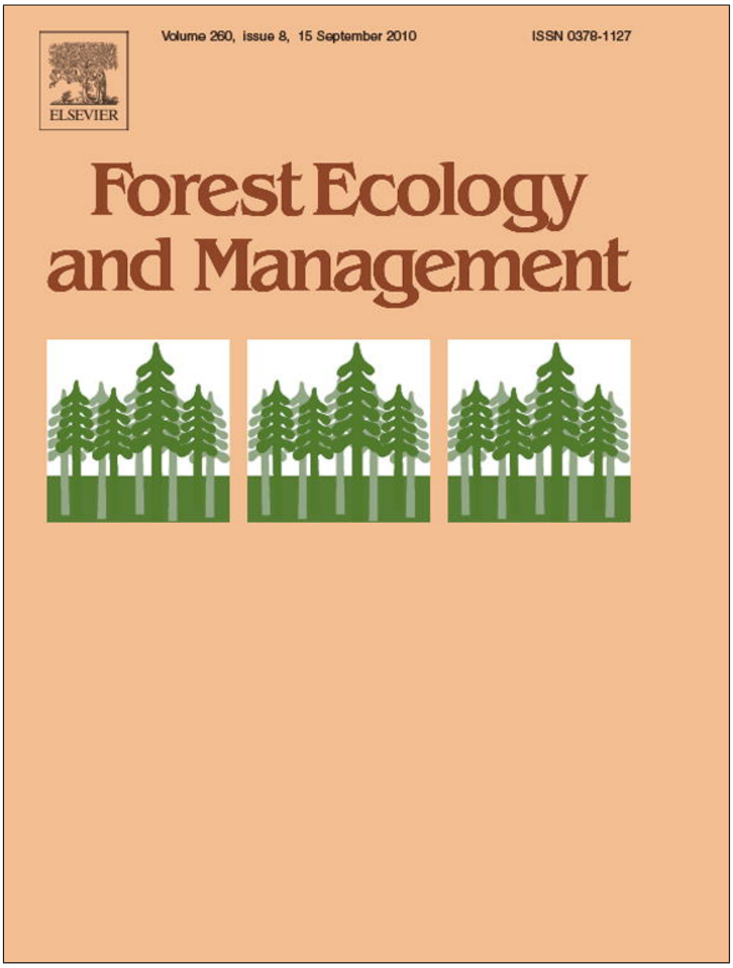
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Fallow to forest: Applying indigenous and scientific knowledge of swidden cultivation to tropical forest restoration

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ABSTRACT

Rotational swidden cultivation systems, with fallow periods long enough for the regeneration of secondary forests are capable of maintaining forest cover and plant diversity in a dynamic balance in swidden cultivation landscapes. Regeneration of secondary forests through several successional stages and by a combination of coppicing and seedling development is still poorly understood, especially the influence of different swiddening practices and the role of animals as seed dispersers. Swidden cultivators possess a vast knowledge of plants growing in swidden fallows and of fallow dynamics as well. Forest restoration in Thailand has been carried out mainly on the basis of experimental research on the potential of indigenous tree species to promote natural forest regeneration and biodiversity recovery; the so-called framework species. Another viable source of knowledge for forest restoration can be the study of the semi-natural revegetation processes in fallows and the indigenous knowledge of swiddeners of these processes. The research presented here was carried out to attain a better understanding of forest regeneration on fallow swiddens under different swiddening regimes and how it may be applied to practical forest restoration, We investigated the vegetation characteristics of from various stages of secondary succession in fallow swiddens of the Karen and Lawa ethnic groups in the Mae Chaem watershed, Chiang Mai province, northern Thailand. Indigenous knowledge on the use of species and traditional ecological processes in swiddening was recorded by questioning key informants. The data were analyzed and discussed with respect to their application in forest restoration and participatory forest management.

