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Recovery Process of Fallow Vegetation in the Traditional Karen Swidden Cultivation System in the Bago Mountain Range, Myanmar

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Abstract

Forests in Myanmar have a long history of teak (*Tectona grandis* Linn.) production, which can be traced back to the age of the English rule in the nineteenth century, when forests in Myanmar were categorized into those for timber production and those for other uses. Many farmers such as the Karen people, who were swidden cultivators, inhabited the forests. Therefore, the government established the "Karen Area" in the late nineteenth century, permitting swidden cultivation (shifting cultivation) for their self consumption. Short cultivation, long fallow swidden cultivation has been continued for over 100 years in the areas. We surveyed fallow vegetation and total carbon and nitrogen after swidden cultivation by Karen people in the Bago mountain range and compared with those in natural teak forests under selective logging systems. We set 9 circular plots 20 m in radius at fallow stands of various ages. Trees were identified and measured by diameter at breast height (DBH). Surface soil was sampled at 0–5cm.

The amounts of total carbon and nitrogen in soils varied among the plots, but no stand age dependency was observed. Grass and herb species such as *Chromolaena odoratum* and *Thysanolaena maxima* were dominant and comprised the maximum biomass in 1-and 2-year fallows. Bamboo species such as *Bambusa polymorpha* and *Bambusa tulda* rapidly recovered after grass and herb species, and the bamboo biomass in the 5-year fallow was nearly equivalent to that in over- 40-year fallows. Tree species recovered to nearly the same biomass level as that of bamboos in the 10-year fallow, and further facilitated the increase in the above-ground biomass. *Xylia xylocarpa* was the most common tree species while species such as *T. grandis* might be excluded from the fallow vegetation cycle. On the whole, swidden cultivation with a short cultivation period of 1 year and over 12-year fallows maintained sufficient fallow vegetation recovery to sustain continuous swidden cultivation in the Bago mountain range.

Keywords: Myanmar, secondary forest, fallow vegetation, soil carbon, swidden cultivation (shifting cultivation), Karen people

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I　Introduction

Myanmar is one of the most densely forested countries in Southeast Asia, with a very high mixed deciduous forest cover. Teak (*Tectona grandis* Linn.) is the most important timber extracted from mixed deciduous forests, and teak production in Myanmar has a long history that can be traced back to the age of the British rule of the nineteenth century. After the annexation of the lower Burma in 1853, unregulated forests were controlled by forest management based on the German forestry system, and in 1869, forests in Myanmar were categorized into forests for timber production (Reserved Forest) and forests for other uses [Bryant 1997]. However, farmers in reserved forests, such as the Karen people, inhabited the middle to eastern regions of Myanmar for centuries [Marshall 1992]. In order to deal with this situation, the colonial government established the "Karen Area," in which swidden cultivation (shifting cultivation) was permitted for the Karen people for self-consumption.

Swidden cultivation is one of the major indigenous agricultural techniques in tropical areas [Ekwall 1955]. Former studies in Northern Thailand have revealed that secondary forests following swidden cultivation by the Karen people had a richer species composition and an enhanced forest structure as compared with other ethnic groups who cultivated with longer cultivation periods and shorter fallow periods [Schmidt-Vogt 1998; 1999]. The short cultivation period and long fallow period in addition to the non-intensive method of forest clearance in which stumps were left in the ground and large trees were preserved on the swidden fields probably aided the forest regeneration process [*ibid.*]. This type of swidden cultivation was classified as "established swidden cultivation," as compared with "pioneer swidden cultivation," in which farmers cultivated fields for many years until the amount harvested declined to an unsatisfactory level [Conklin 1957; Walker 1975; Grandstaff 1980]. In Northern Thailand, the swidden cultivators were settled mostly in montane evergreen forests, and the "established swidden cultivation" largely comprised shorter fallow cycles or were converted to continuous cultivation, except in remote areas where the "established swidden cultivation" with sufficient fallow years is still dominant [Thomas *et al.* 2004]. In Myanmar, short-cropping, long-fallow type of swidden cultivation is still largely practiced in the Karen areas, which are set primarily in mixed deciduous forest areas in the central to eastern Myanmar. However, there is no ecological data regarding secondary vegetation, which is predominant in the Karen areas due to the long history of swidden cultivation.

Secondary vegetation and soil fertility are very important for the sustainability of swidden cultivation in the tropics [Nye and Greenland 1960]. Therefore in this study, we will examine the ecological succession of vegetation and the stock of soil carbon and nitrogen during the fallow period of swidden cultivation by Karen people in Myanmar by comparing them with the surrounding natural teak forest under selective logging.

II Study Area

We conducted our study in the Bago mountain range, Oktwin township, Toungoo district, Bago division located in the central part of Myanmar (Fig. 1). The Bago range is approximately 450 km in length from north to south, and 80 km from east to west. The general elevation of the Bago range is approximately 250–450 m [Watson 1923], and it is largely covered by mixed deciduous forests (MDF) in which *T. grandis* and *Xylia xylocarpa* were the most dominant species. The average annual minimum and maximum temperatures were 21.4℃ and 32.7℃, respectively, and the average annual rainfall was 1,966 mm, ranging from 1,363 to 2,571 mm over a 10-year period (measured from 1993–2002 at the Toungoo weather station, located 15 km east of the foothills of Bago range). Most of the rainfall occurs in a few months during the rainy season (May–October). Most of the area is composed of tertiary sandstones and shale [*ibid.*], and soils are mostly classified as Ultisols.

