# Chapter 4

# Fallow Succession and Regeneration of *Macaranga* in Reduced Rotation Cycle

## 4.1 Introduction

Fallowing, the practice of leaving land to regrowth of natural vegetation for a period of one or more years between cropping, is not new and in Europe may be traced back before the pre-industrial agriculture revolution and in Britain in the 16th -18th centuries (Brookfield, 2001). In Southeast Asia, the practice of fallow may go back into the long history of dry land agriculture. In spite a long history in the mountainous region of Southeast Asia, fallow practice is regarded by policy makers and the general public as "wasteful" and "backward" and many attempts have been and continue to be made by governments to eliminate the fallow land system of shifting cultivation and promote permanent cultivation as alternative (Rerkasem, 2003).

In Northern Thailand, previous studies of fallow succession have been carried out in rotational field's cultivation by Lua and Karen community's tires (Kunstadter *et. al.*, 1978; Sabhasri, 1978; Nakano, 1978 and Schmidt-Vogt, 1995, 2001). In rotational systems, the length of cropping and fallowing and shifting cultivation practices determine the development and structure of fallow regrowth in secondary forests. Sabhasri (1978) pointed out that the length of fallow periods should be at least 10 years for fallow regrowth to reach maturing stage. Nakano (1978) has shown that the length of fallow period is crucial to the recovering of soil fertility through the nutrients stored in the vegetation. As fallow periods become shorter, weeds become dominant. *Eupatorium odoratum*, for example, could survive abundantly under young secondary forest of five years of fallow in Karen community of Mae Tho area, Chiang Mai province. Fallow management that leaves tree stumps and roots in upland rice field is favorable to rapid fallow regeneration and succession (Schmidt-Vogt, 2001). Coppice shoots and root suckers can grow back much quicker than regeneration from seeds. The practice of leaving large trees during bush clearing, referred to as "relict emergent", differ among different ethnic groups. Lua practices selective felling of trees with diameter > 15cm, leaving an average 244 relict emergent $ha^{-1}$. Karen, on the other hand, does not seen to have any idea of selective cutting and apparently fell large and small tree at random. Nevertheless, their shifting cultivation field may contain 20-40 relict emergent. With exemption of Nakano (1978), others studies (Kunstedter *et al.*, 1978; Sabhasri, 1978 and Schmidt-Vogt, 2001) deal with long fallow systems between 9 to 17 years with short cropping of 1 year.

In Tee Cha, as shown in the previous chapter, farmers are managing *Macaranga denticulata* to sustain their traditional shifting cultivation for subsistent production of upland rice and a rich diversity of other swidden crops with fairly short rotation. In an earlier study, it was observed that species richness in the *Macaranga* dominant bush fallow is less than those of forests that were community-managed as well as unmanaged natural ecosystems (Table 4.1). *Macaranga* is a pioneer genus in natural forest succession (Whitmore, 1982). However, no record is available on attempts to examine the biodiversity of *Macaranga* dominant fallow. It is not known whether the abundance of *Macaranga* could lead to the suppression of rich-biodiversity of the secondary forests in a long run. The present study was carried out to

1) Examine species composition and the change in different stages of fallow regrowth.
2) Determine fallow productivity in terms of biomass and nutrient content with respect to densely and sparsely populated *Macaranga* fields at different stage of fallow regrowth, and
3) Explore regeneration process of *Macaranga* in cropping year and after harvesting of upland rice.

**Table 4.1** Number of plant species in various land use stages and field types of Tee Cha village

| Land Use Stags/Field Types | Number of Species | |
|---|---|---|
| | Total | Useful |
| Undisturbed Headwater | 72 | 64 |
| Community Forests (>200 years) | 64 | 57 |
| Utility Forests (Dry Dipterocarpus) | 54 | 45 |
| Bush Fallow with Reduced Cycle (7 years) | 41 | 37 |
| Mixed Perennial and Fruit trees garden (*Mr. Nopporn*) | 49 | 40 |
| Home gardens | 85 | nd |
| Total | 308 | nd |

**Source:** from Rerkasem (2000)

nd= Not determined

### 4.2 Materials and Methods:

It was decided at the onset of this study that fallow succession in Tee Cha could allow opportunity to carry out field work beyond it limited cycle of 7 years, as farmers still remember patches opening up for upland rice cultivation for the past 10-15 years. Therefore, the study of fallow succession in this study has been also extended to include other land use system previously opening up for shifting cultivation in the village in order to obtain it results beyond the limitation of existing shifting cultivation field with 7 years cycle.

#### 4.2.1 Plant Counts and Species Diversity of Fallows

A series of field studies were conducted from December 2001 to January 2003. Species inventories were taken in 2001 for plots 1996, 1998 and 2000 to represent fallow regrowth of 0, 3, 5 years with inclusion of undisturbed fallow > 8 years (Figure 4.1). Theses plots were followed in 2002 (for plot 1996, 1998 and 2000 to represent fallow regrowth of 1, 4, 6 years) and again in 2003 (for plot 1996, 1998 and 2000 to represent fallow regrowth of 2, 7 years) to obtain data for full fallow cycle. Plant count and measurements were made in densely and sparsely *Macaranga* populated plots identified with field checks and farmers' assistance. An unburned field with > 8 years of regrowth was included in the survey for comparison and extrapolation of move mature secondary vegetation. Identification of species and plant count were made in sample plots, 20m X 20m in size. Large trees (> 1.5 m high and diameter >15 cm girth at breast) were counted in 20m X 20m. Small tree (>1.5 m high and diameter < 15 cm girth at breast) were counted in the nested subplot 10m X 10m. Other tree seedling, shrub, herb and grasses (<1.5m high) were counted with 2mX 2m of subplot. In April-May, *Macaranga* were counted in all fallow forests in 10m X 10m quadrants with 3 samples.

Diversity indices were derived in order to compare the species richness, distribution and evenness. As the number of species in quadrant represents species richness the distribution and evenness were calculated by Shannon-Weaver index (Power and McSorley, 2000) as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

When s = total number of types found

$p_i$ = proportion of the number of type i divided by total number of plants in each plot.

Comparisons were made between densely and sparsely populated areas of *Macaranga* and tested statistically with t-test.

#### 4.2.2 Productivity of Fallows

Biomass of forest fallows were undertaken with non-destructive sampling technique (Hairiah *et al.*, 1999). The method is based on the allometric relationship between DBH (diameter at 1.3 m above the ground) and whole-tree biomass. In this study, DBH was measured from all individual trees in the quadrant. Biomass of tree seedlings and other shrubs, herbs etc was determined by cutting off the ground level in 2 m x 2 m. Plants were weighted directly and sub-sample of 3 kg was taken for oven dry at 80 ° c for 48 hr for moisture content. The data were med to estimate above ground biomass as follows

$$\text{Biomass} = 0.139\ \text{DBH}^{2.32}\ \text{kg tree}^{-1}$$

A total of 42 plots were measured.

Sub-samples were dried to constant weight at 80 ° C, ground and analyzed for N, P, K, Ca and Mg (in years 2001). Before burning soil samples were taken from the same area at 0-30 and 30-60 cm for determination of pH (water, 1:1), organic matter content (Walkley-Black), available P (Bray II, Wanatabe and Olsen, 1962), K, Ca and Mg (1 N $NH_4Oac$ pH7).

### 4.2.3 Seed Production and Seed Bank

Seed production was measured form three average size trees for each ages from 3 years old (first seed bearing year) to mature trees before slash and burn. For each tree, seeds were counted according to their components (Kerby *et al.* 2000 and Gardner *et al.* 2000):

$$\text{Seeds tree}^{-1} = \text{branches tree}^{-1} \times \text{inflorescences branch}^{-1} \times \text{Seeds inflorescence}^{-1}$$

Inflorescences per branch were taken randomly from 3 branches tree$^{-1}$ and seeds inflorescences$^{-1}$ were counted from 3 inflorescences branch$^{-1}$. Measurement were made in both sparsely and densely populated *Macaranga* sites in the fields in natural abundance of *Macaranga* trees could be distinguished, i. e. sparsely Vs densely populated site.

