Chapter 7

Restoration of degraded fallows with supplement ash and fertilizers

7.1 Introduction

In area where land is plentiful to allow the practice of long cycle shifting cultivation productivity of upland rice may be reasonably high and stable (e.g. Ruthenberg, 1971). In Southern Asia where land pressure is very strong, it is generally believed that improper shifting cultivation could lead to the dominant of alang-alang (*Imperata cylindica*) and land may be abandoned indefinitely.

The symptoms of degraded shifting cultivation are numerous but the most significant one appears to be associated with the problem of yield decline in subsistence crops (Sanchez, 1976; Hinton, 1978 and Trenbath, 1984). These might be attributed to the decline in soil fertility due to intensification of shifting cultivation or building of pests, disease and weeds or in combinations. With respect to upland rice, reduction of fallow periods from originally >15 years to only 7 years way reduce rice yield greatly by more than 50% (Grandstaff, 1980). The recovery of soil fertility from burning fallow biomass, especially P and other major nutrients has been documented in traditional shifting cultivations of Lua (Zinke *et al*., 1978) and Karen (Nakano, 1978) communities.

In previous chapters, increase in rice yields were obtained at high density of *Macaranga* in the 6 years of fallow regrowth (4,000 trees ha^{-1}) before the field was slashed and burned. Effects of *Macaranga* on rice yield could have been from the above ground biomass of 43 t ha^{-1} which contained 536 kg N, 38 kg P, 253 kg K, 132 kg Ca and

46 kg Mg ha^{-1}. However, it has also been found that *Macaranga* sends a significant proportion of the nutrients to the roots (Chapter 6) and only ¾ of the biomass and nutrients accumulated during the fallow years were accounted for above ground (Chapter 5). Therefore it is postulate that contribution to increase rice yield from *Macaranga* is in the nutrients accumulated both above and below ground, and whether the effect may be replaced by applying ash and chemical fertilizers.

7.2 Materials and Methods

The on-farm experimentation was undertaken in two farmers' fields during April to November 2003. The plots were selected prior to slashing in March 2003 (Figure 7.1). Field selection was carried out with farmers who were knowledgeable about the overall site and soil analysis data shown in Table 7.1. Their experience from past cropping cycle also helped to decide the field layout and superimpose treatments. Field measurements of fallow biomass were undertaken after slashing, plots size were 10 m X 10 m. Nopporn's plot was taken to represent relatively rich and high fertility site with dominance of *Macaranga* trees in the fallow (Figure 7.2). The plot was located at the lower part of the shifting cultivation field on the top of a small ridge with slope varying between 10 -30 degree. Tucare's plot was located on the other side of the field with slope not exceeding 35 degree (Figure 7.3). This side of the field is known to farmers as a rather poor site for upland rice as compared to the opposite side where Nopporn's plot was located. Fallow vegetation was poor with *Macaranga* sparsely distributed. With this contrast between the two selected plots, treatments were superimposed differently with different experimental designs and data were analyzed separately for presentation of the results.

7.2.1 Nopporn's Plot

Four treatments were superimposed in this plot with control as conventional burning of fallow biomass, removed burned biomass (ash) from soil surface, added burned biomass from the removal plot (i.e. double rates of burned biomass), and application 60 kg P_2O_5 ha^{-1} in conventional burning of fallow biomass. Treatments were randomized in 3 replications, giving a complete block design for statistical analysis.

7.2.2 Tucare's Plot

A 2 X 4 factorial combination was laid out with 2 treatments of burned biomass and 4 fertilizer applications. The burned biomass consisted of conventional burned and ash added equivalent amount to obtain the same level of the burned biomass control in Nopporn's plot. Four fertilizer treatments were no application or control, and fertilizer applications with nitrogen (N) only at 60 kg N ha^{-1} or phosphorus (P) only at 60 kg P_2O_5 ha^{-1} and both N and P at 60 kg N and 60 kg P_2O_5 ha^{-1}. Nitrogen and P were broadcasted separately. Half of the N and all of the P were applied one month after rice sowing, the rest of the N one month later.

7.2.3 Crop management

Upland rice was sown on May, 12 and May, 30 in Nopporn's and Tucare's plots, respectively. Seeds were obtained from the plot's owners with Bue Bang (Nopporn's plot) and Bue Gua (Tucare's plot). As Tucare had sown his "Bue Che Buo" with Bue Bang, traditional rules prohibits the sowing of Bue Bang for this experiment in his plot. However, crop cutting in 4 farmers' fields did not show any significant different between the two varieties. Rice was sown conventionally with dibbling stick with labour exchange of 20-30 farmers.

Varying amount of 20-40 seeds were sown in each hill and there were 9-16 hill m^{-2}, giving total plant density between 180 to 400 plants m^{-2}. Weeding was done by hand. First weeding was carried out with exchanged labours at 1 month after rice seeding. Major work was to remove young shoots, root suckers from tree stumps survived after burning. Weeds were removed in the second and third weeding at about 2 and 3 months after rice seeding, respectively. Harvesting was done separately from each farmer's main crop, in order to avoid mistakes from the harvesting crew.