Data of secondary forest under the swidden cultivation system was collected at the S village, located in a Karen area (18° 49′–55′ N, 95° 51′–55′ E; elevation between 250–450 m) in the Pyukun reserved forest. The Pyukun reserved forest is one of the 6 reserved forests belonging to the Oktwin township, located in the west of the Bago range. The Karen area was established in 1884 for the local Karen people who resided around the study area, and swidden cultivation has been permitted for this population [Tani 1998]. The S village was established in 1962 in the Karen area of 3,971 ha. In 2002, 370 Sgaw-Karen people (68 households) lived in the village [Takeda *et al.* 2007]. Their

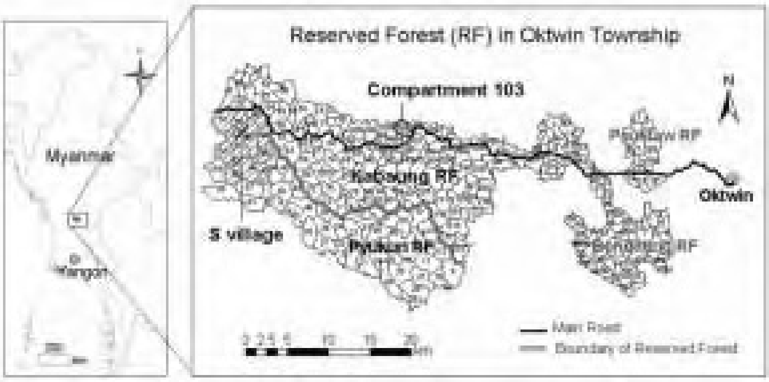

Fig. 1 Location of the study area. Ecological data of the fallow forest was collected in the S village, and that of the natural teak forest was collected in compartment 103.

livelihood almost completely depended on swidden cultivation for self-consumption. The current swidden field area in 2002 totaled 161 ha [*ibid.*].

Their main crops were upland rice mixed with various vegetables, spices, cotton, and sesame. These crops were mainly for self-consumption, but small amounts of red pepper and cotton were cultivated for trade. The villagers selected the field to be used for the next year (usually one field per household) in December to January, and they cut trees and bamboos from January to February. After drying the trees and bamboos for 2 or 3 months, the farmers burned them from the end of March to the beginning of April, just at the beginning of the rainy season. Approximately 1 month after the burning, rice seeds were sown. The rice was harvested from the end of October to November. After the harvest of crops in 1 year, the farmers moved to a new site for cultivating the crops next year, and field was fallowed for at least 12 years (personal communication 2002).

Data of the natural teak forest under selective logging operation was collected by Hla Maung Thein *et al.* [2007] in compartment 103 of the Kabaung reserved forest located at approximately 20 km to the east from the S village (18°52′–53′ N, 96°03′–04′ E; elevation between 250–350 m). *T. grandis* and other useful timber were produced under the Myanmar Selection System, in which only trees over the exploitable girth limit (For teak, 73 cm diameter at breast height (DBH) is the applicable limit in good teak forests and 63 cm in bad teak forests) are selected and cut down. Logged trees were skidded out from the stumps to the log depots or road heads by elephants working under the Myanmar Timber Enterprise (MTE). Details of the study area have been described in Hla Maung Thein *et al.* [2007].

III　Methods

We sampled 9 stands from a current swidden field; from 1-, 2-, 5-, 10-, 15-, 18-, and over 40-year fallow forests; and from an old-growth forest stand adjacent to the residential area of the S village, which has been conserved by the villagers and excluded from the swidden cycle (Fig. 2). All sampling points in the S village were set on the upper slope with 20° to 30° slope inclination. These 9 plots were labeled according to their stand ages. The current field stand was designated P0, and the 1-, 2-, 5-, …, 18-, and over-40-year fallow stands were termed P1, P2, P 05, …, P18, and P40, respectively. The old-growth forest stand was designated as P-old.

One circular plot with a radius of 20 m was set in each stand (Fig. 3). Trees with DBH ≥ 10 cm were identified and measured by DBH. Smaller trees with DBH ≥ 1 cm were sampled only in the inner circle of 10 m radius. We selected 10 trees of various sizes from each stand for height measurement to estimate the height-DBH allometry. Allometric equations provided by Ogawa *et al.* [1965] were used to estimate the biomass of trees.

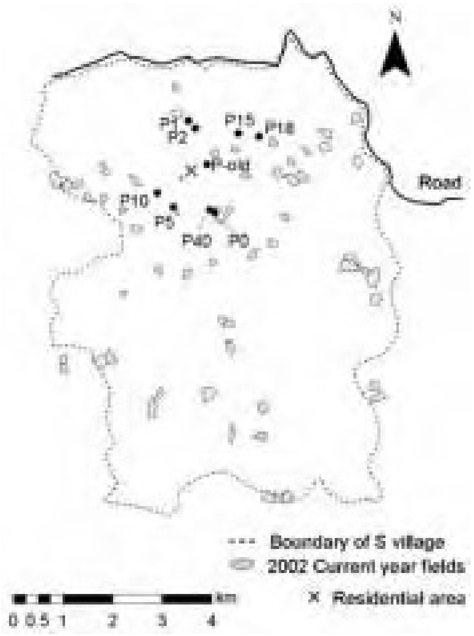

Fig. 2 Location of sampling plots in the S village.