The number of seeds in the soil, regularly referred as seed bank (Harper, 1973), was determined in the field at 5 depths, 0-5, 5-10, 10-20, 20-30 and 30-50 cm from ground level. Soils were taken from sample area of 50 cm X 50 cm at depth and seeds were recovered from the soil by collected in the April 2004 from densely population area and cross section of slope 3 points.

### 4.2.4 Recruitment, Establishment and Survival rates of *Macaranga* Seedlings

Seedling recruitment was measured in the cropping and fallow fields after rice harvest especially in plots 2002 and 2003.

In 2002 plot, count of *Macaranga* seedlings started from 1, 2, 5, 8 and 12 months after emergence in upland rice. Nopporn's plot was taken for seedling count. Quadrants (10m X 10m in size) were placed in both densely and sparsely populated areas with three replicates.

### 4.2.5 Seed Germination and Variability Tests

On 30 August 2003, mature fruits of *Macaranga* were collected for 6 years old plant and air-dried for 1 month before threshing. 100 seeds were placed in germination tray filled up with soil taken from the fields. Treatments included 10 different periods of seed ages after fruit harvests; 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 months from fruit harvests. Seeds were placed in plastic net bags and stored in open room with average temperature 32$^0$C.

Due to intermittent germination, germination counts were taken monthly for five months after sowing during October 2003- June 2004. Randomized block design was adopted with 3 replicates and data were analyzed statistically.

In a separate experiment, 20 seeds were used for seed viable test with Tetra-Zolium (TZ) test (Peters, 2000 and ISTA, 1999). Seed age varied from 1, 2, 3, 5 and 7 months after fruit harvest in year 2003. Each test was carried out with 4 replicates of 20 seeds each. This allowed T-test for comparison between populations with different seed age.

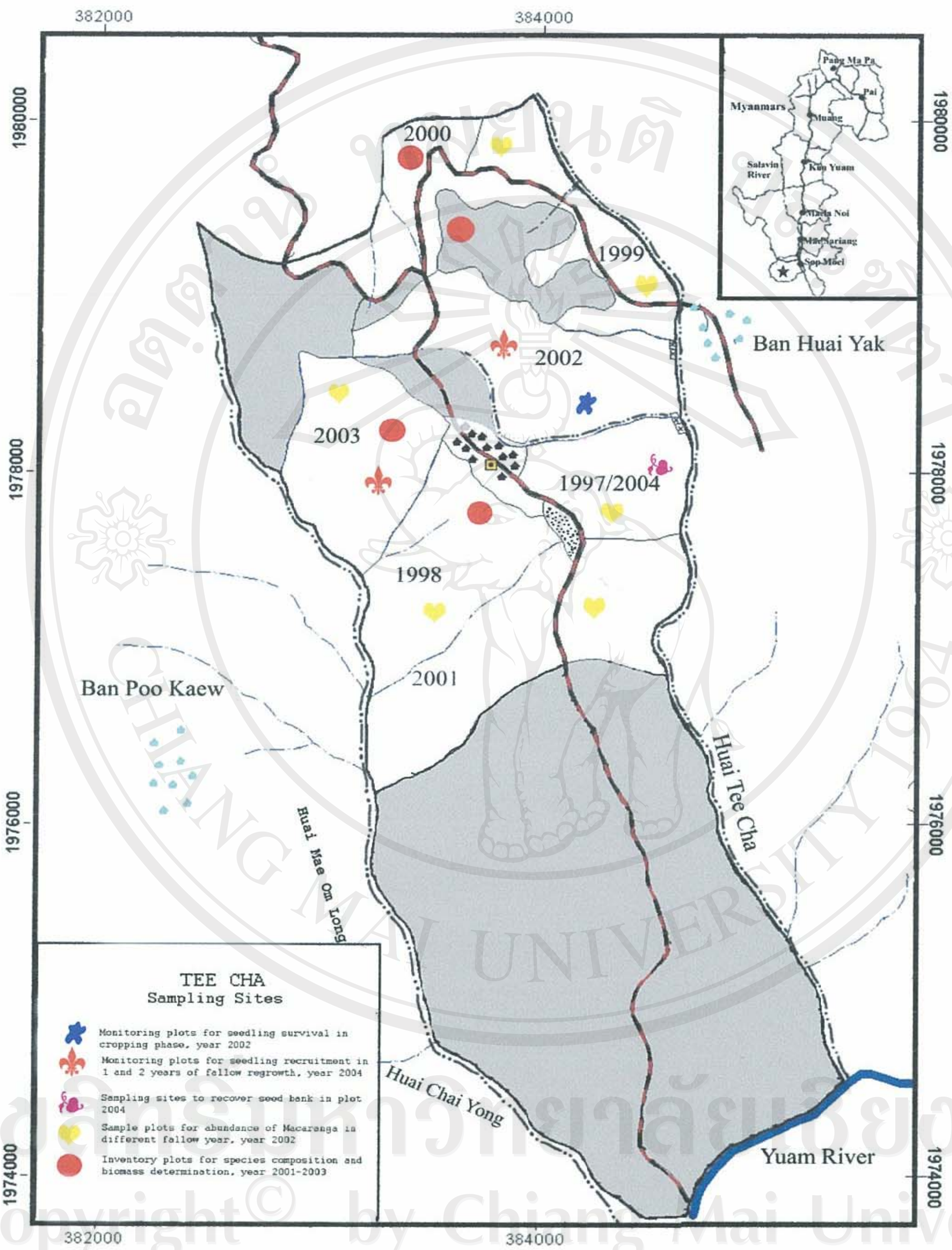





**Figure 4.1** Sites for sampling and monitoring in a study of the dynamics of *Macaranga*.

### 4.3 Results

#### 4.3.1 Species composition

The species composition between areas densely and sparsely populated with *Macaranga* in the same fallow year are not significant different. The major growth forms present were: climber, fern, grass, herb, palm, shrub, small tree, tree, and woody climber (Table 4.2 and Appendix E). Trees were the most common type of plants during the fallow periods, comprising 30% of all species in the early fallow period and reaching 50% of the total in fallow years 3 or 4. The grass and herb types were found mostly in the early stages of fallow and decrease in the later fallow years (Figure 4.2).

#### 4.3.2 Fallow succession

The successional stages of fallow regrowth are shown in Figure 4.3 examples of vegetation treatment measured in selected samples of cropping year, $2^{nd}$, $4^{th}$ and $6^{th}$ years of fallow regrowth are graphically illustrated in Figure 4.4.

Successional process began at the time of slashing following by burning (Figure 4.5). At this stage, farmers cut tree Diversity, measured as Species Richness and Shannon-Weaver indices, of swidden crops in the fields of invididual farm households. Selectively depending on those trees they want to leave in the field. These include those that are big trees belong to the climax species. Trees chosen for coppicing and those that grow back as root suckers are cut differently.

The re-growth patterns of the plants after the farmers cut and burn are as follows:

a) Shredded tree - branches re-growth from the old big trees.

b) Coppicing - new shoot from the trees was 2 groups.

1. Coppice stool above ground e.g. *Fernandoa adenophylla, Glochidion sphaerogynum.*

2. Coppice stool below ground e.g. *Lithocarpus sootepensis,* and *Microcos peniculata.*

*c)* Seedling - new germination from seeds. e.g. *Clerodendrum infortunatum, Chromolaena odorata, Aguatum comyzodes,* and *Macaranga denticulata.*

Adding the management of *Macaranga* in upland rice, successional stages of fallow began with sparsely populated of climax species and suckers on the top and tree seedlings and new shoots emerged from seeds and coppicing species of various species on the floor of vegetation (Figure 4.4a). In this case, the serial stages of fallows could progressively develop to tree composition instead of grasses and herbs dominated vegetation in limited short fallow.