7.2.4 Plot size and Data Collection

Before tree cutting in early April 2003, 10 m X 10 m quadrants were placed in both Nopporn's and Tucare's plots to determine species composition and aboveground biomass. There were 3 sample quadrants for each site. Fresh weights were determined immediately after cutting and sub-samples were taken for oven drying to determine dry weight of biomass. Sub-sample of 1.0 kg was collected for each quadrant to adjust moisture content, then ground and digested for nutrient analysis (N, P, K, Ca and Mg). Analytical methods for nutrient content were given in Chapter 6. Roots were also recovered for determination of below ground biomass. Three soil pits (0.5 m X 0.5 m X 0.5 m) were dug in each quadrant. Roots were separated from the soil and dried at 80^0 C for 48 hours to determine root dry weight. Dried root samples were analysed for N, P, K, Ca and Mg content separately from the above ground materials.

Plot size 5 m X 5 m were measured and laid out in both Nopporn's and Tucare's plots, giving the total experimental areas of 12 and 24 5 m X 5 m plots, respectively.

As plot size was relatively small, upland rice was planted without guard rows to give solid stand in farmers' fields and avoid edge effects. During the rice growing season, plant height and tiller numbers were taken at 35, 65, 95 and 125 day after rice seeding. Plant heights were taken randomly in 3 spots to provide the average height of each plot. Tillers were counted in standing crops without destructive sample of 10 hills per plot.

At 35 days from rice seeding, sample of ten plants were cut off at ground level in each plot. Samples were oven dried at 80^0C for 48 hours to obtain dry weight. Samples were taken nutrient analysis in laboratory for N, P, K, Ca and Mg.

At harvest, dry matter and grain yields were measured from samples of 2 m X 5 m each. Plants were cut at ground level for threshing to obtain grain and straw weight separately. Grains were sun-dried for 3 days before weighting. At this time, the grain moisture content was reduced to 12%. Straw was oven dried at 80^0C for 48 hours before weighing. Sub samples of 10 hills were taken from each plot for yield component determination, i.e. number of tillers hill^{-1}, number of panicles hill^{-1} and individual grain weight. Number of hill m^{-2} was counted from the sample area and 1,000 grain weights were obtained from sub-samples. Tiller and panicle numbers were counted on individual hill basis. Plant samples were kept for nutrient analysis in laboratory.

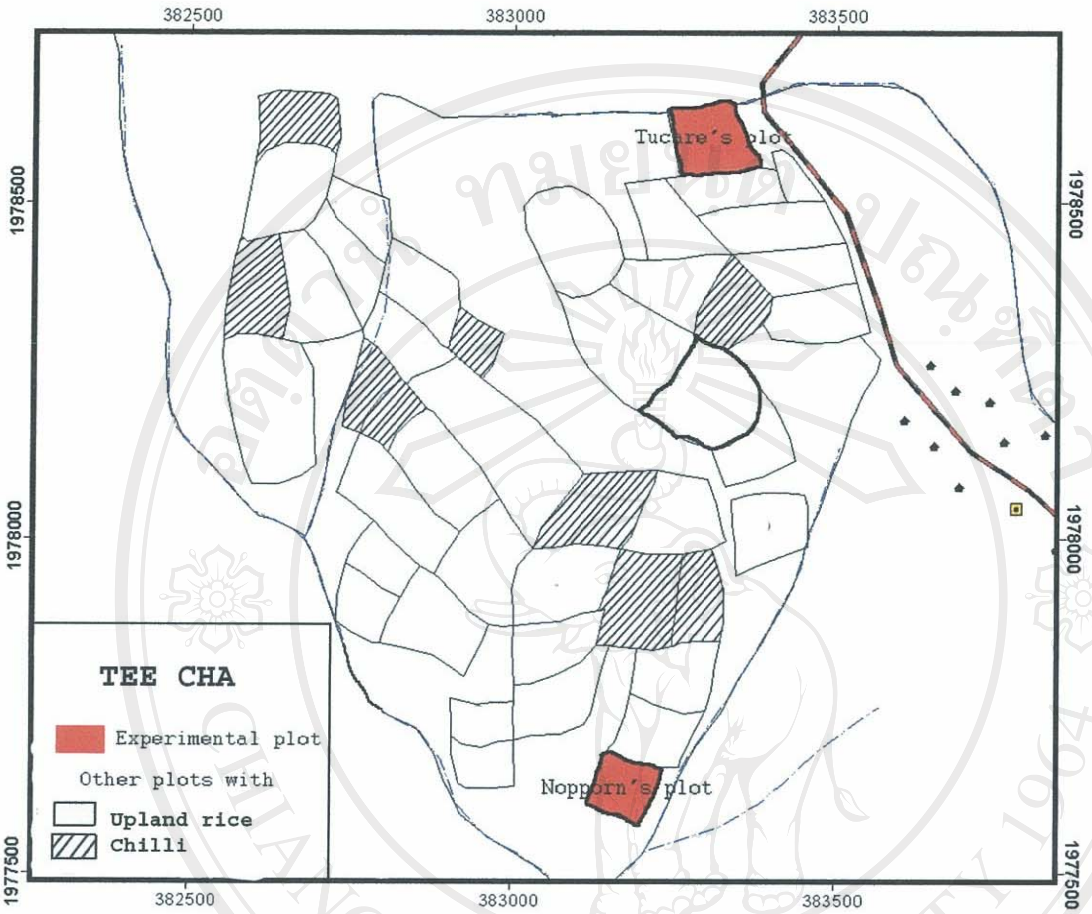

Figure 7.1 Experimental sites in shifting cultivation field, cropping year 2003.