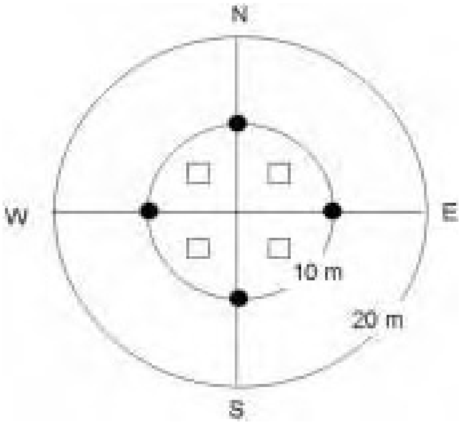

Fig. 3 Design of sampling plots. Surface soils (0–5cm) were collected at the points indicated by ●. The undergrowth was sampled from the 4 points represented by □.

$$w_s = 0.0396\,(DBH^2H)^{0.9326},\ (\mathrm{kg,\ cm^2m})$$
$$w_b = 0.00602\,(DBH^2H)^{1.027},\ (\mathrm{kg,\ cm^2m})$$
$$1/w_l = 26/(w_s + w_b)\ (\mathrm{kg,\ kg}),$$

in which w_s, w_b, and w_l are the dry weights of the stem, branches, and leaves of a tree, respectively.

Bamboo clumps with over 1-cm-culms with over 1 cm of DBH were measured by the DBH of the biggest and smallest culms, and the number of culms was recorded. To estimate the DBH-height allometry, 5 clumps were selected for height measurement. We also cut down 21 culms of 3 bamboo species (*Bambusa polymorpha*, 10 culms; *Bambusa tulda*, 6 culms; and *Cephalostachyum pergracile*, 5 culms), and determined the allometry between the DBH of culms and dry weight of each organ. The estimated parameters of the allometry are described in Table 1. We set 4 subplots (1 m × 1 m) in each of the circular plots (Fig. 3) and collected all of the undergrowth plants (mainly grasses and herbs) in the subplots, and recorded only the major species observed. After oven-drying, the samples were weighed. Litter samples were also collected in the same subplots and weighed.

Soil samples were collected only in the S village from the surface soil (0–5cm) of 4 points (10 m to the north, east, south, and west from the center) in each plot (Fig. 3). All

Table 1 Allometry between the culm DBH and weight of stem, branch, and leaf (w). In the table, parameters a and b of the allometric relation $w = a\ DBH^b$ are presented.

Species	Organ	a	b	r^2
Bambusa polymorpha	Stem (kg d.w.)	0.0522	2.58	0.977
	Branch (kg d.w.)	0.0312	1.6	0.96
	Leaf (kg d.w.)	0.0363	1.36	0.907
Bambusa tulda	Stem (kg d.w.)	0.141	2.48	0.973
	Branch (kg d.w.)	0.0715	1.9	0.856
	Leaf (kg d.w.)	0.125	0.68	0.375
Cephalostachyum pergracile	Stem (kg d.w.)	0.089	2.35	0.974
	Branch (kg d.w.)	0.0273	1.72	0.954
	Leaf (kg d.w.)	0.0415	1.45	0.902

samples were air-dried and sieved through a 2-mm mesh. Total carbon (TC) and total nitrogen (TN) were measured using an NC analyzer (Sumigraph NC-800, Sumika Chem. Anal. Service).

We sampled 33 stands from a natural teak forest in compartment 103 [Hla Maung Thein *et al.* 2007]. The 33 stands in the forest were systematically sampled to cover the whole variety of vegetation in the logging compartment. A circular plot with a radius of 20 m was set in each stand, and tree census was conducted in the same manner as in the S village. Details of the tree and bamboo census are described in Hla Maung Thein *et al.* [2007]. Soil data of natural teak forest was quoted from Suzuki (unpublished).

Statistical tests with Scheffe's test and Spearman's test were carried out using SPSS software (SPSS 10.0.7 J, Inc., 1988–99) for total soil carbon and nitrogen data. Shannon's index of diversity [Shannon and Weaver 1949] was used for diversity analysis of tree and bamboo species.

IV Results

1. *Total Carbon and Nitrogen in the Surface Soil*

Figs. 4 and 5 illustrate the TC and TN contents in the surface soil (0–5cm). TC was low in P0 (10.0 ± 1.7 t/ha), P2 (10.1 ± 1.1 t/ha), P10 (12.6 ± 1.6 t/ha) and P40 (12.2 ± 3.4 t/ha); whereas it was high in P18 (20.3 ± 1.5 t/ha) (Scheffe $p < 0.05$). TN was low in P0 (0.72 ± 0.03 t/ha) and P2 (0.70 ± 0.07 t/ha) and high in P18 (1.18 ± 0.05 t/ha) (Scheffe $p < 0.05$). However, TC in old-growth stands (14.7 ± 1.5 t/ha) and natural teak forests (13.8 ± 1.9 t/ha) and TN in old-growth stands (10.1 ± 1.1 t/ha) and natural teak forests (10.1 ± 1.1 t/ha) were not significantly different from that in the fallow forest stands (Scheffe $p < 0.05$). Also, no significant correlation was observed between the TC and TN values and fallow years (Spearman $p = 0.207$ and 0.183, respectively). The C/N ratios of fallows were approximately 14, except those of P15 and P18, which were approximately 16 (Fig. 6).

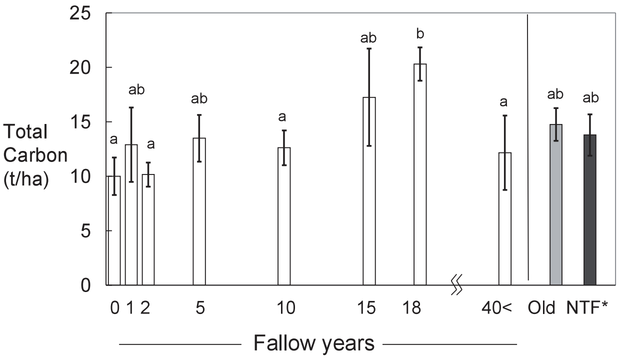

Fig. 4 Total carbon in the surface soil (0–5cm). Data of NTF was quoted from Suzuki [unpublished].