The inclusion of a field with >8 years of forest regrowth (Figures 4.3 and 4.5) confirmed that if the short and dominant *Macaranga* fallow vegetation was allowed to develop beyond the cycle limit, natural forest succession in likely to be achieved on a long run. Climax species replaced pioneer species and shading control vegetation below the canopy.

**Table 4.2** The number species by plant types in fallow fields at different ages.

| *Macaranga* density | Fallow year | Species type | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | U | C | F | G | H | P | S | ST | T | WC | TO |
| Dense | After rice harvest | 0 | 1 | 4 | 4 | 13 | 1 | 5 | 7 | 14 | 6 | 55 |
| | Year 1 | 0 | 0 | 0 | 9 | 6 | 0 | 2 | 4 | 12 | 4 | 37 |
| | Year 2 | 0 | 0 | 2 | 2 | 2 | 0 | 4 | 5 | 16 | 2 | 33 |
| | Year 3 | 0 | 0 | 3 | 1 | 3 | 0 | 2 | 12 | 20 | 2 | 43 |
| | Year 4 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 8 | 19 | 1 | 34 |
| | Year 5 | 0 | 0 | 3 | 0 | 1 | 1 | 3 | 9 | 16 | 2 | 35 |
| | Year 6 | 1 | 1 | 2 | 1 | 3 | 0 | 2 | 6 | 19 | 4 | 40 |
| Sparse | After rice harvest | 0 | 1 | 4 | 6 | 15 | 1 | 5 | 9 | 16 | 6 | 63 |
| | Year 1 | 0 | 0 | 0 | 12 | 7 | 0 | 1 | 6 | 7 | 3 | 36 |
| | Year 2 | 0 | 0 | 2 | 2 | 2 | 0 | 4 | 8 | 16 | 2 | 36 |
| | Year 3 | 0 | 0 | 3 | 1 | 3 | 0 | 1 | 9 | 20 | 2 | 39 |
| | Year 4 | 2 | 0 | 2 | 0 | 0 | 2 | 3 | 5 | 18 | 0 | 32 |
| | Year 5 | 0 | 0 | 3 | 0 | 1 | 1 | 2 | 8 | 19 | 2 | 36 |
| | Year 6 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 9 | 17 | 3 | 35 |
| Total | After rice harvest | 0 | 1 | 4 | 6 | 15 | 1 | 5 | 11 | 18 | 6 | 67 |
| | Year 1 | 0 | 0 | 0 | 18 | 10 | 0 | 3 | 7 | 16 | 5 | 59 |
| | Year 2 | 0 | 0 | 2 | 2 | 2 | 0 | 4 | 8 | 24 | 2 | 44 |
| | Year 3 | 0 | 0 | 3 | 1 | 3 | 0 | 2 | 12 | 24 | 2 | 47 |
| | Year 4 | 2 | 0 | 3 | 1 | 2 | 2 | 4 | 8 | 28 | 1 | 51 |
| | Year 5 | 0 | 0 | 4 | 0 | 1 | 1 | 4 | 10 | 23 | 3 | 46 |
| | Year 6 | 0 | 1 | 2 | 1 | 3 | 0 | 3 | 9 | 23 | 4 | 47 |
| Total | | 4 | 1 | 4 | 26 | 26 | 2 | 11 | 28 | 63 | 11 | 176 |

**Note:**
U = unknown (Grass / Herb /Shrub)
C = Climber
F = Fern
G = Grass
H = Herb
P = Palm
S = Shrub
ST = Small Tree
T = Tree
WC = Woody Climber
TO = Total species

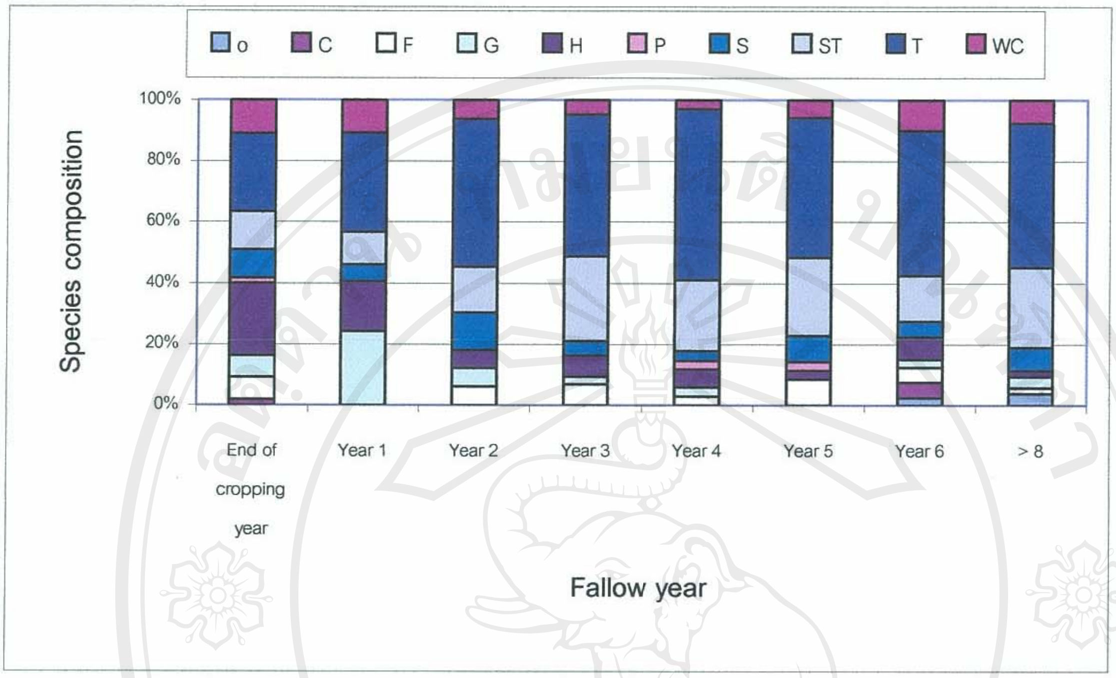



**Figure 4.2a** The composition of species in the dense area of *Macaranga* between in each fallow year.

**Note:**

U = unknown (Grass / Herb /Shrub)
F = Fern
H = Herb
S = Shrub
T = Tree

C = Climber
G = Grass
P = Palm
ST = Small Tree
WC = Woody Climber
TO = Total species

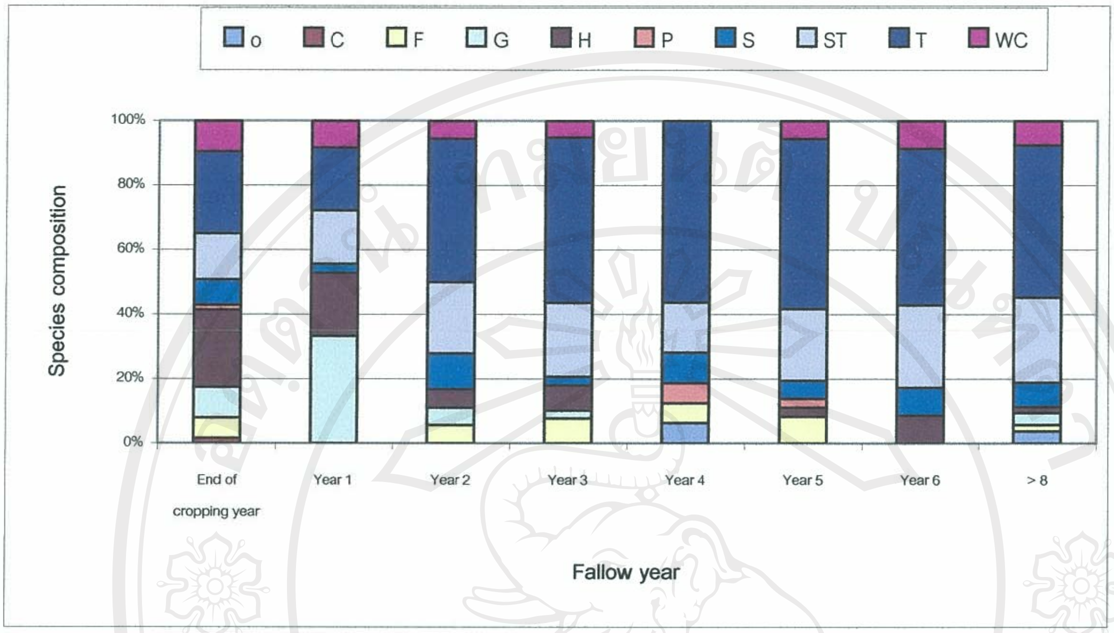



**Figure 4.2b** The composition of species in the sparse area of *Macaranga* between in each fallow year.

**Note:**

U = unknown (Grass / Herb /Shrub)
F = Fern
H = Herb
S = Shrub
T = Tree

C = Climber
G = Grass
P = Palm
ST = Small Tree
WC = Woody Climber
TO = Total species