Table 7.1 Soil characteristics of experimental sites in shifting cultivation field, Nopporn' and Tucare's plots.

Time Collection		0-15 cm from ground level		15-30 cm from ground level	
		Nopporn	Tucare	Nopporn	Tucare
Before[1] burning	OM	5.96	5.69	4.83	3.42
	pH	6.17	5.40	6.20	5.24
	N(%)	0.33	0.40	0.29	0.26
	P(ppm)	6.30	5.28	4.50	2.50
	K(ppm)	130.33	121.00	110.00	119.33
	Ca(ppm)	8.59	3.72	4.59	0.40
	Mg(ppm)	1.14	0.96	1.18	0.42
After burning	OM	6.01	8.81	3.87	5.15
	pH	6.25	5.28	5.85	4.76
	N(%)	0.31	0.43	0.23	0.29
	P(ppm)	9.78	17.20	3.88	2.56
	K(ppm)	194.33	177.00	108.00	108.67
	Ca(ppm)	8.80	4.69	5.87	2.02
	Mg(ppm)	2.72	1.10	2.64	1.00

Note: 1= collected 4 March, 2003

Figure 7.2 Nopporn's plot was taken to represent relatively rich and high fertility site with dominance of *Macaranga* trees.

Figure 7.3 Tucare's plot was located on the other side of the field with slope not exceeding 35 degree.

7.3 Results

7.3.1 The fallow biomass and nutrient content

The total amounts of total above ground biomass averaged at 57.3 and 22.0 t ha^{-1} in Nopporn's and Tucare's plots respectively (Table 7.2). Below ground biomasses were recorded at 16.2 and 8.5 t ha^{-1} for the two plots respectively. These gave the total biomass production at 73.4 t ha^{-1} in Nopporn's plot as compare to only 30.5 t ha^{-1} in Tucare's plot (Table 7.2). Nutrient contents in both above and below ground were consistently higher in Nopporn's plot than those in Tucare's plot (Table 7.3). The differences for total nutrient content varied from 2.6 folds in N, 3.9 folds in P and 3.0 folds in K. For Ca and Mg the differences were somewhat less pronounced, with the values of 1.5 and 2.2 folds respectively.

Table 7.2 Productivity of fallow biomass (t ha^{-1}) in Nopporn's and Tucare's plots before burning.

Biomass	Biomass Productivity (t ha^{-1})		Significant difference by t-test
	Nopporn	Tucare	
Above ground	57.25 b	22.04 a	P< 0.05
Below ground	16.18 b	8.47 a	P< 0.01
Total	73.43 b	30.51 a	P< 0.01
Shoot:Root Ratio	3.54 b	2.60 a	P< 0.01

Note: Different letters designate significant difference (by t-test; P < 0.05) between Nopporn's and Tucare's plots.

Table 7.3 Nutrient content (kg ha^{-1}) in fallow biomass of Nopporn's and Tucare's plots.

Nutrients	Nopporn's plot			Tucare's plot		
	Shoots	Roots	Total	Shoots	Roots	Total
N	562 a	110 a	671 a	214 b	40 b	254 b
P	76 a	26 a	102 a	20 b	6 b	26 b
K	297 a	75 a	371 a	93 b	30 b	122 b
Ca	148	144	292 a	69	126	195 b
Mg	127 a	36	163 a	54 b	20	74 b

Note: Different letters designate significant difference (by t-test, $P < 0.05$) between Nopporn's and Tucare's plots.

7.3.2. Effects of burned biomass and phosphorus in Nopporn's plot.

1) Height and tiller numbers of rice

Effects of burned biomass and P application on plant height were determined at 65 days and maintained throughout the growing season (Figure 7.4). By 125 days after seeding, added burned biomass gave the highest height at 162 cm and the lower height was observed in ash removal plot (Table 7.4). The differences between the numbers of tillers per hill were less consistent but the trends were similar to plant height. Number of tillers reached maximum by 35 days after seeding in all treatments (Figure 7.5). At the end of the growing season, the number of tiller was lowest in the removal burned biomass plot but the differences were barely significant (Table 7.4).

Table 7.4 Effects of burned biomass and phosphorus on height and tiller numbers of upland rice at 125 days from sowing, Nopporn's plot.