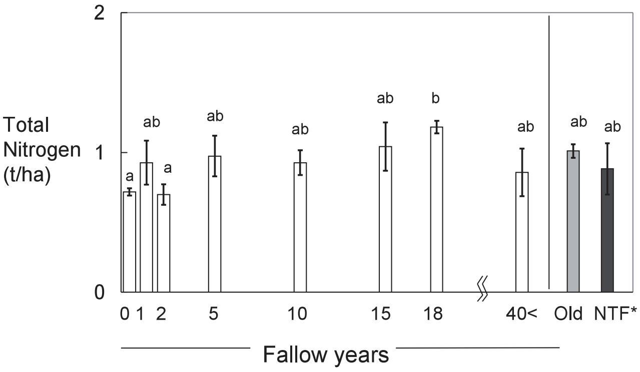

Fig. 5 Total nitrogen in the surface soil (0–5cm). Data of NTF was quoted from Suzuki [unpublished].

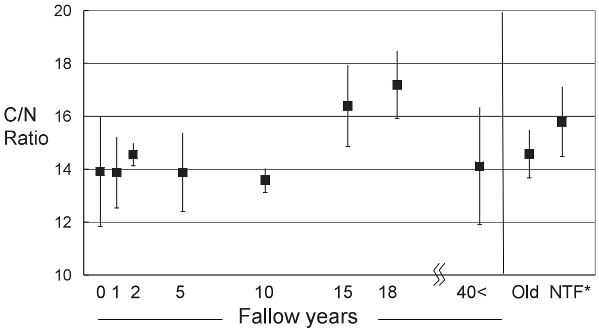

Fig. 6 The C/N ratio in the surface soil (0–5cm). Data of NTF was quoted from Suzuki [unpublished].

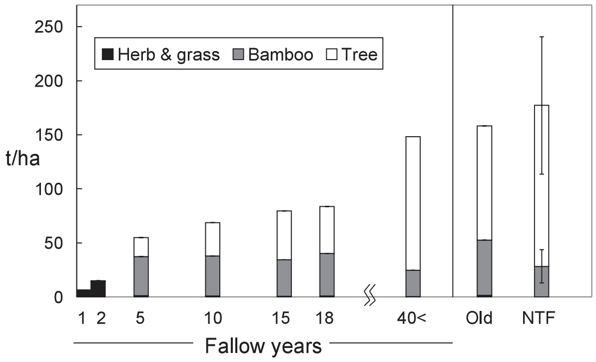

Fig. 7 Dynamics of the above-ground biomass after cropping. Stand ages of old-growth stands (P-old) and natural teak forest stands (NTF) are unknown.

However, the C/N ratio of each stand did not significantly differ (Scheffe $p < 0.05$).

2. *Above-ground Biomass*

Fig. 7 illustrates the total above-ground biomass (TAGB) of fallow forest stands, an old forest stand in the S village and natural teak forest stands. The TAGB of P1 was 6.6 t/ha, which consisted of 6.3 t/ha of grass and herb species, mainly comprising *Chromolaena odoratum*. The TAGB of P2 was 14.9 t/ha, which consisted of 14.2 t/ha of grass and herb species mainly comprising *Thysanolaena maxima* and *C. odoratum*.

The TAGB of P5 was 55.0 t/ha comprising 36.2 t/ha of bamboo and 17.8 t/ha of tree biomass, and there was only a slight undergrowth biomass in P5 and the other older stands. The bamboo biomass of P5 attained almost the same level as that in the old-growth stand (51.5 t/ha) and natural teak forest stands (34.5 t/ha in average). The bamboo biomasses of P10, P15, P18, and P40 were 37.1 t/ha, 33.8 t/ha, 39.4 t/ha, and 24.5 t/ha, respectively, and there was no significant trend in biomass recovery with stand age (Spearman $p = 0.229$). On the other hand, the tree biomass significantly increase with stand age (Spearman $p = 0.000$), which were 17.8 t/ha, 30.7 t/ha, 45.2 t/ha, 43.5 t/ha, and 123.2 t/ha in P5, P10, P15, P18, and P40, respectively.

The TAGB constantly increased with fallow years (Spearman $p = 1.00$). The TAGB of P5 attained to 34.8% of that of P-old, and to 30.0% of the averaged TAGB of 33 natural teak forest stands. The TAGB of P10–P18 increased to 43.4%–52.9% of that of P-old, and to 37.4%–45.6% of the averaged TAGB of natural teak forest stands. The TAGB of P40 attained to 93.6% of that of P-old, and to 80.7% of the averaged TAGB of natural teak forest stands.

3. *Species Appearing in Fallow Vegetation and Natural Teak Forest*

We recorded 57 tree species (49 genera, 30 families) and 3 bamboo species (2 genera) in the 9 stands excluding P0 in the S village (total sampling area, 1.0 ha), and 99 tree species (65 genera, 30 families) and 4 bamboo species (4 genera) in the 33 natural teak forest stands (total sampling area, 4.1 ha). Of these, 39 species (36 genera, 23 families) appeared both in the S village and natural teak forest. The number of species per plot did not significantly differ in the fallow forest stands and natural teak forest stands (ANOVA, $p = 0.94$). Shannon's index of species diversity of stands in S village was 15.6 (± 5.2 standard deviation) in average, and that of natural teak forest stands was 15.5 (± 3.2 standard deviation) in average. These values did not significantly differ each other (ANOVA, $p = 0.71$).

