-disturbed forest patch near the planting site, Toong Yah village, Mae Chaem district, Chiang Mai province.

Species	Family	Primary Seed Dispersal Mechanism [14]
Adinandra integerrima T.Anderson *ex* Dyer	Theaceae	Animal
Alstonia rostrata C.E.C.Fisch.	Apocynaceae	Wind
Betula alnoides Buch.-Ham. *ex* G.Don	Betulaceae	Wind
Castanopsis diversifolia (Kruz) King	Fagaceae	Animal
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	Animal
Chionanthus ramiflorus Roxb.	Oleaceae	Animal
Diospyros glandulosa Lace	Ebenaceae	Animal
Elaeocarpus floribundus Blume var. *floribundus*	Elaeocarpaceae	Unknown
Engelhardtia serrata Blume var. *serrata*	Juglandaceae	Unknown
Engelhardtia spicata Blume var. *integra* (Kurz) Mann.	Juglandaceae	Unknown
Eryobotrya bengalensis (Roxb.) Hk. f. forma *bengalensis*	Rosaceae	Unknown
Eurya acuminata DC. var. *wallichiana* Dyer	Theaceae	Animal
Lithocarpus elegans (Blume) Hatus. *ex* Soepadmo	Fagaceae	Animal
Lithocarpus spicatus (Sm.) Rehder & Wilson var. *brevipetiolatus* (A.DC.) Rehder	Fagaceae	Unknown
Litsea salicifolia Nees *ex* Roxb.	Lauraceae	Animal
Machilus bombycina King *ex* Hook.f.	Lauraceae	Unknown
Maesa montana A.DC.	Myrsinaceae	Unknown
Melastoma malabathricum L. ssp. *normale* (D.Don) F.K.Mey	Melastomaceae	Unknown
Michelia champaca L. var. *champaca*	Magnoliaceae	Animal
Saurauia roxburghii Wall.	Saurauiaceae	Animal
Schima wallichii (DC.) Korth.	Theaceae	Wind
Sterculia balanghas L.	Sterculiaceae	Unknown
Sterculia villosa Roxb.	Sterculiaceae	Wind
Styrax benzoides Craib	Styracaceae	Animal
Turpinia pomifera (Roxb.) DC.	Staphyleaceae	Animal
Wendlandia scabra Kruz. var. *scabra*	Rubiaceae	Unknown

However, by the end of the first growing season, survival rates had declined substantially, probably due to the exposed, ridge-top position of the plots and strong prevailing wind, which resulted in desiccation (browning of young shoots) and death of the trees. During the second year after planting survival rates dropped even more dramatically mostly because cows broke through the fence and ate or trampled many of the planted trees (**Table 3**). The survival rates of all the planted trees, except that of *F. fistulosa* (68.0 %), failed to reach 50 % after the second growing season, which was an acceptable level for framework species [6]. *Debregeasia velutina* Gaudich achieved a 48 % survival rate while *F. subalata* Blume and *H. dulcis* survived at about 45 %.

Table 3 Survival rates of the 20 planted tree species at Toong Yah village, Mae Chaem district, Chiang Mai province.