Treatments	Height (cm)	Tillers per hill
Conventional	153.6 b	17.7 bc
Ash removed	145.4 a	16.0 a
Ash added	161.9 c	18.7 c
P-application	150.7 ab	16.7 ab

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

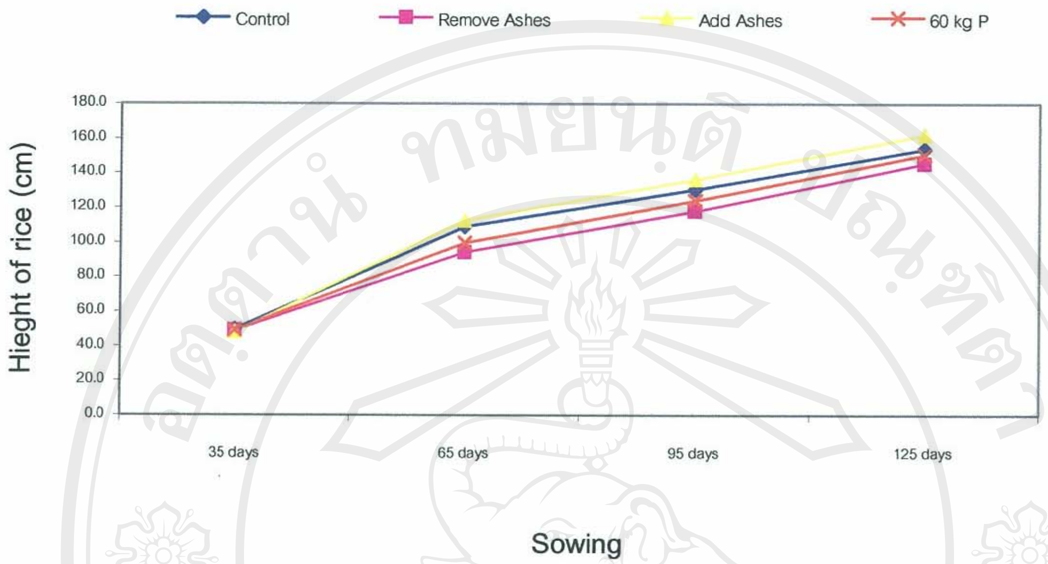

Figure 7.4 Height (cm) of upland rice in different management of fallow in densely populated *Macaranga* area in year 2003, Nopporn's plot.

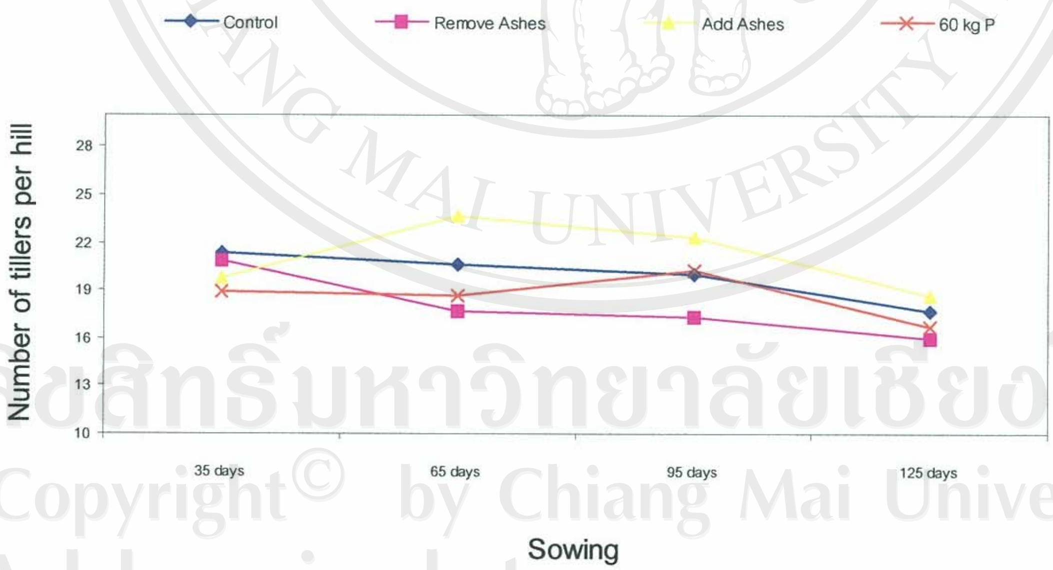

Figure 7.5 Number of tillers per hill of upland rice with different management of fallow in densely populated *Macaranga* area in year 2003, Nopporn'splot.

2) Yield and yield components

Removal of burned biomass depressed rice grain and dry matter yield by more than 20%, constituting a loss of half a ton of paddy and one ton of dry weight per ha (Table 7.5). Doubling the amount of burned biomass or applying P did not have any significant beneficial effects on rice yield. These results suggested that amount of nutrients in burned fallow biomass could have been sufficient to support rice yields above 2-3 t ha^{-1} in the dominant *Macaranga* fallow.

Table 7.5 Yield of upland rice (t ha^{-1}) between different treatments, Nopporn's plot.