Table 2 illustrates all the species present in the stands in the S village in the order of their above-ground biomass values. *Bambusa polymorpha* was dominant in P5, P10, P40, and P-old and *Bambusa tulda*, in P15 and P18. Both are major bamboo species occurring in mixed deciduous forests; however, *B. tulda* did not occur in natural teak forest stands. *Cephalostachyum pergracile* was distributed in the smallest number and it was only found in P-old. *X. xylocarpa* had the largest average biomass among tree species in fallow forest stands (8.1 t/ha), and occurred in all stands, except P2. *Eriolaena candollei* and *Anogeissus acuminata* also had large average biomass, but these species occurred only in P40. *Mitragyna rotundifolia* had the fourth largest average biomass (2.4 t/ha) and appeared in all fallow stands. This species was followed by *Spondias pinnata, Cordia grandis*, and *Stereospermum colais* with biomasses of 1.8–1.9 t/ha and frequencies ranging from 42.9%–57.1%. The 17 most dominant species based on biomass also appeared in natural teak forest stands. Twenty species appeared only in fallow forest stands, and most of them were shrubs or small trees that were present in semi-open areas [Gardner *et al.* 2000].

Table 3 illustrates all species present in natural teak forest stands in the order of their average above-ground biomass values. *B. polymorpha* and *C. pergracile* were the 2 most dominant species in biomass in natural teak forest stands, which were 20.0 t/ha and 8.0 t/ha of the above-ground biomass with frequencies of 90.9% and 93.9%, respectively. *T. grandis* possessed the largest average biomass of tree species (38.4 t/ha) and the highest frequency (84.8%), but it did not appear in fallow forest stands in the S village. *X. xylocarpa* had the second largest average biomass (25.9 t/ha) and also the forth highest frequency (72.7%), followed by *Protium serratum* and *M. rotundifolia* with 12.2 and 7.0 t/ha of biomass, that had the second and third highest frequencies of 78.8% and 75.8%, respectively. *P. serratum* also did not appear in fallow forest stands.

Table 2 Fallow forest stands (8 stands) and old-growth forest stands (1 stand). Species marked by * appeared only in these stands in the S village and did not appear in natural teak forest stands.

	Species	P1	P2	P5	P10	P15	P18	P40	Frequency (%)	Average biomass in fallow stands (t/ha)	P-old
1	*Bambusa polymorpha Munro*	0.20		36.2	37.1			24.5	50.0	13.99	50.9
2*	*Bambusa tulda* Roxb.		0.20			33.8	39.4		37.5	10.47	
3	*Cephalostachyum pergracile* Munro								—	—	0.2
	Bamboo total (t/ha)	0.20	0.20	36.2	37.1	33.8	39.4	24.5	—	27.8	51.1
1	*Xylia xylocarpa* (Roxb.) Taub.	0.00		0.7	15.0	0.3	23.3	17.4	85.7	8.08	0.0
2	*Eriolaena candollei* Wall.							20.4	14.3	2.92	
3	*Anogeissus acuminate* Wall.				2.4			17.7	28.6	2.88	
4	*Mitragyna rotundifolia* (Roxb.) Kuntze	0.01	0.02	1.2	1.6	2.1	4.6	7.3	100.0	2.41	1.6
5	*Dalbergia ovata* Grah.					14.8		1.2	28.6	2.28	
6	*Spondias pinnata* (L.) Kurz			0.2	0.0			13.0	42.9	1.89	14.8
7	*Cordia grandis* Roxb.			1.1	1.3		1.9	8.8	57.1	1.86	15.2
8	*Stereospermum colais* (Buch.-Ham. ex Dillwyn) Mabb.					1.6	1.3	9.8	42.9	1.83	14.4
9	*Croton oblongifolius* Roxb.			7.0	1.8				28.6	1.26	0.3
10	*Diospyros ehretioides* Wall.					8.3	0.1		28.6	1.19	
11	*Lagerstroemia villosa* Wall. ex C. B. Clarke		0.03		1.7			5.5	42.9	1.03	0.8
12	*Terminalia tomentosa* Wight & Arn.		0.01		0.8	6.1			42.9	0.99	
13	*Garuga pinnata* Roxb.			0.8	2.3			3.1	42.9	0.88	
14	*Senna timoriensis* (DC.) Irwin & Barneby			0.9			4.6		28.6	0.79	
15	*Lannea grandis*							5.0	14.3	0.71	
16	*Dalbergia cultrate* Grah.		0.00				4.7		28.6	0.67	
17	*Bombax insigne* Wall.					0.4		3.7	28.6	0.58	
18*	*Syzygium* sp.			3.8					14.3	0.55	
19*	*Strychnos nux-blanda* A. W. Hill					3.8			14.3	0.55	
20	*Markhamia stipulate* (Wall.) Seem. ex K. Schum.						0.3	2.7	28.6	0.43	
21*	*Cratoxylum* sp.		0.02			2.4			28.6	0.34	
22*	*Erythrina stricta* Roxb.						0.6	1.6	28.6	0.32	
23	*Stereospermum* sp.				0.4			1.8	28.6	0.32	
24*	*Premna latifolia* Roxb.					0.0	0.1	1.9	42.9	0.30	
25	*Schleichera oleosa* (Lour.) Oken							2.0	14.3	0.29	
26	*Gmelina arborea* Roxb.				2.0				14.3	0.28	
27	*Albizia odoratissima* (L. f.) Benth.			0.4	1.2				28.6	0.23	
28*	*Diospyros* sp.					0.7	0.4		28.6	0.15	
29	*Cassia fistula* L.			1.0					14.3	0.15	
30	*Lagerstroemia speciosa* (L.) Pers.					1.0			14.3	0.14	
31	*Vitex peduncularis* Wall. ex Schauer					0.9			14.3	0.13	19.5
32*	Malvaceae sp.					0.8			14.3	0.11	