Cropping year

1-year fallow regrowth

2-year fallow regrowth

3-year fallow regrowth

4-year fallow regrowth

5-year fallow regrowth

6-year fallow regrowth

Climax forest

**Figure 4.3** The successional stages of the rotational shifting cultivation in Tee Cha village.

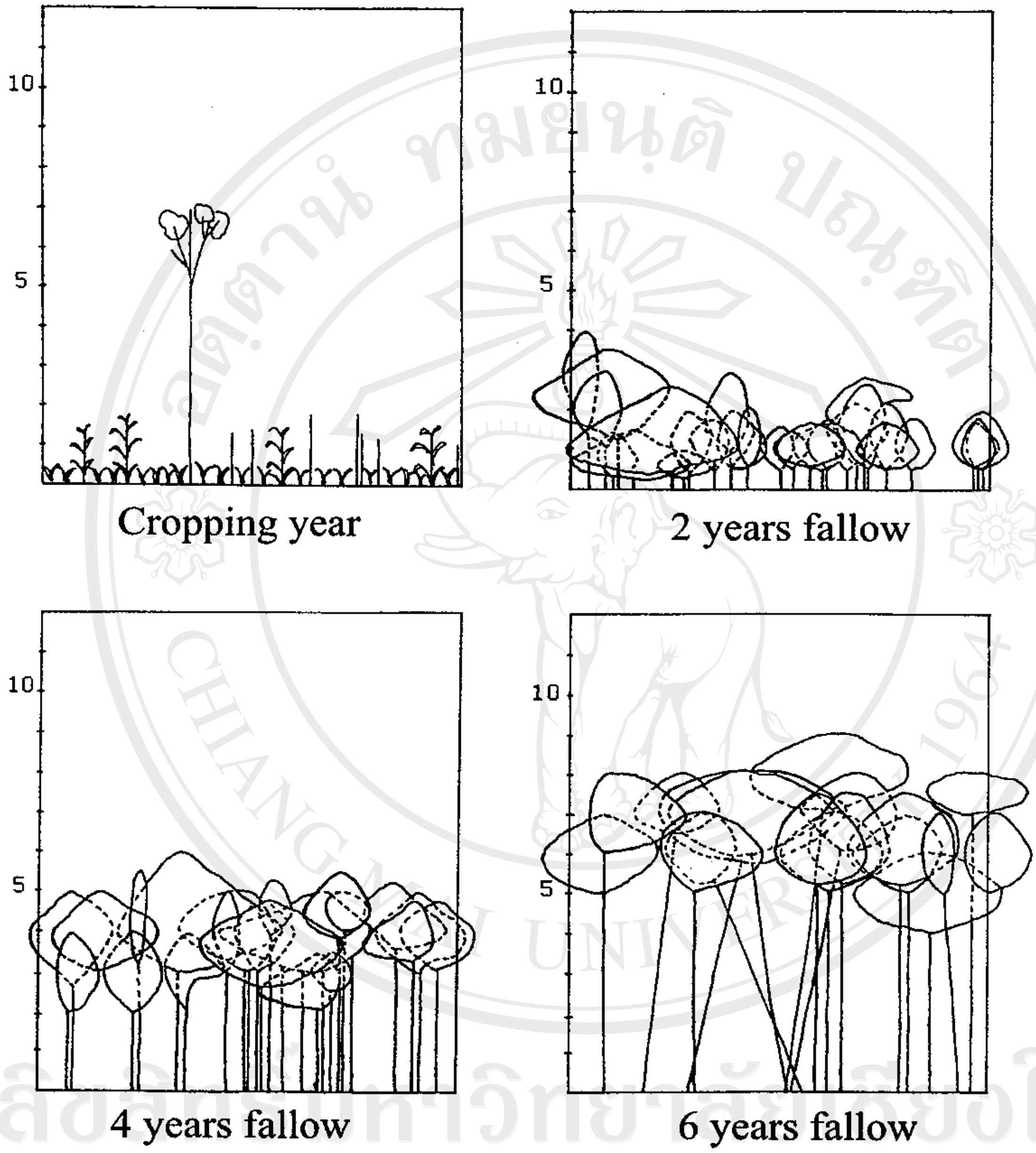





**Figure 4.4** The diagram of plants in the difference fields' age of rotate system (cropping year= plot 2004, 2 years fallow= plot 2002, 4 years fallow= plot 2000 and 6 years fallow= plot 1998; plot size 10m X 10m).