Treatments	Yield (t ha^{-1})			
	Grain	Straw	Total	Harvest index
Conventional	2.35 bc	1.93 b	4.27 b	54.98
Ash removed	1.82 a	1.55 a	3.37 a	54.03
Ash added	2.54 c	1.95 b	4.49 c	56.62
P-application	2.32 b	1.87 b	4.19 b	55.98

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

The effects of the removal of burned biomass on grain yield were mainly due to the reduction in panicle numbers (Table 7.6). The effects were detected as early as 65 days from sowing in tiller numbers (Figure 7.5). Proportions of fertile tillers at the end of the growing season were unaffected with an average of 76.5 % (Table 7.6). Seed weight was also unaffected with an average of 26.9 mg.

Table 7.6 Yield components of upland rice between different treatments, Nopporn's plot.

Treatments	Yield component					
	Hill m^{-2}	Tillers $hill^{-1}$	Panicles m^{-2}	Panicles $hill^{-1}$	Fertile[1] tillers (%)	1000 seed weight (g)
Conventional	6.27	17.7 bc	90.0 c	14.37	81.2	26.83
Ash removed	6.30	16.0 a	74.6 a	12.00	75.0	26.86
Ash added	6.53	18.7 c	85.0 bc	13.13	70.2	26.92
P-application	6.20	16.7 ab	81.3 ab	13.30	79.6	26.99

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments

1 = Percentage of fertile tillers = $\frac{\text{Panicles hill}^{-1}}{\text{Tillers hill}^{-1}} \times 100$

3) Nutrient content in upland rice

3.1) At 35 days after rice seeding

At 35 days after upland rice seeding, there was only significant effect of treatments on K concentration (Table 7.7). It appeared that K concentration was lowest when burned biomass was removed. However, the effects were only slightly significant (Table 7.7).

Table 7.7 Nutrient concentration in upland rice at 35 days after seeding between different treatments, Nopporn's plot.

Treatments	Nutrient concentration (%)				
	N	P	K	Ca	Mg
Conventional	3.62	0.19	3.11 b	0.38	0.25
Ash removed	3.16	0.19	2.77 a	0.37	0.24
Ash added	3.69	0.20	3.21 b	0.35	0.27
P-application	3.49	0.23	3.03 ab	0.38	0.26

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

3.2) At 125 days from rice seeding

At 125 days when upland rice was mature, the effects of treatments on nutrient content were apparent in both grain and straw (Table 7.8). For grain, N and P content were to be lowest in removal of burned biomass plot. Adding burned biomass increased Ca and Mg content in both grain and straw. The overall effect of ash removal was to depress total nutrient uptake by the rice plant, while adding ash increased nutrient uptake, though the effect was smaller with P application.

Table 7.8 Effects of treatments on nutrients content in grain, straw and total dry matter of upland rice at 125 days from seeding, Nopporn's plot.

a) Grain

Treatments	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	13.42 b	1.41 ab	42.95	8.20	4.03 ab
Ash removed	10.00 a	0.96 a	39.49	5.87	3.17 a
Ash added	14.57 b	2.28 c	56.17	8.03	5.14 c
P-application	13.15 b	1.94 bc	49.23	7.61	4.88 bc

b) Straw

Treatments	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	3.79	0.71 b	2.31 b	1.11 a	0.27 a
Ash removed	3.00	0.51 a	1.54 a	0.75 a	0.18 a
Ash added	3.83	0.76 b	2.66 b	1.63 b	0.44 b
P-application	3.28	0.71 b	2.08 ab	0.97 a	0.23 a

c) Total dry matter

Treatments	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	17.21 bc	2.12 b	45.26	9.31	4.30 ab
Ash removed	13.00 a	1.47 a	41.02	6.62	3.35 a
Ash added	18.40 c	3.04 c	58.83	9.66	5.57 c
P-application	16.43 b	2.65 bc	51.31	8.58	5.11 bc

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

7.3.3 Effects of burned biomass and fertilizers in Tucare's plot

1) Plant height and number of tillers

In general, plant height responded positively to fertilizer application and the response was more pronounced in the low level of burned biomass treatment (Figure 7.6) and Table 7.9).