Table 2–Continued

	Species	P1	P 2	P5	P10	P15	P18	P40	Frequency (%)	Average biomass in fallow stands (t/ha)	P-old
33	*Bauhinia racemosa* Lam.					0.3	0.4		28.6	0.10	
34	*Berrya mollis* Wall. ex Kurz		0.25			0.4			28.6	0.10	
35*	*Grewia eriocarpa* Juss.						0.7		14.3	0.10	
36	*Bridelia tomentosa* Blume			0.5	0.1				28.6	0.08	0.0
37*	*Bridelia retusa* (L.) A. Juss.					0.5			14.3	0.07	
38*	*Phyllanthus embrica* L.				0.0	0.5			28.6	0.07	
39	Sapotaceae sp.							0.4	14.3	0.06	
40*	*Stereospermum neuranthum* Kurz		0.01			0.3			28.6	0.04	
41	*Terminalia chebula* Retz.						0.2		14.3	0.03	0.1
42*	*Lophopetalum wallichii* Kurz						0.2		14.3	0.02	
43*	*Symplocos racemosa* Roxb.?						0.1		14.3	0.02	
44*	*Flacourtia rotundifolia* Clos					0.1			14.3	0.02	4.2
45	*Antidesma ghesaembilla* Gaertn.					0.1			14.3	0.01	25.1
46	*Semecarpus anacardium* L. f.				0.1				14.3	0.01	
47*	*Careya arborea Roxb.*		0.06						14.3	0.01	
48	*Colona floribunda* (Kurz) Craib	0.05							14.3	0.01	
49*	*Wrightia arborea* (Dennst.) Mabb.				0.0				14.3	0.00	
50	Rubiaceae sp.		0.02						14.3	0.00	
51*	*Flemingia* sp.		0.00		0.0				28.6	0.00	0.5
52	*Buddleja* sp.	0.01							14.3	0.00	
53*	*Xantolis tomentosa* Raf.				0.0				14.3	0.00	0.5
54*	*Butea superba* Roxb.	0.01							14.3	0.00	
55	*Neonauclea excelsa* Blume					0.0			14.3	0.00	
56*	Ulticaceae sp.	0.00							14.3	0.00	
57	*Combretum* sp.								0.0	—	8.6
	Tree total (t/ha)	0.1	0.4	17.8	30.7	45.2	43.5	123.2	—	45.8	105.5
	All species total	0.3	0.6	53.9	67.8	79.0	82.9	147.6	—	73.6	156.6

Table 3 Natural teak forest stands (33 stands). Species marked by * appeared only in these stands and not in the stands in the S village.