Species	Survival (%)				
	2 weeks after planting (July 2002)	**End of 1st growing season (Feb 2003)**	**End of 1st dry season (May 2003)**	**End of 2nd growing season (June 2004)**	**FORRU [6]**
Acrocarpus fraxinifolius Wight *ex* Arn.	98.7	50.1	33.5	14.9	25.0**
Afzelia xylocarpa (Kurz) Craib	100.0	64.0	43.8	4.1	-
Alseodaphne andersonii (King *ex* Hook.f.) Koskrm	91.2	37.7	17.7	11.9	-
Castanopsis acuminatissima (Blume) A.DC.	98.6	68.0	55.6	20.0	62.5**
Castanopsis diversifolia (Kurz) King	98.6	37.3	29.2	8.6	-
Castanopsis tribuloides (Sm.) A.DC.^	100.0	73.3 *51.0* (Mar 05)	39.2	13.3	-
Dalbergia ovata Graham	96.0	74.3	72.0	32.0	-
Debregeasia velutina Gaudich	97.3	76.0	76.0	48.0	-
Erythrina subumbrans (Hassk.) Merr.	71.2	33.8	21.9	8.0	89.5* 58.3**
Tetradium glabrifolium (Champ. *ex* Benth) T.Hart.	97.3	37.8	34.7	14.9	-
Ficus fistulosa Reinw. *ex* Blume^	100.0	84.0 *46.0* (Mar 05)	82.7	68.0	-
Ficus subulata Blume	100.0	78.7	66.7	45.3	72.3**
Helicia nilagirica Bedd.	100.0	58.7	34.7	16.0	70.8*
Hovenia dulcis Thunb.^	97.3	61.3 *70.0* (Mar 05)	54.1	45.3	80.0* 85.4**
Ostodes paniculata Blume^	98.5	70.1 *41.0* (Mar 05)	45.6	18.3	-
Phyllanthus emblica L.	97.2	52.0	57.0	41.3	-
Prunus cerasoides D.Don^	98.6	62.7 *31.0* (Mar 05)	40.1	14.9	86.7* 47.9**
Quercus vestita Rehd. & Wils.	97.2	44.0	30.1	10.7	-
Schima wallichii (DC.) Korth	97.2	52.0	45.1	38.9	-
Terminalia bellirica (Gaertn.) Roxb.	100.0	70.1	64.4	21.3	-

^ Species replanted in 2004. Their survival rates after the first growing season (March 2005) are shown as italicized numbers.

* End of 2nd growing season. At FORRU's Mae Sa Mai site (planted in 1998).

**End of 2nd growing season. At FORRU's Mae Sa Mai site (planted in 1999).

Obviously, conditions at this site were much harsher than those at Ban Mae Sa Mai. Even though the planted trees performed rather poorly due to disturbance by the cows, it was not a completely failed experiment. It can be stated that one can choose the 4 framework species, i.e. *F. fistulosa*, *D. velutina*, *F. subalata*, and *H. dulcis*, as suitable candidates to be planted in areas where levels of disturbance by animals is high. These framework species can re-sprout after being eaten by the cows. *P. emblica*, with a 41 % survival rate, may be a suitable choice as well. These species could coppice from lateral meristem tissues. This performance might be quantified by measuring the diameter and length of lateral shoots after the apical shoots were damaged.

3. Tree growth

All the remaining trees (**Tables 4** and **5**) failed to achieve FORRU standard for acceptable height (1.5 m) and crown width (1.8 m) by the end of the second growing season within 2 years [5] due to disturbance by the cows.

4. Survey of plant species in the experiment plots

Plant species found in the experimental plots (4 circular sample units of 10 m in diameter in each area of 1 rai) after 2 growing seasons were about 55 % (Sorensen's Similarity Index = 0.55) similar to those found at the beginning of the experiment (**Table 6**). Some plant seedlings were found in 2002 and 2004 surveys, but some were only found either in 2002 or 2004. It should be noted that most seedlings were found in the 1 m circles surrounding the planted seedlings where soils were periodically disturbed by weeding. There was no similarity between the naturally established tree species in the experimental plots and the tree species found in the nearby less disturbed forest patch.

Table 4 Growth of the 20 planted tree species at Toong Yah village, Mae Chaem district, Chiang Mai province.