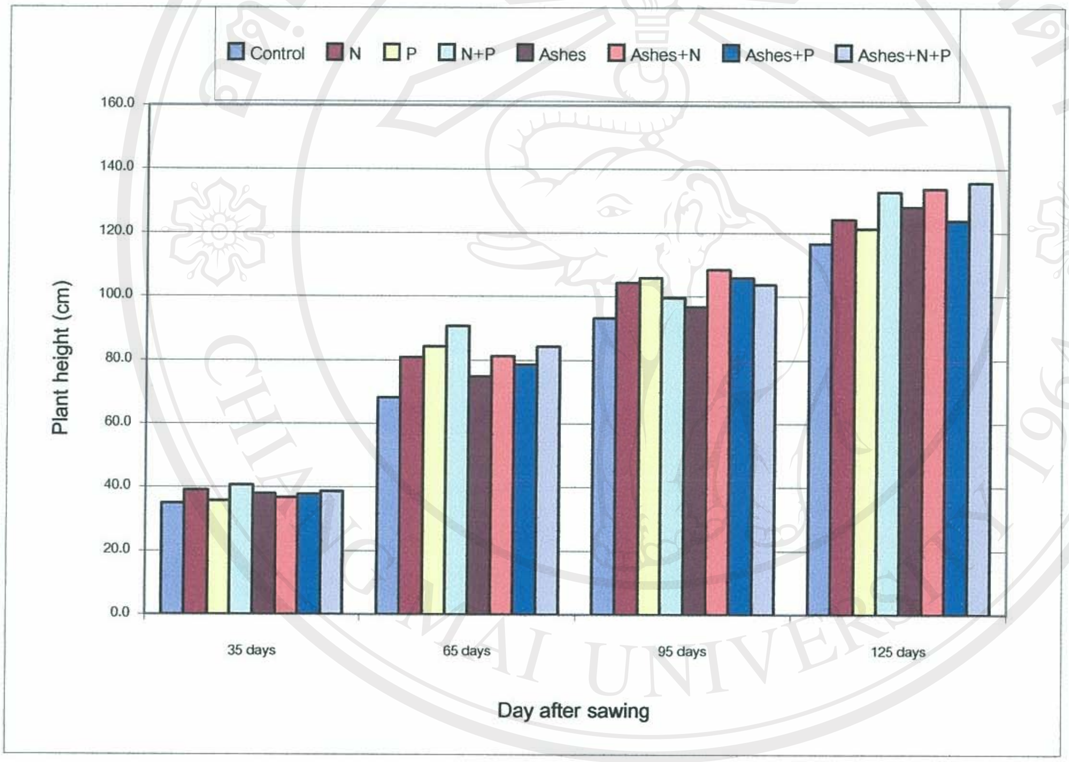

Figure 7.6 Height (cm) of upland rice of between different treatments.

Table 7.9 Height of upland rice (cm) between different treatments, Tucare's plot.

a) At 35 days after seeding

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	34.93 a	39.03 cd	35.77 ab	40.67 d
Added	37.93 bc	36.70 abc	37.77 bc	38.77 cd
Difference	3.00	-2.27	2.00	-1.9

b) At 65 days after seeding

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	68.17 a	80.80 bc	84.23 c	90.70 d
Added	74.90 b	81.20 c	78.47 bc	84.27 c
Difference	6.87	0.40	-5.76	-5.43

c) At 95 days after seeding

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	93.13	104.30	105.80	99.57
Added	96.77	108.43	105.93	103.67
Difference	3.63	4.13	0.13	4.10

d) At 125 days after seeding

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	116.7 a	124.3 bc	121.4 b	132.8 d
Add	128.2 c	133.9 d	123.8 bc	135.7 d
Different	11.5	9.6	2.4	2.9

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between different treatments.

There was no interaction between burned biomass and fertilizer treatment on tiller numbers. The effect of burning biomass was detected on 65 days and maintained throughout the growing periods. Added burned biomass could increase tiller number slightly (Table 7.10). The effect of fertilizer was detected as early as 35 days from seeding and maintained throughout the growing periods. However, the differences in number of tillers were small with only 1-2 tillers $hill^{-1}$ (Table 7.11).

Table 7.10 Effects of burned biomass on tillers $hill^{-1}$ from 35 to 125 days from seeding, Tucare's plot.

Burned Biomass	Days from Seeding			
	35	65	95	125
Conventional	11.0	12.4	10.8 a	11.6 a
Added	11.6	12.3	12.4 b	12.8 b

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between different treatments.

Table 7.11 Effects of fertilizers on tillers $hill^{-1}$ from 35 to 125 days from seeding, Tucare's plot.

Fertilizers	Days from Sowing			
	35	65	95	125
Conventional	10.7 a	12.0 ab	11.0 a	11.5 a
N	11.0 a	12.7 b	11.7 a	12.2 a
P	11.0 a	10.5 a	10.7 a	11.3 a
N+P	12.8 b	14.5 c	13.2 b	13.8 b

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between different treatments.

2) Yield and yield components

The interaction between burned biomass and fertilizer application were significant with respect to grain yield, total biomass and harvest index (Table 7.12). Without fertilizer, adding burned biomass increased grain yield and total dry matter by 63.2 and 45.2 % respectively (Table 7.12a). Adding N and P increased grain yield in conventional burning by 67.6 %. When additional burned biomass was given, N and P application together almost doubled rice grain yield. This treatment gave almost to the same yield as Nopporn's (2.35 t ha^{-1}) plot with dense *Macaranga* in the fallow. Similar response was evident in total dry matter but the effect was less obvious in harvest index (Table 7.12a,b). Harvest index was improved greatly when N and P were added to additional treatment of burned biomass plot (Table 7.12c). The effect of N has shown to be more pronounced in comparison to that of P.