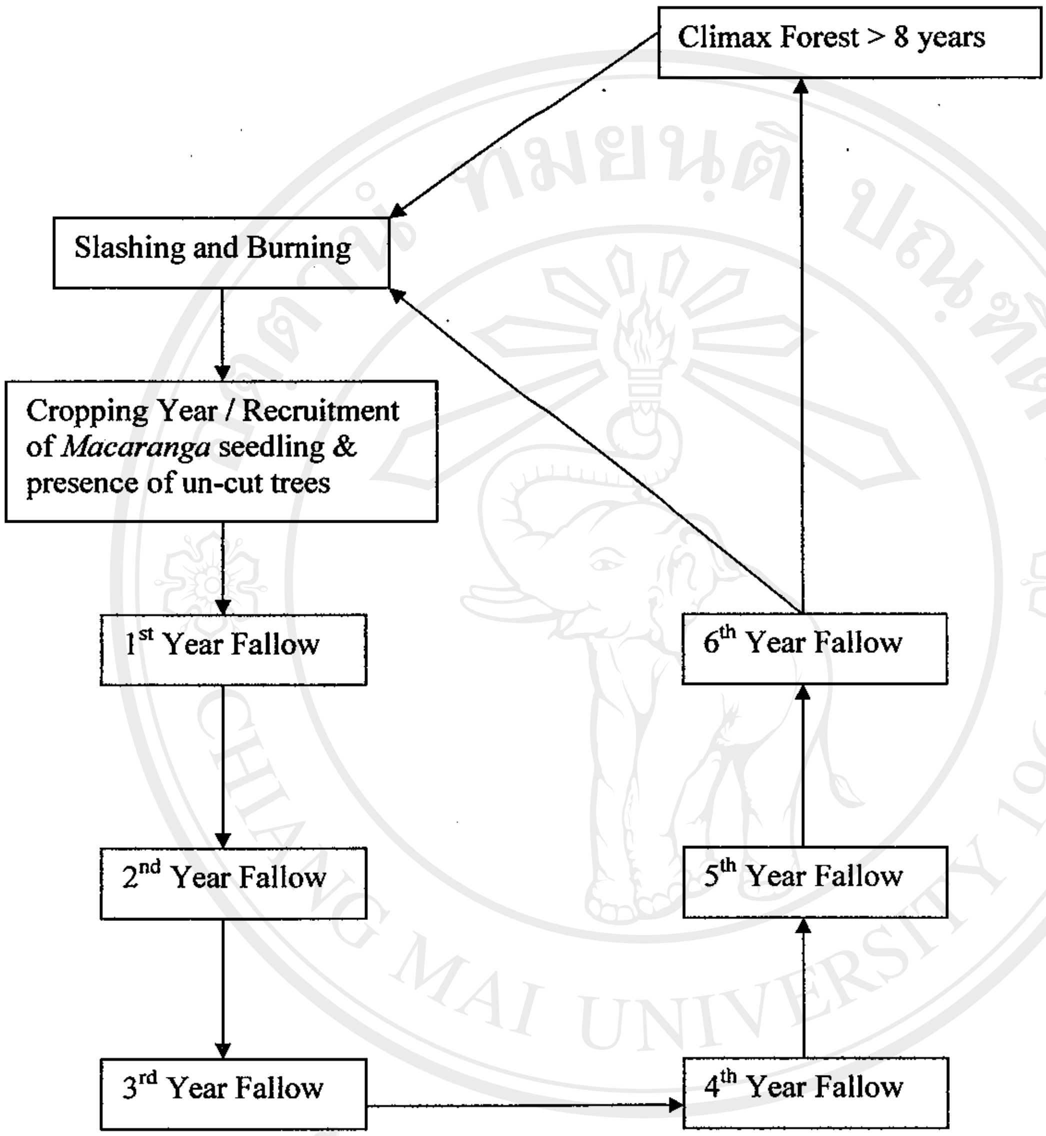





**Figure 4.5** Stages of fallow succession in reduced cycle of shifting cultivation with dominant of *Macaranga denticulata*.

In the fallows, the total number of species varied between 33-55 species in the densely populated area and 32-63 species in the sparsely populated area. The overall number of species were not statistically significant different between the two areas in Table 4.3.

**Table 4.3** The number of species between different *Macaranga denticulata* densities area in different fallow re-growth.

| Fallow year | Number of Species | | |
|---|---|---|---|
| | Dense area | Sparse area | Total |
| 0 (Rice year) | 55 | 63 | 67 |
| 1 | 37 | 36 | 59 |
| 2 | 33 | 36 | 44 |
| 3 | 43 | 39 | 47 |
| 4 | 34 | 32 | 51 |
| 5 | 35 | 36 | 46 |
| 6 | 40 | 35 | 47 |
| 8 | 53 | 53 | 53 |

**Note:** Data in the fallow year >8 of dense and sparse area are same plots.

### 4.3.3 Abundance, Species Richness and Evenness

The number of *Macaranga* and others trees declined significantly as the fallow developed from 2 to 6 years of re-growth in both dense and sparse *Macaranga* (Tables 4.4 and 4.5). The numbers of *Macaranga* trees in densely populated area were always higher than those in sparse area throughout the re-growth periods. In the first 2 years of regrowth, there were about twice as many *Macaranga* trees in densely populated area than those in sparse area. By the 5th and 6th year of re-growth, the number of *Macaranga* in densely populated area was quadruple of those in sparsely populated area but the numbers of other trees were about the same in areas with dense and sparse *Macaranga*. This result indicated that the dominance of *Macaranga* in the fallow has no effect on biodiversity of forest fallows. Some 25 tree species were found at the end of the fallow period but their distribution were more evenly distributed in sparsely populated *Macaranga* area as reflected by Shannon-Weaver's Index (Table 4.6). Seedling competition within and between species (i.e. *Macaranga*) could have been very strong at early stages of fallow regrowth. This led to self-thinning of *Macaranga*, stands from the first few years before stabilizing at about 4,150 trees $ha^{-1}$ in densely populated *Macaranga* area and over 1,010 trees $ha^{-1}$ in sparsely populated *Macaranga* area. Low rate of *Macaranga* seedling survival in sparsely populated *Macaranga* area may be caused by many density independent factors. The role of AM fungi might have helped higher rate of survival in densely populated *Macaranga* area, especially the few first dry seasons. This needs further investigation.

**Table 4.4** Number of *Macaranga denticulata* (trees ha$^{-1}$) in the dense and sparse areas at different years of fallow regrowth.

| Fallow year | *Macaranga denticulata* density | | T-test |
|---|---|---|---|
| | Dense | Sparse | |
| 1 | 19,067 | 9,967 | ** |
| 2 | 10,925 | 5,162 | ** |
| 3 | 6,925 | 2,633 | ** |
| 4 | 4,000 | 1,323 | ** |
| 5 | 4,250 | 1,142 | ** |
| 6 | 4,150 | 1,010 | ** |

**Note:** ** =significant by T-test ($p < 0.01$)
NS =not significant

**Table 4.5** Abundance of *Macaranga denticulata* and other species in fallow re-growth with dense and sparse *Macaranga*.

| Fallow year | Plant Numbers (trees ha$^{-1}$) | | | |
|---|---|---|---|---|
| | Dense area | | Sparse area | |
| | *Macaranga* | Others | *Macaranga* | Others |
| After rice harvest | - | - | - | - |
| 1 | - | - | - | - |
| 2 | 10,925 | 3,708 | 51,62 | 5,683 |
| 3 | 6,925 | 3,602 | 2,633 | 6,100 |
| 4 | 4,000 | 4,758 | 1,323 | 6,937 |
| 5 | 4,250 | 3,075 | 1,142 | 4,850 |
| 6 | 4,150 | 2,950 | 1,010 | 3,350 |
| >8 | 1,653 | 5,488 | - | - |

**Note:** The number of plants calculated from Tree and Small tree species are higher than 1.5m.
Fallow year > 8 use data same plot, don't separate between densely and sparsely population.
Data is based on tree height above 1.5 m. Fallow > 8 years of regrowth is based on field previously dominated with *Macaranga*.

**Table 4.6** Plant numbers, species richness and Shannon-Weaver's Index in fallow regeneration of different fallow ages, with dense and sparse *Macaranga*.

| Fallow year | Dense area | | | Sparse area | | |
|---|---|---|---|---|---|---|
| | Total Number of trees (plants $ha^{-1}$) | Species Richness[1] | Shannon-Weaver's Index | Total Number of trees (plants $ha^{-1}$) | Species Richness[1] | Shannon-Weaver's Index |
| 0 (Rice year) | - | 21 | - | - | 25 | - |
| 1 | - | 16 | - | - | 13 | - |
| 2 | 14,633 | 21 | 1.22 | 10,766 | 24 | 1.93 |
| 3 | 10,537 | 32 | 1.44 | 8,733 | 29 | 2.35 |
| 4 | 8,758 | 27 | 1.98 | 8,380 | 23 | 1.97 |
| 5 | 7,325 | 25 | 1.90 | 5,992 | 27 | 2.61 |
| 6 | 7,100 | 25 | 1.71 | 4,320 | 26 | 2.48 |
| >8 | 7,141 | 38 | 2.22 | - | - | - |

Comparisons between dense and sparse areas by T-test

| | T-test |
|---|---|
| Total Number of trees (plants $ha^{-1}$) | * |
| Species Richness | NS |
| Shannon-Weaver's Index | ** |

**Notes:** 1= only Tree and Small tree species

** =significant by T-test ($p < 0.01$), * =significant by T-test ($p < 0.05$) and NS =not significant

### 4.3.4 Productivity of Forest fallow

**1) Above ground biomass**

The above ground biomass was generally higher in the dense *Macaranga* area than in the sparse area within the same fallow year (Table 4.7). Above- ground biomass increased slowly in the early stages of fallow (Fallow year 1, 2), and followed by a rapid increase in the fallow year 3 to year 5 and reached maximum biomass production of 40-45 ton $ha^{-1}$ in densely populated *Macaranga* patches. In both densely and sparsely populated areas of *Macaranga*, the production of biomass from trees >1.5m was in the order of 98 % and 97 % in densely and sparsely *Macaranga* populated area respectively (Table 4.7). In there areas, the above ground biomass of $6^{th}$ year regrowth in dense area was 54 % of tree species >1.5m, 43 % of *Macaranga* and 3 % of others species whereas in the sparse area was 77 % of tree species, 8 % of *Macaranga* and 15 % of others species (Table 4.8). The biomass and numbers of trees with respect to species types are summarized in Table 4.9.