1. Introduction

Swidden cultivation is a traditional form of agriculture, which has been practiced for more than thousand years in the mountainous regions of mainland Southeast Asia, *i.e.* Cambodia, Laos, Myanmar, Thailand, Vietnam, and China's Yunnan province (Spencer, 1966; Fox, 2000). In this land use system, patches of forest are cut down and burned during the dry season to clear and fertilize the site for cultivation. The cleared fields are planted for one or more years with upland rice or other crops during the rainy season and then left to lie "fallow" for periods of varying length to allow for natural succession that results in secondary forest (Schmidt-Vogt, 1999, 2001; Mertz et al., 2009). Ethnic minority groups have accumulated indigenous knowledge on cropping, as well as on the ecology and uses of secondary forests (Kunstadter et al., 1978; Anderson, 1993; Nakashima and Roué, 2002; Santasombat, 2003; Hares, 2006). Well-known examples are the Karen (Delang, 2003) and the Lawa (Kunstadter et al., 1978; Schmidt-Vogt, 1997a,b, 1998, 1999, 2000, 2007) ethnic groups in Northern Thailand. Some swidden cultivators perform selective felling before cultivation, to preserve parent trees or relict emergents for subsequent forest regeneration (Kerkhoff and Sharma, 2006; Schmidt-Vogt, 2007; Rerkasem et al., 2009). The fallow phase allows soils to stabilize and gives forest vegetation an opportunity to re-grow, to accumulate biomass, and to provide various non-timber forest products. Moreover, if the fallow phase is long enough, there is considerable opportunity for both carbon sequestration and biodiversity conservation (Lawrence et al., 1998; Rerkasem et al., 2009).

However, population growth as well as social and policy changes exert increasing pressure on shifting cultivators (Delang, 2002; Xu et al., 2009). Commercialization and an increasing demand for cash crops provide incentive to growing commercial crops, intensively with shorter fallow periods or none at all. Although such land use offers almost immediate financial benefits to the farmers, it may have many long-term adverse environmental impacts, as a shortened fallow phases are often

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unsustainable (Wangpakapattanawong, 2001), allowing dominance of herbaceous weeds and grasses and eventually soil degradation (Ramakrishnan, 2006).

Indigenous knowledge is often discussed as a basis of information to be incorporated with changing resource management paradigms (Ellen et al., 2000; Davidson-Hunt and Berkes, 2001). The protection of indigenous knowledge for ecosystem integrity and biodiversity recovery is a focal area of the Convention on Biodiversity (CBD)'s Targets in 2010 (CBD, 2007, http://www.cbd.int/2010-target). The challenge for sustainable forest restoration and management is how to build strategies for incorporating indigenous knowledge into state-driven forestry policy and implementation (He et al., 2009). Thus, in order to assess the indigenous knowledge of swidden cultivators and to combine it with scientific knowledge obtained through field research as a tool for forest restoration and management, a vegetation survey in fallow fields was conducted from the viewpoint of ethnoscience (Rist and Dahdouh-Guebas, 2006). We tested the hypothesis that regeneration processes in fallow swiddens may provide information that can be usefully applied to tropical forest restoration techniques. For example, it is well understood that sprouting from living stumps and rootstocks after clearing and burning is an important process in secondary fallow successions (Schmidt-Vogt, 1999, 2001; Fukushima et al., 2007). The contribution to forest regrowth by tree growing from seeds is less well understood. Dispersal of seeds from surviving forest remnants into the forest restoration sites is, however, a crucial process in forest restoration (Wunderle, 1997; Willson and Traveset, 2000; Clark et al., 2001; Corlett, 2002). We also tested the hypothesis that swidden cultivators are knowledgeable about ecological functions such as seed dispersal, seed establishment and coppicing.

2. Materials and methods

2.1. Study site

Two sites (site 1 is Mae Hae Tai Karen and site 2 is Ban Hor Lawa hilltribe villages), where rotational shifting cultivation is