Table 7.12 The effect of burned biomass and fertilizers on grain yield, total dry matter of upland rice in Tucare's plot.

a) Grain yield (t ha^{-1})

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	0.68 a	1.14 c	1.00 b	1.14 c
Added	1.11 c	1.77 e	1.31 d	2.11 f
Difference	0.43	0.63	0.31	0.97

b) Total dry matter (t ha^{-1})

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	1.26 a	1.88 cd	1.71 b	2.02 de
Add	1.83 bc	2.72 f	2.10 e	3.06 g
Difference	0.57	0.84	0.39	1.04

c) Harvest index (ratio of grain : total dry matter)

Burned biomass	Fertilizer application			
	Nil	N	P	N+P
Conventional	0.54 a	0.60 cd	0.58 bc	0.56 ab
Add	0.61 d	0.65 e	0.63 de	0.69 f
Difference	0.07	0.05	0.05	0.13

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between different treatments.

3) Yield components

With exception of panicle numbers, the interaction between burned biomass and fertilizer were not significant (Table 7.13). When burned biomass was added without any fertilizer, number of panicle m^{-2} was increased by 20.5 %. When N and P were applied, the effects of fertilizer were to increase panicle number by 12.8 % in conventional burned biomass and 14.8 % in added burned biomass plot. However, the increase in panicles number were mainly due to the increase in hill numbers. The effects on number of hills could have been due to farming practices where seeding was carried out conventionally with irregular hill spacing and hand planting by the planting crew. Alternatively, a few of the planted hills had died earlier in the season in the nil treatment.

Although, the effect of fertilizers were to increase number of tiller but percentage of fertile tillers decreased significantly as nitrogen and P were applied together (Table 7.13). Adding burned biomass also increased grain weight slightly from 24.8 mg to 25.4 mg.

Table 7.13 The effect of burned biomass and fertilizers on components of upland rice yield, Tucare's plot.

Burned biomass	Fertilizer	Yield component					
		Hill m^{-2}	Tillers $hill^{-1}$	Panicles m^{-2}	Panicles $hill^{-1}$	Fertile Tillers (%)	Individual grain weight (mg)
Conventional	NIL	5.1	10	39 a	7.7 a	74.9	24.8
	N	5.1	11	46 c	9.1 bc	80.4	24.4
	P	5.3	11	45 c	8.6 b	76.8	25.6
	N + P	5.8	14	44 b	7.5 a	55.5	24.6
Ash Added	NIL	5.5	13	47 c	8.5 b	67.3	25.8
	N	5.8	13	52 d	8.9 bc	70.2	25.1
	P	5.5	11	50 d	9.1 bc	82.3	25.6
	N + P	5.8	14	54 e	9.3 c	66.8	25.2

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between different treatments.

(4) Nutrient concentration in upland rice

4.1) At 35 days after seeding

At 35 days after seeding, application of N fertilizer increased N concentration in upland rice (Table 7.14a). Adding ash increased P concentration significantly and application of P increased P concentration more in adding ash as compared to conventional burning of fallow biomass (Table 7.14b). Ca and Mg also increased significantly in the addition of ash treatment.

Table 7.14 Nutrient concentration (%) at 35 days after seeding between treatments, Tucare's plot.

a) N concentration

Burned biomass	Fertilizer application				
	Nil	N	P	N+P	Average
Conventional	3.30	4.09	3.43	3.89	3.68
Ash Added	3.45	3.84	3.37	4.08	3.69
Average	3.37 a	3.96 b	3.40 a	3.99 b	

b) P concentration

Burned biomass	Fertilizer application				
	Nil	N	P	N+P	Average
Conventional	0.21 a	0.21 a	0.31 de	0.27 bc	0.25 a
Ash Added	0.27 bc	0.25 b	0.34 e	0.29 cd	0.29 b
Average	0.24 a	0.23 a	0.33 c	0.28 b	

c) K concentration

Burned biomass	Fertilizer application				
	Nil	N	P	N+P	Average
Conventional	2.49	2.55	2.75	2.63	2.62
Ash Added	2.76	2.75	2.72	2.84	2.77
Average	2.62	2.65	2.73	2.77	

Table 7.14 (Continued)

d) Ca concentration

Burned biomass	Fertilizer application				
	Nil	N	P	N+P	Average
Conventional	0.35	0.34	0.38	0.36	0.36 a
Ash Added	0.39	0.39	0.41	0.39	0.39 b
Average	0.37	0.36	0.40	0.37	

e) Mg concentration

Burned biomass	Fertilizer application				
	Nil	N	P	N+P	Average
Conventional	0.20	0.23	0.22	0.22	0.22 a
Ash Added	0.23	0.24	0.22	0.25	0.23 b
Average	0.21 a	0.24 c	0.22 ab	0.23 bc	

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

4.2) As 125 days after seeding

At final harvest (125 days after seeding), there were only main effects on nutrient content in grain, straw and total dry matter. Adding ash had significantly increased nutrient content of all nutrients in upland rice (Table 7.15). Although the effect of fertilizes applications were highly significant (Table 7.16) but the percentage of content were less than those found in Nopporn's plot (Table 7.8).