Species	N		Height (cm)		Size (Root collar diameter, mm)		Crown width (cm)	
	2003	2004	2003	2004	2003	2004	2003	2004
Acrocarpus fraxinifolius	25	11	27.2 (17.1)	37.3 (24.0)	6.1 (2.6)	12.6 (4.7)	31.4 (19.0)	29.0 (19.8)
Afzelia xylocarpa	28	3	28.9 (8.8)	40.1 (29.4)	5.4 (1.5)	13.8 (5.1)	9.6 (4.6)	28.3 (19.1)
Alseodaphne andersonii	9	4	26.7 (7.0)	20.7 (9.7)	6.7 (1.9)	12.9 (3.4)	23.7 (6.9)	4.1 (3.6)
Castanopsis acuminatissima	32	15	28.1 (12.3)	25.2 (19.7)	3.9 (1.0)	9.0 (3.6)	19.1 (8.7)	14.5 (9.5)
Castanopsis diversifolia	17	6	31.2 (11.4)	28.4 (13.3)	3.7 (1.1)	8.0 (2.8)	18.2 (9.4)	14.2 (7.1)
Castanopsis tribuloides	25	10	32.2 (13.1)	31.2 (14.8)	4.2 (1.2)	9.5 (5.9)	19.1 (7.5)	16.0 (8.0)
Dalbergia ovata	48	24	37.1 (19.2)	31.6 (15.0)	4.9 (1.5)	9.6 (2.9)	14.8 (8.2)	13.1 (7.6)
Debregeasia longifolia	47	36	47.7 (26.7)	65.2 (26.3)	12.3 (7.1)	23.3 (11.4)	42.0 (25.5)	38.1 (19.6)
Erythrina subumbrans	9	6	34.3 (9.4)	54.0 (29.1)	10.0 (5.2)	18.6 (6.4)	35.0 (12.3)	27.0 (18.7)
Tetradium glabrifolium	18	11	45.2 (15.7)	82.3 (14.3)	6.9 (2.6)	16.9 (3.5)	24.1 (10.4)	13.9 (6.0)
Ficus fistulosa	54	51	25.9 (8.4)	34.3 (13.0)	9.6 (3.8)	19.5 (8.4)	26.1 (13.7)	26.7 (13.8)
Ficus subulata	42	34	26.6 (12.0)	36.0 (13.8)	6.3 (1.8)	14.3 (4.7)	16.9 (6.7)	16.7 (10.2)
Helicia nilagirica	24	12	29.6 (14.7)	31.5 (16.0)	5.1 (2.2)	10.2 (2.1)	19.2 (9.7)	21.6 (15.1)
Hovenia dulcis	37	34	54.9 (17.5)	71.4 (19.3)	7.2 (2.1)	16.3 (4.4)	26.0 (15.1)	15.5 (10.7)
Ostodes paniculata	30	13	30.6 (8.0)	40.4 (14.1)	5.5 (1.8)	12.0 (3.2)	18.9 (6.9)	14.0 (6.8)
Phyllanthus emblica	32	31	28.0 (10.1)	40.0 (11.6)	4.5 (1.7)	11.9 (4.3)	20.2 (8.0)	26.9 (13.3)
Prunus cerasoides	25	11	31.0 (15.6)	36.6 (14.3)	5.1 (1.7)	9.7 (3.2)	14.1 (8.4)	11.7 (8.4)
Quercus vestita	16	8	18.1 (8.0)	22.5 (6.1)	2.7 (2.0)	9.0 (2.5)	15.3 (3.8)	19.2 (10.1)
Schima wallichii	28	28	37.5 (13.5)	46.9 (18.4)	4.4 (2.0)	12.7 (5.3)	23.0 (9.8)	28.4 (15.3)
Terminalia bellirica	38	16	28.9 (14.2)	29.5 (10.6)	3.4 (1.1)	12.3 (16.8)	8.7 (6.0)	2.8 (3.6)

Note: Numbers in parentheses are standard deviations.

Table 5 Comparison of growth at the end of 2nd growing season of the remaining 7 planted tree species between this study and FORRU [6].