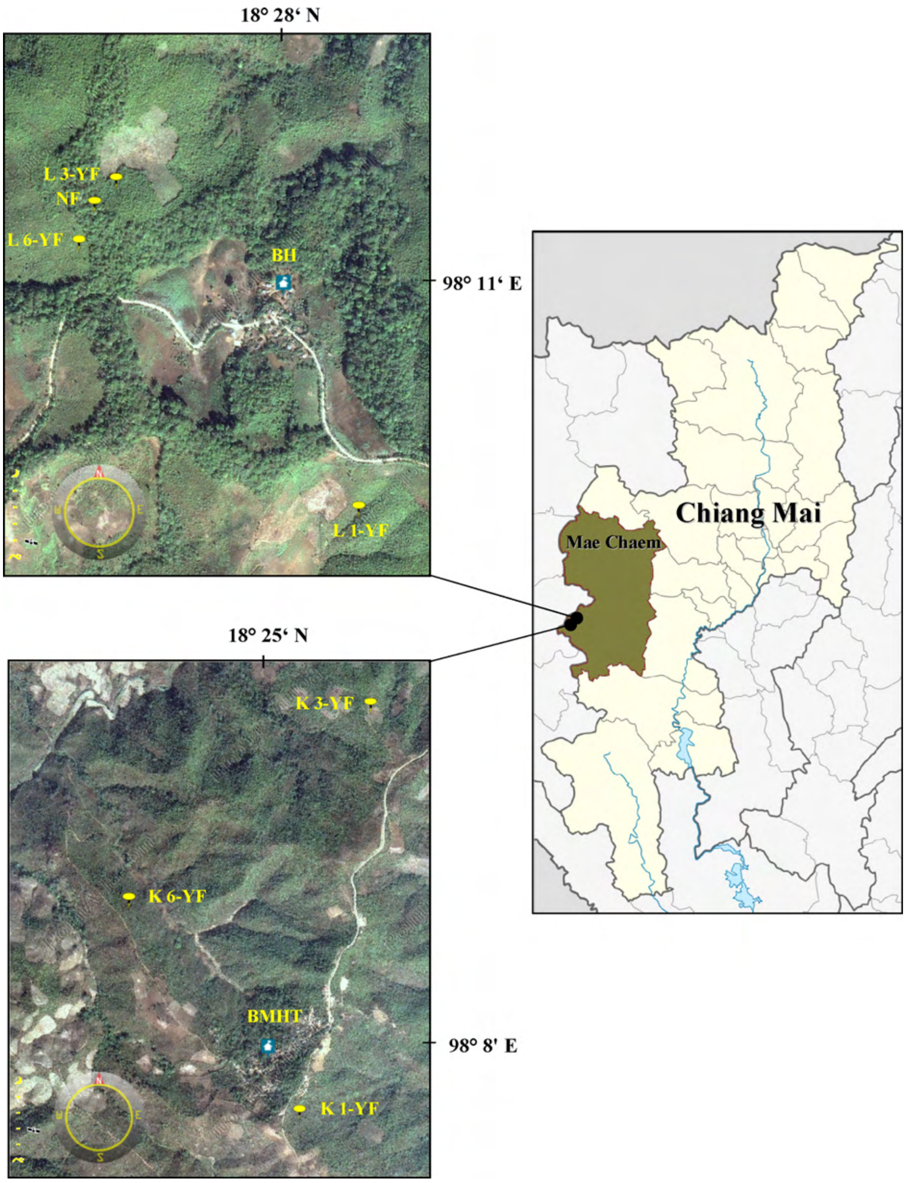

Fig. 1. The study site is located in the Mae Chaem watershed in Chiang Mai province, northern Thailand. Sampling plots were labeled according to sampling plots location; 1-year (K 1-YF), 3-year (K 3-YF), and 6-year fallows (K 6-YF) around Karen village (Ban Mae Hae Tai; BMHT) and 1-year (L 1-YF), 3-year (L 3-YF), 6-year fallows (L 6-YF) and natural forest (NF) around Lawa village (Ban Hor; BH). Map of Chiang Mai province, Thailand, highlighting the district Mae Chaem © 2009 Wikimedia commons. Satellite imagery © 2010 PointAsia.com Version: 1.1.0007.00 (Beta).

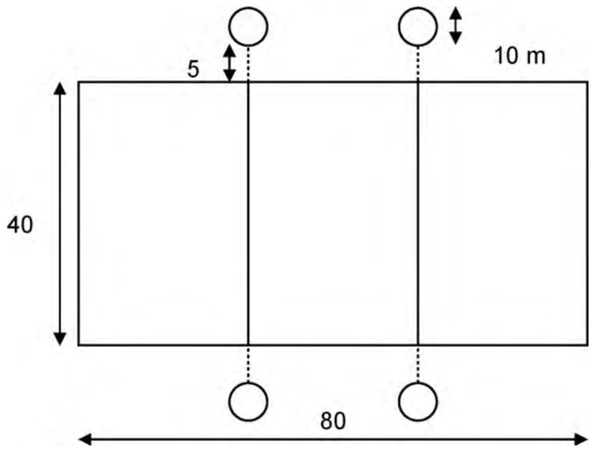

Fig. 2. Belt transect and circular sampling plot diagram.

still practiced, in Mae Chaem watershed (18°06′–19°10′ N and 98°04′–98°34′ E), Chiang Mai province, northern Thailand, were selected for establishing sampling plots in fallow fields of various ages. Quantitative data of fallow vegetation, ethnobotanical use of tree species, and traditional ecological knowledge related to fallow-field management were collected and evaluated.