**Table 4.7** The above ground biomass (ton $ha^{-1}$) between different *Macaranga denticulata* density area of Tee Cha village.

| Fallow year | Dense area | | | Sparse area | | |
|---|---|---|---|---|---|---|
| | > 1.5 m | < 1.5 m | Total | > 1.5 m | < 1.5 m | Total |
| After rice harvest | 0 | 2.16 | 2.16 | 0 | 1.02 | 1.02 |
| Year 1 | 0 | 3.44 | 3.44 | 0 | 1.72 | 1.72 |
| Year 2 | 7.8 | 2.54 | 10.34 | 4.9 | 5.04 | 9.94 |
| Year 3 | 21.9 | 1.91 | 23.01 | 7 | 3.71 | 10.71 |
| Year 4 | 44.55 | 1.76 | 46.31 | 25.17 | 1.45 | 26.62 |
| Year 5 | 39.06 | 1.45 | 40.51 | 33.97 | 0.91 | 34.88 |
| Year 6 | 44.65 | 1.01 | 45.66 | 30.18 | 0.95 | 31.13 |
| > 8 | 79.66 | 0.63 | 80.29 | 79.66 | 0.63 | 80.29 |

Comparisons between dense and sparse areas by T-test

| | T-test |
|---|---|
| Above ground biomass of plant high > 1.5 m | * |
| Above ground biomass of plant high < 1.5 m | NS |
| Total above ground biomass of plant | * |

**Note: * =significant by T-test ($p < 0.05$), NS =not significant**

**Table 4.8** Comparisons between the above ground biomass of plant species (ton $ha^{-1}$) with dense and sparse *Macaranga* in the 6th fallow year.

| *Macaranga* density | Above ground biomass (ton $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Higher 1.5 m | | | Lower 1.5 m | Total |
| | *Macaranga* | Other *spp.* | Total | | |
| Dense | 19.18 | 25.47 | 44.65 | 1.01 | 45.66 |
| Sparse | 2.35 | 27.83 | 30.18 | 0.95 | 31.13 |

**Table 4.9** Numbers plant (tree $ha^{-1}$) and above ground biomass (ton $ha^{-1}$) with dense and sparse *Macaranga* in the 6th fallow year.

| | *Macaranga* density | Species type | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Macaranga* | Others | | | | | | |
| | | | T | ST | S | H | WC | P | Total |
| Number Plants | Dense | 4150 | 2950 | 700 | 0 | 0 | 50 | 0 | 7850 |
| | Sparse | 1010 | 3350 | 625 | 25 | 0 | 100 | 0 | 5100 |
| Biomass (ton$ha^{-1}$) | Dense | 19.2 | 24.2 | 0.7 | 0.0 | 0.0 | 0.6 | 0.0 | 44.7 |
| | Sparse | 2.4 | 23.3 | 3.9 | 0.24 | 0.0 | 0.5 | 0.0 | 30.2 |

**Note:** T=Tree, ST=Small tree, S=Shrub, H=Herb, WC=Woody Climber, and P=Palm

Number plants calculated from plant higher 1.5 m in each species type

**2) Nutrient Uptake**

The above ground biomass in densely populated *Macaranga* patches of 7 years regrowth forest (in year 2000 before cutting, biomass 43 ton $ha^{-1}$) contained 536 kg N, 38 kg P, 253 kg K, 132 kg Ca and 46 kg Mg $ha^{-1}$. This was 10% more N, 34% more P, 92% more K, 80% more Ca and 107 % more Mg than that in the sparsely populated *Macaranga* patches (Table 4.10).

**Table 4.10** Above ground nutrient contents in the fallow vegetation after seven years of regeneration of a rotation shifting cultivation in year 2000.

| Vegetation type | Nutrient element | Nutrient content (kg $ha^{-1}$) | | Significant difference by T-test |
|---|---|---|---|---|
| | | Dense | Sparse | |
| *Macaranga* | N | 289 | 131 | P < 0.01 |
| | P | 21 | 6 | P < 0.01 |
| | K | 97 | 32 | P < 0.01 |
| | Ca | 72 | 21 | P < 0.01 |
| | Mg | 10 | 6 | P < 0.05 |
| Other | N | 191 | 297 | P < 0.01 |
| | P | 12 | 18 | P < 0.05 |
| | K | 118 | 85 | P < 0.01 |
| | Ca | 28 | 36 | NS |
| | Mg | 23 | 6 | P < 0.01 |
| Litter | N | 56 | 59 | NS |
| | P | 5 | 4 | NS |
| | K | 38 | 14 | P < 0.01 |
| | Ca | 32 | 16 | P < 0.05 |
| | Mg | 13 | 10 | NS |
| Total | N | 536 | 488 | P < 0.01 |
| | P | 39 | 29 | P < 0.05 |
| | K | 253 | 132 | P < 0.01 |
| | Ca | 132 | 73 | P < 0.01 |
| | Mg | 46 | 22 | P < 0.01 |

**4.3.5 Regeneration of *Macaranga***

**1) The Plant**

*Macaranga* tree is self-seeding plant and the first fruit bearing starts in the wet season of the third year of fallow regrowth (Figure 4.6). Small flowers form in inflorescences (Figure 4.7) and the trees with male and female flowers were separated. Flowering occurs in November to February. The fruit has 2 seeds inside, is green when immature but ripening to brown or black in July to August. When mature, the fruit opens to shed the seed on the ground. In the cropping year, *Macaranga* seedlings germinated about the same time as rice in May to June, showing 2 bright purple cotyledons. The *Macaranga* seedlings survive and grow in the field for 2 year in juvenile stage. After 3 years the *Macaranga* trees enter adult stage and begin to reproduce. The growth and development cycle is shown in Figure 4.6.