Species	N			Height (cm)			Crown width (cm)		
	This study*	FORRU [6]		This study*	FORRU [6]		This study*	FORRU [6]	
		1998	1999		1998	1999		1998	1999
Acrocarpus fraxinifolius	11	-	7	37.3 (24.0)	-	210.0 (107.1)	29.0 (19.8)	-	192.6 (124.0)
Castanopsis acuminatissima	15	-	14	25.2 (19.7)	-	135.2 (41.3)	14.5 (9.5)	-	112.1 (42.6)
Erythrina subumbrans	6	11	10	54.0 (29.1)	258.7 (72.9)	281.5 (51.0)	27.0 (18.7)	261.5 (92.6)	280.2 (82.5)
Ficus subulata	34	-	7	36.0 (13.8)	-	105.6 (131.7)	16.7 (10.2)	-	105.6 (131.7)
Helicia nilagirica	12	16	-	31.5 (16.0)	74.1 (58.4)	-	21.6 (15.1)	57.5 (23.3)	-
Hovenia dulcis	34	10	13	71.4 (19.3)	155.1 (51.5)	223.1 (44.4)	15.5 (10.7)	133.9 (61.8)	148.5 (35.4)
Prunus cerasoides	11	10	6	36.6 (14.3)	241.0 (88.1)	188.7 (55.2)	11.7 (8.4)	303.3 (37.2)	241.7 (102.1)

* Planted in 2002

Note: Numbers in parentheses are standard deviations.

Table 6 Forty naturally established seedlings in the planting area surveyed and identified in June 2002 and May 2004.

Species	Family	2002	2004
Ageratum conyzoides L.	Asteraceae	/	/
Albizia chinensis (Osbeck) Merr.	Fabaceae	-	/
Alternanthera sessilis (L.) DC. var. *sessilis*	Amaranthaceae	-	/
Alysicarpus vaginalis (L.) DC.	Fabaceae	-	/
Amaranthus viridis L.	Amaranthaceae	-	/
Amorphophallus yunnanensis Engl.	Araceae	-	/
Anaphalis adnata DC.	Asteraceae	-	/
Anaphalis margaritacea (L.) Benth. & Hook.f.	Asteraceae	/	/
Anneslea fragrans Wall.	Theaceae	/	
Barleria cristata L.	Acanthaceae	/	/
Bidens pilosa L.	Asteraceae	/	/
Blumea balsamifera (L.) DC.	Asteraceae	/	-
Boehmeria chiangmaiensis Yahara	Urticaceae	/	/
Borreria alata (Aubl.) DC.	Rubiaceae	-	/
Borreria laevis (Lam.) Griseb.	Rubiaceae	-	/
Borreria repens DC.	Rubiaceae	/	-
Carex baccans Nees	Cyperaceae	/	-
Cissus repens Lam.	Vitaceae	-	/
Commelina diffusa Burm.f.	Commelinaceae	/	/
Conyza sumatrensis (Retz.) Walk.	Asteraceae	/	/
Crassocephalum crepidioides (Benth) S.Moore	Asteraceae	/	/
Crotalaria albida Heyne *ex* Roth	Fabaceae	/	/
Crotalaria filiformis Wall. *ex* Bth. var. *kerrii* (Craib) Niyo.	Fabaceae	/	-
Cyperus cyperoides (L.) Kuntze	Cyperaceae	/	/
Cyrtococcum accrescens (Trin.) Stapf	Poaceae	/	/
Desmodium heterocarpon (L.) DC. ssp. *heterocarpon* var. *strigosum* Meeuwen	Fabaceae	/	/
Desmodium mulfiflorum DC.	Fabaceae	/	-
Desmodium repandum (Vahl) DC.	Fabaceae	/	/
Digitaria setigera Roth *ex* Roem. & Schult. var. *setigera*	Poaceae	/	-
Drymaria diandra Blume	Caryophyllaceae	/	-
Elsholtzia blanda H.Keng	Labiatae	/	-
Eupatorium adenophorum Spreng.	Asteraceae	/	/
Eupatorium odoratum L.	Asteraceae	/	-
Eurya acuminata DC. var. *wallichiana* Dyer	Theaceae	/	-
Ficus hirta Vahl. var. *hirta*	Moraceae	-	/
Fimbristylis dichotoma (L.) Vahl. ssp. *dichotoma*	Cyperaceae	-	/
Galinsoga parviflora Cav.	Asteraceae	/	-
Imperata cyclindrica (L.) P.Beauv.	Poaceae	/	/
Indigofera spicata Forssk.	Fabaceae	/	-
Murdannia simpler (Vahl) Brea.	Commelinaceae	/	-