Table 7.15 Effects of burned biomass on nutrient content in the grain, straw and total dry matter of upland rice at harvest period, Tucare's plot.

a) Grain

Burned Biomass	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	6.67 a	0.65 a	17.75 a	3.41 a	1.38 a
Ash Added	7.90 b	0.91 b	23.78 b	4.15 b	1.73 b

b) Straw

Burned Biomass	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	1.78 a	0.13 a	2.07 a	0.36 a	0.14 a
Ash Added	2.03 b	0.16 b	2.05 b	0.41 b	0.16 b

c) Total dry matter

Burned Biomass	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
Conventional	8.45 a	0.78 a	19.82 a	3.77 a	1.51 a
Ash Added	9.93 b	1.07 b	26.28 b	4.56 b	1.89 b

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

Table 7.16 Effects of fertilizers on nutrient content in the grain, straw and total dry matter of upland rice at harvest, Tucare's plot.

a) Grain

Fertilizer	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
No fertilizer	5.56 a	0.73 a	17.02 a	3.16 a	1.24 a
N	7.49 b	0.66 a	23.40 b	3.99 b	1.73 b
P	6.81 b	0.96 b	17.70 a	3.78 ab	1.41 a
N+P	9.29 c	0.78 ab	24.95 b	4.20 b	1.84 b

b) Straw

Fertilizer	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
No fertilizer	1.37 a	0.12 a	1.83 a	0.31 a	0.11 a
N	2.12 c	0.15 b	2.54 c	0.40 cd	0.19 b
P	1.72 b	0.15 b	2.19 b	0.36 ab	0.13 a
N+P	2.41 d	0.16 b	2.59 c	0.46 d	0.18 b

c) Total dry matter

Fertilizer	Nutrient content (kg ha^{-1})				
	N	P	K	Ca	Mg
No fertilizer	6.84 a	0.85 a	18.85 a	3.47 a	1.34 a
N	9.60 b	0.81 a	25.93 b	4.38 b	1.92 b
P	8.53 b	1.11 b	19.89 a	4.14 ab	1.54 a
N+P	11.69 c	0.94 ab	27.53 b	4.66 b	2.02 b

Note: Different letters designate significant difference (by LSD, $p < 0.05$) between treatments.

7.4 Discussion

Results from this experiment have shown that restoration of soil fertility in degraded fallows with low population of *Macaranga* (e.g. Tucare's plot) is possible to some extent with improved fallow biomass for burning and application of fertilizers. For example, adding burned biomass increased grain yield 63.2 %, adding N and P increased grain yield in conventional burning by 67.6 % and when additional burned biomass was given, N and P application almost doubled rice grain yield (Table 7.12).

The total fallow biomass of high fertility site (Nopporn's) both above and below ground biomass are higher than that of poor fertility site (Tucare's) by 160 % and 91 % respectively. In the same time, the high fertility site supported higher total nutrient content in fallow biomass than the poor fertility site (Table 7.3). The *Macaranga* has helped to restore those nutrients and enrich fallow vegetations, preventing them from further degradation similar to traditional long fallow cultivations elsewhere (Zinke *et al.*, 1978). The importance of maintaining long fallow to restore soil fertility has been raised in other studies in Northern Thailand (Zinke *et al.*, 1978; Nakano, 1978) and elsewhere (Greenland and Kowal, 1960; Sanchez, 1976; and Nye and Greenland, 1960). When fallows are degrading, Ca, P and K are returned inadequately to the soil from the ash after burning. In Table 7.5, I found that the rice yield of ash removed plot was reduced by 23 % of conventional yield and total nutrient content at 125 days from seeding (harvesting time) was lower significance than conventional especially N and P (Table 7.8). However, the contribution of nutrients stored in the roots of fallow vegetation could play an important role in this nutrient cycling system.

Much emphasis have been given to the importance of almost nutrients in fallow vegetation, the recovery of nutrients from fallow soil and below ground recovery process in nutrient cycling have been given less emphasis. Where successful fallow enrichment can be achieved, *Macaranga* in this case, an enormous amount of N in the roots in Nopporn's plot could have contributed significantly to upland rice after burning. Results from this study show that significant proportion has come from the roots after burning e.g. the grain yield of ash removed treatment of Nopporn's plot (Table 7.5) higher than that of conventional treatment of Tucare's plot (Table 7.12). Nutrient accumulation from fallow litters should not be overlooked. In *Macaranga* abundant fallow, the plant produced thick and lays leave canopy and shreds regularly during the dry season. The study has shown litters in the area of *Macaranga* abundant were 36 % higher than other area (Chapter 5).

In conclusion, short fallow regeneration could lead to deterioration of shifting cultivation due to soil fertility decline; restoration of soil fertility is the dominant factor in maintaining upland rice productivity. Short cultivated, prolific seed producing of pioneer tree species such as *Macaranga denticulata* has capacity to restore fertility of short cycle shifting cultivation for a few decades. This system could also maintain relatively high proportion of tree species composition, hence, preventing degradation due to weedy vegetation with productive nutrient cycling. Application of chemical fertilizers could restore rice yield to a larger extent but they could also aggregate weed and pest problems. Because of longer term solution to the degradation of shifting cultivation could not be achieved e.g. weed disease and pest build up (Nye and Greenland, 1960 and Trenbath *et al.*, 1990).