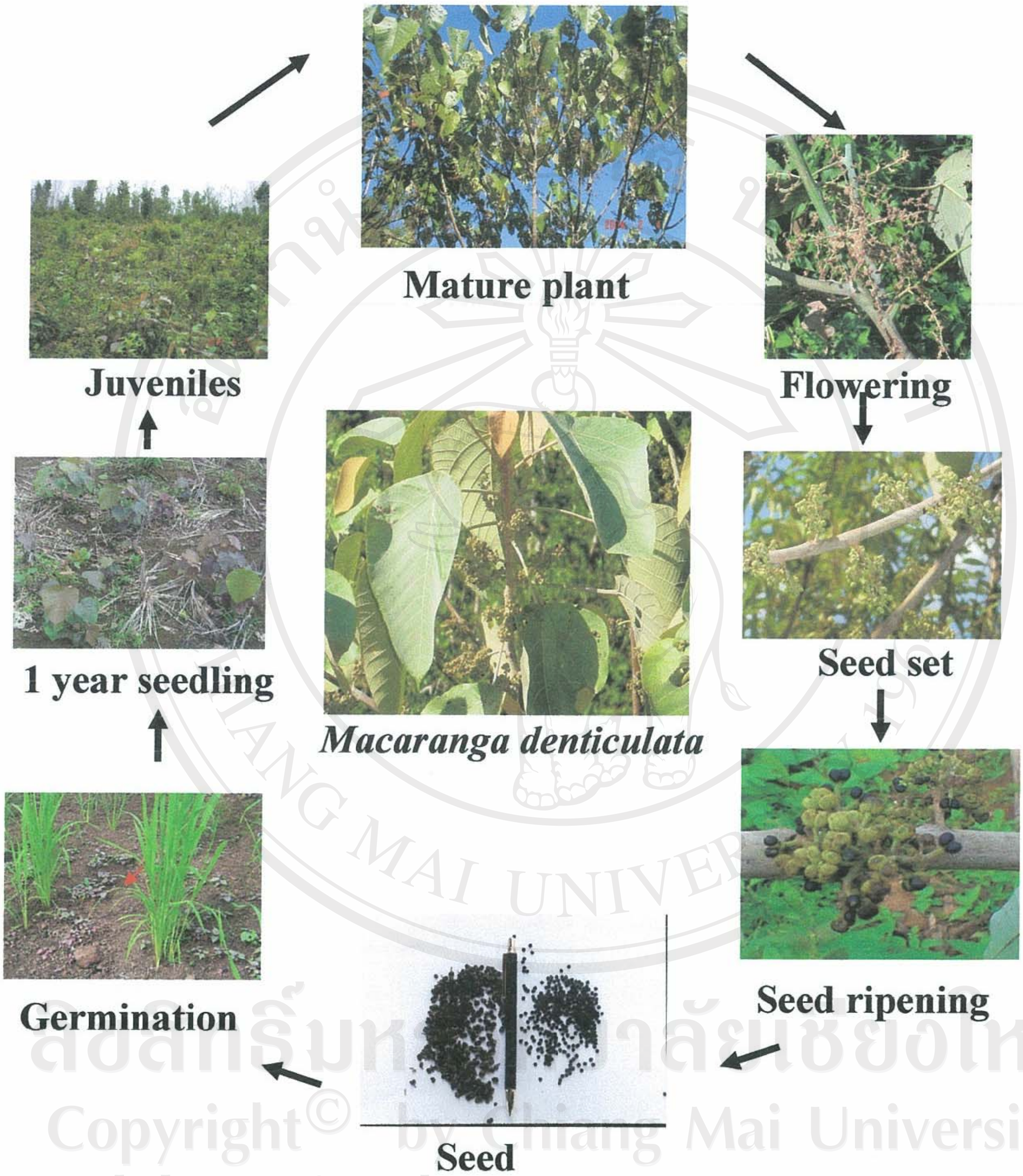





**Figure 4.6** Life cycle of *Macaranga denticulata* in shifting cultivation.

**Male inflorescence** **Female inflorescence**

**Male flower**

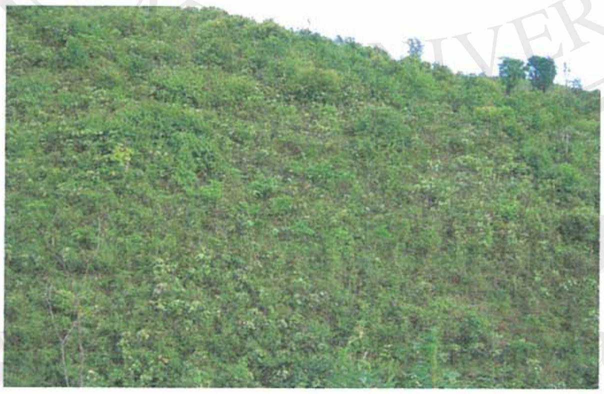
**Female flower**



**Figure 4.7** The inflorescence and flowers of male and female *Macaranga* plants.

a) Patchiness of *Macaranga*


b) Dense area



c) Sparse area

**Figure 4.8** Distribution of *Macaranga denticulata* in s shifting cultivation field of Tee Cha village.

**2) Seed Rain**

Seed production was estimated for all fallows and compared between densely and sparsely populated *Macaranga* densities. *Macaranga* commenced to produce seed in the 2nd year of fallow, when the trees were 3 years old. At this stage, *Macaranga* in dense area produced six times as many seeds tree$^{-1}$ as those in sparse area. The difference in seed productions were progressively less over the years, and by year 6 of fallow regrowth the number of seeds tree$^{-1}$ were similar between the different *Macaranga* densities (Table 4.11). This suggests that number of seeds were regulated with proportional to number of *Macaranga* trees in mature fallow, giving 463,664 seeds m$^{-2}$ in densely and 89,416 seeds m$^{-2}$ in sparsely population area of *Macaranga* respectively.

**Table 4.11** Seed production of *Macaranga* in dense and sparse patches in different fallow years (seeds tree$^{-1}$)

| Fallow year | *Macaranga* density | | T-test |
|---|---|---|---|
| | Dense | Sparse | |
| 2 | 779 | 126 | * |
| 3 | 17,087 | 10,527 | ** |
| 4 | 24,455 | 16,066 | ** |
| 5 | 30,970 | 23,928 | * |
| 6 | 42,625 | 38,769 | NS |

**Note:** * =significant by T-test ($p < 0.05$)
** =significant by T-test ($p < 0.01$)
NS =not significant

**3) Seed bank**

Comparison of the numbers of normal seeds in the same soil depth between dense and sparse *Macaranga* areas showed that numbers of seeds were in most cases significantly higher in the dense areas than in sparse areas (except at 30-50 cm depth) (Table 4.12). The numbers of abnormal seeds (seeds are broken more than 50% of total seed) were not different between dense and sparse *Macaranga* density area. The total number of seeds in the dense area (48,634) seeds was more than 3 times that in the sparse area. Over 90 % of total number of seeds were found on soil surface with 10 cm depth. It should also be noted that only 9 % of seed rain (Table 4.11) had entered into the seed bank.

**Table 4.12** The seeds in the soil (seeds $m^{-2}$.) from different *Macaranga denticulata* density area in the 6[th] fallow years.

| Depth of soil (cm.) | Number of seeds | | | | | |
|---|---|---|---|---|---|---|
| | Normal seed | | | Abnormal seed | | |
| | Dense | Sparse | T-test | Dense | Sparse | T-test |
| 0-5 | 26659 | 8332 | ** | 1265 | 473 | NS |
| 5-10 | 16717 | 4580 | *** | 953 | 937 | NS |
| 10-20 | 1975 | 904 | * | 147 | 0 | NS |
| 20-30 | 577 | 143 | * | 65 | 15 | NS |
| 30-50 | 245 | 103 | NS | 31 | 5 | * |
| Total | 46173 | 14061 | ** | 2461 | 1431 | * |

**Note:** * =significant by T-test ($p < 0.05$)
** =significant by T-test ($p < 0.01$)
NS =not significant

Viability of seed was reduced markedly from 85% after 1 month from fruit maturity to only 6 % after 7 months (Table 4.13). Therefore only the seed produced in the 6th year of fallow would contribute to the regeneration because the seed produced in the previous years would have all lost viability in less than one year. Almost 80% of the seeds in the soil lost their viability and about 18% could potentially germinate from the bank for the next rice crop (Table 4.14).

**Table 4.13** Viability test of *Macaranga* seeds from trees.

| Months after collection | % Viable seeds |
|---|---|
| 1 | 85.0 a |
| 2 | 77.5 a |
| 3 | 60.0 b |
| 5 | 25.0 c |
| 7 | 6.5 d |
| $LSD_{0.05}$ | 11.9 |

**Note:** Experiment takes 4 replications and 20 seeds per replication, from October 2003-Marth 2004
Test by Tetra-Zolium dye.
Seeds collected from *Macaranga* trees in August 2003.

**Table 4.14** Viability test of *Macaranga* seeds recovered from soil at different depth of seed survived.

| Seeds depth from ground level (cm) | Viabile seeds[1] (%) |
|---|---|
| 0-5 | 10.00 a |
| 5-10 | 7.50 a |
| 10-20 | 2.50 b |
| 20-30 | 1.25 b |
| 30-50 | 1.25 b |
| $LSD_{0.05}$ | 4.72 |

**Note:** Experiment takes 4 replications and 20 seeds per replication, June 2004.
Test by Tetra-Zolium dye,
Seeds collected from *Macaranga* soil in April 2004.

[1] Numbers followed by different letters are significantly different by t-test ($P < 0.05$).

**4) Seedling Recruitment**

**4.1) Germination of seed bank**

About half of fresh seed harvested from 7 years old *Macaranga* germinated (in pot experiment) within one month of sowing (Table 4.15). Only a few more seeds germinated in the next 3 months and no more after that. Germination was lessened when sowing was delayed. Only 1/3 of the seed germinated when sown at 3 months after maturity, and less than 20% at 4 months. When seed age increased to 5-10 months, germination was negligible.