2.2. Vegetation Sampling

At both sites, vegetation sampling was conducted in 1-year, 3-year, and 6-year fallows fields. In order to compare the vegetation composition between the fallow fields and uncultivated lands never been subject to swiddening, one area of natural forest on the upper slope close to cultivated fields and the fallows was chosen as a control plot (Fig. 1). It is a forest stand that has never been subject to swiddening, but which has been used for other purposes. The canopy layer exceeds 10 m and is composed of *Archidendron clypearia* var. *clypearia*, *Castanopsis* spp., *Magnolia bombycina*, *Schima wallichii* and *Styrax benzoides*. The sub-canopy layer is characterized by high tree and seedling density. Several trees were cut, or had parts removed for traditional uses. A sample plot (80 m × 40 m) in each of the categorized fallows were established with belt transects parallel to the contour lines. In each plot, standing trees were counted and identified. Tree seedlings were surveyed in 4 circular plots, 5 m in diameter, and 5 m from the middle of the sampling site (Fig. 2). All tree/seedling species were identified by a botanist of Herbarium of Department of Biology, Faculty of Science, Chiang Mai University.

2.3. Questionnaires of indigenous knowledge

From among the swiddeners, 1 key informant was selected from each village. The informants imparted their knowledge on traditional use of tree species for food (for human consumption and animal feed), medicinal use, firewood, construction, etc.). Sprouting abilities of each species, one of the key properties of the framework tree species, and seed-dispersing wildlife of those trees was assessed by questioning the key informants and direct observation.

2.4. Data analysis

The relative density and frequency of trees and seedlings were assessed. Species diversity was calculated using the Shannon-Wiener index of diversity. Equitability of tree species community was calculated using evenness index. Comparison of percent similarity (PS) of the plant species between the two sampled plots was done by calculating Sørensen's index. Statistical analyses using paired *t*-test were conducted to examine significant differences of tree and seedling communities at the two sites.

3. Results

Numbers of tree species were highest in the 6-year fallow of site 1, while the numbers of individuals and density were highest in the natural forest (Table 1). Species numbers in fallows of site 2 were lowest in the 3-year plot even though the number of individual trees was greater than in the 1-year plot. Tree densities were highest in the 3-year plots and decreased in the 6-year plots in the fallows of both sites. Seedlings were represented by only 17 species in the 1-year plots of site 1, which was less than on the 1-year plots of site-2 fallows. Seedling species diversity was highest in the 6-year fallow of site 1 and the natural forest plot, while the numbers of individuals and density were highest in the 6-year fallow of site 2. The seedling communities of site 2 fallows exhibited an increase of species number, number of individuals and density as the ages of the fallow increase.

Young fallows at site 1 were characterized by a high density of one species: *A. fragrans* which dominated the plot (Table 2). The most abundant species in site 1 was *Flacourtia indica*, followed by *Eugenia fruticosa*, *Buddleja asiatica*, *Aporosa octandra*, *A. villosa* and *Melicope glomerata*. The most abundant species in site 2 was *Anneslea fragrans* followed by *Wendlandia tinctoria* subsp. *orientalis*, *Lithocarpus polystachyus*, *Macaranga kurzii* and *Eurya acuminata* var. *wallichiana*. Among the most abundant species and highest relative density in uncultivated forest plots were *A. clypearia* var. *clypearia*, *M. kurzii* and *L. polystachyus*, respectively.

Table 1
Studied plots locations and results of vegetation sampling.