	Species	Frequency (%)	Average biomass (t/ha)
1	*Bambusa polymorpha* Munro	90.9	19.99
2	*Cephalostachyum pergracile* Munro	93.9	8.01
3*	*Dinochloa maclellandii* (Munro) Kurz	45.5	0.17
4*	*Gigantochloa nigrociliata* (Buse) Kurz	3.0	0.04
	Bamboo total (t/ha)	—	28.2
1*	*Tectona grandis* L. f.	84.8	38.4
2	*Xylia xylocarpa* (Roxb.) Taub.	72.7	25.9
3*	*Protium serratum* Engl.	78.8	12.2
4	*Mitragyna rotundifolia* (Roxb.) Kuntze	75.8	7.0
5	*Stereospermum colais* (Buch.–Ham. ex Dillwyn) Mabb.	33.3	4.6
6*	*Millettia brandisiana* Kurz	60.6	4.1
7	*Dalbergia cultrate* Grah.	30.3	3.3
8	*Spondias pinnata* (L.) Kurz	33.3	3.2
9	*Schleichera oleosa* (Lour.) Oken	27.3	3.1
10	*Terminalia tomentosa* Wight & Arn.	12.1	2.6
11	*Garuga pinnata* Roxb.	24.2	2.5
12*	*Homalium tomentosum* Benth.	30.3	2.3
13	*Cordia grandis* Roxb.	39.4	2.1
14	*Lagerstroemia villosa* Wall. ex Kurz	39.4	2.0
15*	*Mangifera odorata* Griff.	9.1	2.0
16	*Bridelia retusa* (L.) A. Juss.	27.3	2.0
17*	*Lagerstroemia tomentosa* Presl	12.1	1.9
18	*Lannea grandis*	24.2	1.8
19*	*Terminalia bellerica* Roxb.	15.2	1.6
20*	*Ficus semicordata* Buch.-Ham. ex J. E. Sm.	9.1	1.5
21	*Dalbergia ovata* Grah.	33.3	1.4
22	*Vitex peduncularis* Wall. ex Schauer	24.2	1.3
23	*Croton oblongifolius* Roxb.	42.4	1.3
24	*Anogeissus acuminate* Wall.	30.3	1.3
25	*Eriolaena candollei* Wall.	24.2	1.1
26*	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	12.1	1.0
27*	*Flacourtia cataphracta* Roxb.	12.1	1.0
28	*Bombax insigne* Wall.	15.2	1.0
29	*Terminalia chebula* Retz.	12.1	0.9
30*	*Adina cordifolia* Hook. f.	6.1	0.9
31*	*Dalbergia fusca* Pierre	9.1	0.9
32*	*Sterculia versicolor* Wall.	3.0	0.9
33*	*Bombax ceiba* L.	3.0	0.8
34	*Neonauclea excelsa* Blume	3.0	0.8
35	*Bauhinia racemosa* Lam.	15.2	0.7
36*	*Elaeocarpus* sp.	6.1	0.6
37*	*Hymenodictyon orixense* (Roxb.) Mabb.	12.1	0.5
38	*Stereospermum* sp.	15.2	0.4
39	*Grewia eriocarpa* Juss.	15.2	0.4
40*	*Kydia calycina* Roxb.	6.1	0.4
41	*Albizia odoratissima* (L. f.) Benth.	9.1	0.4
42*	*Lagerstroemia macrocarpa* Kurz	12.1	0.4
43*	*Chisocheton* sp.	3.0	0.4
44*	*Heterophragma adenophylla* (Wall.) Seem. ex *Benth. & Hook.*	30.3	0.3
45*	*Morus* sp.	3.0	0.3
46	*Gmelina arborea* Roxb.	3.0	0.3
47*	*Sterculia villosa* Roxb.	6.1	0.3
48*	*Milletia* sp.	3.0	0.3
49*	Unidentified sp. 1	3.0	0.3
50	*Colona floribunda* (Kurz) Craib	12.1	0.3
51*	*Albizia lucidior* (Steud.) Nielsen?	3.0	0.3
52*	*Cratoxylum neriifolium* Kurz	3.0	0.2
53*	*Rinorea bengalensis* Kuntze	3.0	0.2
54*	*Microcos paniculata* L.	3.0	0.2
55	*Semecarpus anacardium* L. f.	12.1	0.2
56*	*Holarrhena pubescens* Wall. ex G. Don	3.0	0.2
57	*Lagerstroemia speciosa* (L.) Pers.	9.1	0.2
58*	Leguminosae sp. 1	3.0	0.1
59*	*Alstonia scholaris* (L.) R. Br.	3.0	0.1
60*	Unidentified sp. 2	3.0	0.1
61	*Diospyros ehretioides* Wall.	3.0	0.1
62*	*Oroxylum indicum* (L.) Kurz	6.1	0.1
63*	*Anthocephalus morindaefolius* Korth.	3.0	0.1
64*	*Diospyros Montana* Roxb.	6.1	0.1
65*	Leguminosae sp. 2	3.0	0.1
66*	*Pterospermum semisagittatum* Buch.-Ham.	6.1	0.1
67*	*Diospyros* sp. 1	6.1	0.1
68*	*Diospyros* sp. 2	3.0	0.1
69*	*Gomphandra* sp.	12.1	0.1
70	*Senna timoriensis* (DC.) Irwin & Barneby	3.0	0.1
71	*Butea superba* Roxb.	3.0	0.0
72	Rubiaceae sp.	3.0	0.0
73	*Antidesma ghesaembilla* Gaertn.	6.1	0.0
74	*Cassia fistula* L.	6.1	0.0
75*	*Phyllanthus columnaris* Muell. Arg.	3.0	0.0
76	*Berrya mollis* Wall. ex Kurz	3.0	0.0
77*	*Dalbergia* sp.	3.0	0.0
78	*Markhamia stipulate* (Wall.) Seem. ex K. Schum.	3.0	0.0
79*	Leguminosae sp. 3	3.0	0.0
80*	*Michelia* sp.	3.0	0.0
81*	*Sapindus saponaria* L.	3.0	0.0
82*	Unidentified sp. 3	3.0	0.0
83*	Bignoniaceae sp.	3.0	0.0
84*	*Pithecellobium* sp.	3.0	0.0
85*	*Mallotus philippinensis* (Lam.) Muell. Arg.	3.0	0.0
86*	Unidentified sp. 4	3.0	0.0
87*	*Terminalia pyrifolia* Kurz	3.0	0.0
88	*Phyllanthus emblica* L.	3.0	0.0
89*	*Mansonia* sp.	3.0	0.0
90*	Unidentified sp. 5	3.0	0.0
91*	*Miliusa* sp.	6.1	0.0
92*	*Semecarpus* sp.	3.0	0.0
93*	Unidentified sp. 6	3.0	0.0
94*	Unidentified sp. 7	3.0	0.0
95*	*Grewia tiliifolia* Vahl	3.0	0.0
96*	*Pterocarpus macrocarpus* Kurz	3.0	0.0
97*	Unidentified sp. 8	3.0	0.0
98*	*Pittosporum* sp.	3.0	0.0
99*	Leguminosae sp. 4	3.0	0.0
	Tree total (t/ha)	—	149.0
	All species total	—	177.2

V Discussion

1. *Soil Stability during the Cultivation Period and Early Fallow Period*

Management of soil organic matter is very important for the sustainability of agriculture in tropical areas [Woomer *et al.* 1994]. Tulaphitak *et al.* [1985] reported that soil organic matter reduced during the cultivation period because of the increase in soil respiration and erosion. Funakawa *et al.* [1997] also reported that organic matter-related resources decreased in the soil under continuous farming. However, there was no significant decrease in TC and TN in the surface soils of the current and young fallow fields in the S village. These results suggest that the loss of soil organic matter from the surface soil during cultivation was not considerably large in the S village; this is probably because the duration of cultivation was only one year. Additionally, the rapid cover of *Chromolaena odoratum* within one year after the abandonment might contribute to the prevention of soil erosion in the early stages of the fallow period. *C. odoratum* originated in Latin America, and invaded Southeast Asia in the nineteenth century and is commonly found in fallow vegetation [McFadyen and Skarratt 1996]. Koutika *et al.* [2002] reported that soil fertility is richer in fallow with *C. odoratum* than those without this species. Moreover, the mortality of *C. odoratum* increases and the recruitment of new individuals decreases in fallow fields older than 3 years [Kushwaha *et al.* 1981]. In the fallow vegetation observed in the S village, this species did not successfully recruit under the closed canopy dominated by bamboos that covered the fields until 5 years after the abandonment. This initial herbaceous biomass at the early stage of fallow vegetation is indispensable for maintaining the soil organic matter in the field [Funakawa *et al.* 2006].