**Table 4.15** Cumulative germination *Macaranga* seeds kept over time after collection from trees.

| Months after collected seeds | % seed germination (Months after sowing) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | 43 | 47 | 49 | 50 | 50 |
| 2 | 39 | 42 | 43 | 43 | 43 |
| 3 | 25 | 32 | 33 | 33 | 33 |
| 4 | 11 | 17 | 18 | 18 | 18 |
| 5 | 4 | 5 | 6 | 6 | 6 |
| 6 | 3 | 4 | 4 | 4 | 4 |
| 7 | 2 | 3 | 3 | 3 | 3 |
| 8 | 2 | 3 | 3 | 3 | 3 |
| 9 | 1 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 |

**Note:** Experiment takes 4 replications, and made from October 2003-June 2004.
Seeds collected from *Macaranga* trees in August 2003.

**4.2) Seedling survival**

Seedling numbers declined markedly over the period of the cropping year after germination. The number of seedling was significantly higher in dense *Macaranga* area, with about 4 time of the sparse *Macaranga* area (Table 4.16). This difference, once established, appeared to be maintained through out the following fallow period until the next cropping cycle.

**Table 4.16** Number of newly emerged *Macaranga* seedlings (per $ha^{-1}$) in the densely and sparsely populated area of different months in the cropping year.

| Months from emergence of first *Macaranga* seedlings | Number of *Macaranga* seedlings (x10,000) | | T-test |
|---|---|---|---|
| | Dense | Sparse | |
| 1 | 280 | 202 | * |
| 2 | 211 | 126 | * |
| 5 | 35 | 21 | ** |
| 8 | 5 | 2 | ** |
| 12 | 4 | 1 | ** |

**Note:** * =significant by T-test ($p < 0.05$)
** =significant by T-test ($p < 0.01$)
NS =not significant

Germination of *Macaranga* seed bank in the year of rice cropping contributed entirely to its regeneration. No new recruitment of *Macaranga* seedlings was observed in the monitoring plots in the first and second year of fallow (Table 4.17).

**Table 4.17** Numbers of new plants emerging in 2004 in year 1 (cropping year 2003) and year 2 (cropping year 2002) of fallow.

| Fallow age (yr) (Cropping year in brackets) | Rep | Number of new emerging plants in 2004 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *Macaranga* | Others | | | | | |
| | | 8/3/04[1] | 8/3/04 | 19/4/04 | 22/5/04 | 4/6/04 | 30/6/04 | 19/8/04 |
| 1 (2003) | 1 | 7 | 22 | 85 | 126 | 155 | 198 | 98 |
| | 2 | 22 | 29 | 65 | 368 | 368 | 170 | 65 |
| | 3 | 17 | 20 | 74 | 265 | 263 | 126 | 74 |
| | 4 | 10 | 27 | 72 | 365 | 365 | 108 | 78 |
| | Average | 14 | 24.5 | 74 | 281 | 287.75 | 150.5 | 78.75 |
| 2 (2002) | 1 | 2 | 36 | 149 | 502 | 318 | 214 | 149 |
| | 2 | 3 | 34 | 185 | 602 | 587 | 221 | 185 |
| | 3 | 6 | 25 | 164 | 489 | 372 | 403 | 164 |
| | 4 | 9 | 15 | 136 | 254 | 474 | 254 | 136 |
| | Average | 5 | 27.5 | 158.5 | 461.75 | 437.75 | 273 | 158.5 |

**Note**: Plot size is 1m X 1m

[1] No new *Macaranga* seedling emerged after this first date.

There were > 30 species and >90 % belong to the grass and herb families, and only <10 % belong to tree species.

### 4.4 Discussion

#### 4.4.1 Fallow Succession and Species Diversity

In agreement with an earlier observation (Rerkasem, 2000), species richness and diversity index in managed fallow in Tee Cha were lower than in undisturbed forest. Density of *Macaranga*, however, had no effect on species diversity and species composition for forest fallow regrowth. This suggests that if secondary forest successions are allowed to progress naturally beyond the limit of the current shifting cultivation cycle, regeneration will be the same in dense and sparse *Macaranga* patches with more or less similar species composition. In degraded area without *Macaranga*, fallow regeneration may switch to different path way with dominant herbaceous and grass species, e.g. *Chommolaena, Imperata,* and *Ageratum*. In succession stages, species richness varied between 32-63 species, with maximum species diversity occurring earliest, during the cropping year and the first year of fallow following harvesting of upland rice. Except for the *Macaranga*, the pattern of fallow succession is similar to those reported in earlier studies with longer fallow periods (Sabhasri, 1978 and Schmidt-Vogt, 1995, 2001), but quite different from the short fallow of Skaw Karen in Mae Tho studied by Nakano (1978). In this latter case, grasses and herbaceous species were dominant through out the 5 years of fallow regrowth, vegetation succession not proceed to mature stage of forest vegetation and overall productivity of fallow regrowth is poor, productivity of the cropping period was dependent on biomass of weeds and shrub species, e.g. *Chromoleana odorata*. In the present study, the grasses and herbaceous species which dominated in the first year of fallow, disappeared in the following years when the fallow became dominated by trees. Farmers' management of *Macaranga* in this study is thus highly successful, in term of ecological succession, with reduced cycle. This study provide evidence that, contrary to common belief used as basis for conservation policy, shifting cultivation does not always lead to forest destruction, but with appropriate management by farmers and communities can contribute towards biodiversity conservation. In the next chapter, I will show that this management is also sufficiently productive to support farmers' livelihood as well.

### 4.4.2 Fallow Productivity

This study found almost all above- ground biomass of $6^{th}$ year regrowth come from trees and small tree species: in dense area was 54 % of tree species >1.5m, 43 % of *Macaranga* and 3 % of others species whereas in the sparse area was 77 % of tree species, 8 % of *Macaranga* and 15 % of others species. Managed fallows with dominant of *Macaranga* also give high biomass production of fallow vegetation up to 45 ton $ha^{-1}$ and 30 % more than that in sparse area. In comparison to the Lua shifting cultivation with long fallow system regrowth studied by Sabhasri (1978), the biomass of *Macaranga* dominated fallow could be higher by about 60 % and that reflects efficient nutrient accumulation within the limit cycle of 7 years. It should be, however, noted that soils under *Macaranga* dominated fallow are poor on steep slopes. Contribution of *Macaranga* to upland rice in this same of shifting cultivation will be presented and discussed in the following chapter.

### 4.4.3 Regeneration of *Macaranga*

Evidences from field studies and monitoring the dynamics of *Macaranga*, seeds are relatively short-lived and almost total loss in viability within only 7 months after fruit maturity. More than 80% of buried seeds are lying within the soil surface between 0 to 10 cm below ground, and these would represent potential numbers for seedling recruitment. Some 5% of seed bank may be lost due to natural decay and soil predators. As *Macaranga* is a prolific seed producing tree species, the numbers in the bank would be high enough to ensure significant number for fallow enrichment and regeneration.

The recruitment of seedling is very large as much as 2-3 million seedlings $ha^{-1}$ after the first opening rains in upland rice crop but the survival of seedling in the first year was very low. The number of *Macaranga* plants was regulated to about 10,000-40,000 seedlings $ha^{-1}$ by the end of Diversity, measured as Species Richness and Shannon-Weaver indices, of swidden crops in the fields of invididual farm households the cropping season. In the dense patches, farmers thinned out large numbers to avoid competitive effects on upland rice (Chapter 3). Very few new plants germinated after this, and the number declined to about 20,000 $ha^{-1}$ in dense patches and 10,000 $ha^{-1}$ in sparse patches in the first year of fallow. After this the number declined, much more rapidly in sparse than in dense *Macaranga* area, to 1,010 and 4,150 trees $ha^{-1}$, respectively. The final number of *Macaranga* in the fallow is determined at two stages. The first stage occurs with germination of the seedbank during the rice cropping season. Since the seedling recruitment numbered 2-3 millions $ha^{-1}$, seedling number as such does not appear to be limiting where *Macaranga* is sparse. The second, and more critical stage occurs over the fallow years, when the number of *Macaranga* trees declined, more rapidly in the sparse than in dense patches.