Site	1			2			Forest (NF)
Fallow age	1-year (K 1-YF)	3-year (K 3-YF)	6-year (K 6-YF)	1-year (L 1-YF)	3-year (L 3-YF)	6-year (L 6-YF)	
Elevation (m)	1109	1050	1090	1276	1221	1272	1261
Location coordinates	N 18°25′33.1″, E 98°8′20.5″	N 18°26′30.2″, E 98°8′28.7″	N 18°25′59.8″, E 98°7′47.8″	N 18°27′42.2″, E 98°11′31.5″	N 18°28′7.6″, E 98°11′10.8″	N 18°28′4.5″, E 98°11′8.2″	N 18°28′6.4″, E 98°11′9.8″
Tree (in 40 × 80 m^2)							
No. of species	49	77	98	70	69	78	92
No. of trees	3267	3503	2338	3913	4057	3068	4870
Tree density (m^{-2}) (mean ± S.D.)	1.02 ± 0.04	1.09 ± 0.04	0.73 ± 0.01	1.22 ± 0.05	1.26 ± 0.04	0.96 ± 0.02	1.52 ± 0.04
Seedling (4 circular plots, 314.3 m^2)							
No. of species	17	22	33	23	27	32	33
No. of seedling	116	104	294	107	410	459	401
Seedling density (m^{-2}) (mean ± S.D.)	0.37 ± 0.02	0.33 ± 0.02	0.93 ± 0.04	0.34 ± 0.03	1.30 ± 0.11	1.46 ± 0.13	1.27 ± 0.04

Table 2
List of the dominant tree species found in all sampling sites.

Species	Family	Relative density							Relative frequency
		Site 1			Site 2			Forest	
		1-year	3-year	6-year	1-year	3-year	6-year		
1. *Anneslea fragrans*	Theaceae	3.34	1.26	0.34	28.70	0.84	1.24	0.45	1.31
2. *Aporosa octandra*	Euphorbiaceae	2.08	12.76	3.25	8.30	1.63	12.23	0.72	1.31
3. *Aporosa villosa*	Euphorbiaceae	12.79	0.14	2.74	2.96	0.99	6.94	0.29	1.31
4. *Archidendron clypearia* var. *clypearia*	Leguminosae, Mimosoideae	–	–	0.13	0.05	2.59	0.39	23.76	0.94
5. *Buddleja asiatica*	Buddlejaceae	14.88	0.03	0.17	4.52	0.20	–	0.04	1.13
6. *Eugenia albiflora*	Myrtaceae	–	3.40	3.42	0.13	0.89	0.85	2.03	1.13
7. *Eugenia fruticosa*	Myrtaceae	15.89	0.31	0.43	0.03	–	0.10	0.02	1.13
8. *Eurya acuminata* var. *wallichiana*	Theaceae	0.21	0.80	1.45	4.14	12.40	4.30	0.84	1.31
9. *Ficus hirta*	Moraceae	0.06	0.28	1.50	0.66	2.93	0.88	2.69	1.31
10. *Flacourtia indica*	Flacourtiaceae	0.43	27.03	2.01	0.07	0.05	–	–	0.94
11. *Glochidion sphaerogynum*	Euphorbiaceae	3.58	0.43	0.51	1.69	0.67	1.82	1.05	1.31
12. *Lithocarpus polystachyus*	Fagaceae	2.26	6.05	0.47	0.64	4.07	15.71	5.65	1.31
13. *Macaranga denticulata*	Euphorbiaceae	–	0.46	4.79	0.10	4.39	2.35	0.74	1.13
14. *Macaranga kurzii*	Euphorbiaceae	–	–	–	–	14.79	–	15.03	0.38
15. *Melastoma malabathricum* subsp. *normale*	Melastomaceae	4.71	0.06	7.27	8.74	6.73	3.39	1.09	1.31
16. *Melicope glomerata*	Rutaceae	10.93	3.82	1.97	1.92	0.62	7.76	0.62	1.31
17. *Mitragyna hirsuta*	Rubiaceae	–	–	10.35	–	–	–	–	0.19
18. *Schima wallichii*	Theaceae	0.67	0.37	1.93	0.41	3.03	1.56	1.58	1.31
19. *Vernonia parishii*	Compositae	–	0.51	0.17	3.86	2.81	2.28	4.09	1.13
20. *Wendlandia tinctoria* subsp. *orientalis*	Theaceae	0.06	2.03	0.51	3.91	21.27	1.56	2.83	1.31

Table 3
List of the dominant seedling species found in all sampling sites.