2. *Dynamics in Above-ground Biomass Recovery*

Bamboo facilitated the recovery of fallow vegetation. The total above-ground biomass of the 5-year fallow was 55.0 t/ha, with 36.2 t/ha of bamboo biomass. Sabhasri [1978] reported that the above-ground biomass in a 4-year fallow in the absence of bamboo species was 29.9 t/ha in a Karen village in Northern Thailand, where the climax vegetation was montane evergreen forest. This suggests that the recovery of the above-ground biomass in the early fallow stage was comparatively rapid in the S village, owing to the rapid recovery of bamboos. This rapid recovery was facilitated by sprouting from remaining stumps in the fields and from the bamboos that survived the burning. Ramakrishnan [1992] also reported that a shift from predominantly herbaceous vegetation to that with bamboo and other species took place in the 5-year fallows in northeastern India and the latter became dominant in the 10-year fallows.

Tree species assume the role of facilitator of biomass recovery in later stages. Sprouting from the remaining stumps cut at 1 m height by the villagers may enable the trees to grow rapidly even after bamboos cover the field because the remaining stumps and roots that survive after cutting and burning store reservoir material for rapid recovery. Tree biomass continued to increase in fallow forest stands older than 5 years to attain an above-ground biomass equivalent to that of bamboo species between 10 to 15 years after the abandonment. Farmers in the S village avoid selecting fallow fields younger than 12 years as cropping sites (personal communication 2002). According to informants from the village, the best fallow forest for burning is a mixture of trees and bamboos in a ratio of 1 : 1, in which fallen bamboos are cracked by fallen trees. Our results demonstrate that the approximately 12-year-fallows are at a stage where the biomass of trees approach that of the bamboos. This is consistent with the observation of the villagers, suggesting that the recovery of tree species is also a very important factor in fallow vegetation in this swidden system.

3. *Differentiation of Species Composition during the Long History of Swidden Cultivation in Karen Area*

As a result of the repeated cutting and burning practice after the long history of swidden cultivation, the species composition of fallow vegetation in the Karen area has been differentiated.

Cephalostachyum pergracile appeared only in small numbers surrounding the S village, but it is abundant in some stands in natural teak forest stands. Considering that *C. pergracile* occurs in somewhat drier areas in which *B. polymorpha* is characteristically found [Jansen and Duriyaprapan 1995], such distribution may be a natural occurrence. *Bambusa polymorpha* and *Bambusa tulda* were the dominant bamboo species in fallow forest stands and did not mix with each other in the stands. *B. polymorpha* is known to be an indicator species of deep, rich, well-drained soils on which *T. grandis* also develops well [*ibid.*], while *B. tulda* frequently occurs in soils of finer textures [Seethalakshmi and Muktesh Kumar 1998], which are usually poorly drained. Thus, these species may also naturally be distributed across different environmental conditions, and become dominant in fallow vegetation.

X. xylocarpa was the most dominant species in biomass with high frequency in fallow vegetation. Marod *et al.* [2004] reported that *X. xylocarpa* increased root biomass after fire treatment and resulted in higher fire resistance. This species is also known as the rapid regeneration species in fire-prone areas of Northern Thailand [Gardner *et al.* 2000]. The relatively high priority of this species in fire tolerance than other tree species might enable this species to survive from the cutting and burning and increase in fallow vegetation. *Mitragyna rotundifolia* also appeared in fallow forest stands with high frequency. The small seed of this species might have advantages in wide seed disposal in open areas, thus enabling the seedlings of this species to germinate.

T. grandis was dominant species in natural teak forest, but was not recorded in the fallow forest stands that we surveyed. *T. grandis* is also known as a fire-tolerant and first-growing species which grows well after being planted [Sakurai and de la Cruz 1993]. In fact, *T. grandis* was observed in some fallow fields located farther from the residential areas than our sampling plots, in which swidden cultivation might not have been opened frequently. This suggests that *T. grandis* might appear in the fallow vegetation at the first few swiddening cycles after the sites were newly opened, but it might decrease after repeated cutting and burning in these sites probably due to comparatively lower sprouting ability against fire disturbance than other species such as *X. xylocarpa*. *P. serratum*, which dominated in natural teak forest stands, appeared in small numbers might also exhibit the same patterns, but further study is required to clarify the dynamics of these species after repeated cutting and burning.

VI Conclusion

The characteristics of fallow vegetation under the Karen swidden cultivation system in the Bago mountain range are summarized below.

1) Rapid growth of species such as *Chromolaena odoratum* after the abandonment of the field prevented significant loss of surface soil during the first few years of cultivation period.
2) Bamboo species such as *B. polymorpha* and *B. tulda* facilitated the rapid recovery of above-ground biomass in the early fallow stage, followed by trees which attained biomass equivalent to that of the bamboos approximately 10–15 years after the abandonment.
3) Fire tolerant and/or vigorously sprouting tree species such as *X. xylocarpa* were dominant species that played an important role in fallow vegetation, while some common MDF species such as *T. grandis* might have decreased in the fallow vegetation during the long history of swidden cultivation.

On the whole, the swidden cultivation method with a short cultivation period of 1 year and long fallow period of over 12 years maintained sufficient fallow vegetation recovery to sustain continuous swidden cultivation in the Bago mountain range.

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