CONCLUSIONS

Overall, the seedlings planted in 2002 and 2004 at the site near Toong Yah village, Mae Chaem district, Chiang Mai province, performed worse than the seedlings planted in 1998 and 1999 at Mae Sa Mai village (FORRU's original site). The major contributing factor was the invasion of the cows into the site. Weed growth appeared to be higher than at Mae Sa Mai, which was possibly due to the absence of herbicide at the site preparation and cardboard mulch. Fire did not occur in the first dry season, so the fire-resistant properties of the species could not be evaluated at this studied site.

ACKNOWLEDGEMENTS

This work was support by the TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT_345001 and BRT_348003. It was also partially supported by World Agroforestry Center (ICRAF), Chiang Mai province, Thailand. The first author thanks the Department of Biology, Chiang Mai University for logistical support.

REFERENCES

[1] KD Holl and M Kappelle. Tropical forest recovery and restoration. *Trends Ecol. Evol.* 1999; **14**, 378-9.

[2] JA Parrotta, JW Turnbull and N Jones. Catalyzing native forest restoration on degraded tropical lands. *Forest Ecol. Manag.* 1997; **99**, 1-7.

[3] W Fang and SL Peng. Development of species diversity in the restoration process of establishing a tropical man-made forest ecosystem in China. *Forest Ecol. Manag.* 1997; **99**, 185-96.

[4] G Pakkad, F Torre, S Elliott and D Blakesley. Selecting seed trees for a forest restoration program: A case study using *Spondias axillaries* Roxb. (Anacardiaceae). *Forest. Ecol. Manag.* 2003; **99**, 363-70.

[5] Forest Restoration Research Unite (FORRU). *How to Plant a Forest: The Principles and Practice of Restoring Tropical Forests*. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, 2006.

[6] S Elliott, P Navakitbumrung, C Kuarak, S Zangkum, V Anusarnsunthorn and D Blakesley. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. *Forest. Ecol. Manag.* 2003; **184**, 177-91.

[7] S Elliott, V Anusarnsunthorn, N Garwood and D Blakesley 1995. Research needs for restoring the forests of Thailand. *Nat. Hist. Bull. Siam. Soc.* 1995; **43**, 179-84.

[8] SP Goosem and NIJ Tucker. *Repairing the Rainforest - Theory and Practice of Rainforest Re-establishment in North Queensland's Wet Tropics*. Wet Tropics Management Authority, Cairns, 1995.

[9] S Elliott. *Introduction*. *In*: S Elliott, J Kerby, D Blakesley, K Hardwick, K Woods and V Anusarnsunthorn (eds.). Forest Restoration for Wildlife Conservation. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University, 2000, p. 385-411.

[10] S Elliott, J Kerby, V Baimai and A Kaosa-ard. *Implementing the agenda*. *In*: S Elliott, J Kerby, D Blakesley, K Hardwick, K Woods, V Anusarnsunthorn (eds.). Forest Restoration for Wildlife Conservation. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University, 2000, p. 417-20.

[11] World Agroforestry Centre (ICRAF). *Mae Chaem watershed*, 2001, Unpublished data.

[12] T Santisuk. *An Account of the Vegetation of Northern Thailand, Geoecological Research*, Vol V. Schweinfurth, U. Stuttgart: Franz Steiner Verlag Wiesbadens Gmth, 1988.

[13] Royal Forestry Department. *Weather data at the Mae Chaem watershed Research Station. Chiang Mai: Royal Forest Department*, 2001, Unpublished data.

[14] D Blakesley, S Elliott, C Kuarak, P Navakitbumrung, S Zangkum and V Anusarnsunthorn. Propagating framework tree species to restore seasonally dry tropical forest: Implications of seasonal seed dispersal and dormancy. *Forest Ecol. Manag.* 2002; **164**, 31-8.

บทคัดย่อ

ประสิทธิ์ วังภคพัฒนวงศ์ และ สตีเฟ่น เอลเลียต

การทดสอบการฟื้นฟูป่าด้วยวิธีพรรณไม้โครงสร้างในจังหวัดเชียงใหม่ ประเทศไทย

การฟื้นฟูป่าโดยวิธีพรรณไม้โครงสร้างที่พัฒนาโดยหน่วยวิจัยการฟื้นฟูป่า เป็นวิธีการฟื้นฟูป่าไม่ผลัดใบที่เสื่อมโทรมจากการเกษตรบริเวณอุทยานแห่งชาติดอยสุเทพ-ปุยที่ประสบความสำเร็จ รายงานวิจัยนี้เป็นผลการศึกษา 3 ปี ของการพยายามนำวิธีการฟื้นฟูป่าแบบพรรณไม้โครงสร้างไปทำซ้ำที่บ้านทุ่งหญ้า อำเภอแม่แจ่ม ที่มีความสูงจากระดับน้ำทะเลใกล้เคียงกับบ้านแม่สาใหม่ อำเภอแม่ริม ซึ่งเป็นพื้นที่วิจัยหลักของหน่วยวิจัยการฟื้นฟูป่า โดยปลูกกล้าไม้ 20 ชนิด ในเดือนมิถุนายน 2545 ผลการศึกษาในปีที่ 2 พบว่า กล้าไม้มีอัตราการรอดตาย ความสูง ขนาดลำต้น และความกว้างเรือนยอดต่ำกว่ากล้าไม้ที่ปลูกที่บ้านแม่สาใหม่ อำเภอแม่ริม กล้าไม้หลายชนิดตายเพราะวัวเหยียบและกล้าไม้บางชนิดตายเพราะวัวกิน อย่างไรก็ตาม กล้าไม้บางชนิด เช่น *Ficus fistulosa* และ *Phyllanthus emblica* สามารถแตกตาข้างใหม่ได้หลังจากวัวกิน ในปี พุทธศักราช 2547 ได้ปลูกกล้าไม้ที่รอดตายค่อนข้างมาก 5 ชนิดคือ *Castanopsis tribuloides*, *Ficus fistulosa*, *Hovenia dulcis*, *Ostodes paniculata* และ *Prunus cerasoides* พร้อมทั้งกล้าไม้ที่ยังไม่เคยปลูกในพื้นที่อีก 12 ชนิด ในเดือนมิถุนายน ผลการศึกษาพบว่า หลังฤดูฝนแรก กล้าไม้มีอัตราการรอดตาย ความสูง ขนาดลำต้น และความกว้างเรือนยอดต่ำกว่ากล้าไม้ที่ปลูกที่บ้านแม่สาใหม่ กล้าไม้ทั้ง 17 ชนิดมีอัตราการรอดตายเฉลี่ย 50 เปอร์เซ็นต์หลังฤดูปลูกแรก เนื่องจากพื้นที่วิจัยเป็นพื้นที่โล่ง ดังนั้น ลมที่พัดแรงอาจเป็นสาเหตุหนึ่งที่ทำให้กล้าไม้รอดตายน้อยและเจริญเติบโตได้ค่อนข้างช้ากว่าที่คาดไว้ กระบวนการเตรียมพื้นที่ที่แนะนำโดยหน่วยวิจัยการฟื้นฟูป่า โดยการกำจัดวัชพืชด้วยสารปราบวัชพืชและการใช้กระดาษลูกฟูกคลุมบริเวณรอบโคนต้นน่าจะช่วยให้กล้าไม้รอดตายและเติบโตมากขึ้นในพื้นที่วิจัยนี้

ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยเชียงใหม่ อำเภอเมือง จังหวัดเชียงใหม่ 50200