Species	Family	Relative density							Relative frequency
		Site1			Site 2			Forest	
		1-year	3-year	6-year	1-year	3-year	6-year		
1. *Aporosa octandra*	Euphorbiaceae	15.52	28.84	11.57	38.32	1.95	0.87	2.99	3.80
2. *Aporosa villosa*	Euphorbiaceae	6.04	2.88	3.74	0.93	0.24	1.74	0.50	3.80
3. *Archidendron clypearia* var. *clypearia*	Leguminosae, Mimosoideae	–	–	16.67	–	–	0.22	49.88	1.63
4. *Buddleja asiatica*	Buddlejaceae	12.93	0.96	–	4.67	0.24	–	–	2.17
5. *Castanopsis diversifolia*	Fagaceae	–	–	–	–	1.71	–	4.49	2.17
6. *Castanopsis tribuloides*	Fagaceae	–	–	0.34	–	0.24	2.83	3.24	1.09
7. *Dalbergia cultrata*	Leguminosae, Papilionoideae	–	5.77	0.34	5.61	–	6.10	–	2.17
8. *Eugenia albiflora*	Myrtaceae	–	–	15.65	–	–	1.53	3.99	1.63
9. *Eurya acuminata* var. *wallichiana*	Theaceae	1.72	–	–	0.93	7.80	0.65	0.50	2.72
10. *Ficus hirta*	Moraceae	2.59	–	0.68	0.93	7.07	1.74	5.24	3.26
11. *Leea indica*	Leeaceae	–	–	13.27	0.93	–	0.44	–	1.63
12. *Lithocarpus polystachyus*	Fagaceae	–	–	0.34	0.93	0.49	53.61	2.49	2.17
13. *Litsea glutinosa* var. *glutinosa*	Lauraceae	0.86	–	–	11.21	–	1.53	–	1.63
14. *Macaranga denticulata*	Euphorbiaceae	–	–	0.68	–	2.20	1.96	0.50	2.17
15. *Macaranga kurzii*	Euphorbiaceae	–	–	–	–	9.27	–	1.75	1.09
16. *Melastoma malabathricum* subsp. *normale*	Melastomaceae	12.07	–	1.02	0.93	3.66	1.31	0.50	3.26
17. *Melicope glomerata*	Rutaceae	17.25	18.26	3.74	0.93	0.98	10.46	1.75	3.80
18. *Symplocos macrophylla* subsp. *sulcata* var. *sulcata*	Symplocaceae	–	0.96	0.34	–	–	0.44	3.74	2.17
19. *Wendlandia scabra* var. *scabra*	Theaceae	–	–	–	–	8.54	–	2.74	1.09
20. *Wendlandia tinctoria* subsp. *orientalis*	Theaceae	–	–	1.02	0.93	47.32	–	0.25	2.72

Species richness and abundance were greater in the seedling communities in site 2 than in site 1 (Table 3). *A. octandra* and *M. glomerata* were the most abundant in the 1-year, 3-year fallow plots of site 1, respectively, while *A. clypearia* var. *clypearia*, *Eugenia albiflora* and *Leea indica* were the most abundant in the 6-year plot. *A. octandra*, *W. tinctoria* subsp. *orientalis* and *L. polystachyus* were the most abundant in the 1-year, 3-year, and 6-year fallow plots of site 2, respectively and *A. clypearia* var. *clypearia* were the most abundant seedlings in the natural forest.

Highest diversity was found in the 6-year fallow of site 1, while the lowest diversity was found in the 1-year fallow (Table 4). Highest evenness was found in the 6-year fallow of site 1, while the lowest evenness was found in the 1-year fallow of site 2. Percent similarity was higher when plots were compared within the same site than when comparing plots between sites (Table 5). Percent

Table 4
Species diversity and evenness of tree species and seedling species (numbers in parentheses) at each site.

Sites	Fallow/plot age	Species richness	Shannon diversity	Evenness
Site 1	1-year	49 (17)	2.78 (2.24)	0.71 (0.86)
	3-year	77 (22)	3.10 (2.78)	0.71 (0.76)
	6-year	98 (33)	3.77 (3.24)	0.82 (0.79)
Site 2	1-year	70 (23)	2.82 (2.01)	0.66 (0.71)
	3-year	69 (27)	2.87 (2.04)	0.68 (0.62)
	6-year	78 (32)	3.28 (2.37)	0.75 (0.58)
Forest		92 (33)	3.13 (2.80)	0.69 (0.51)

Table 5
Percent similarity (Sørensen's index) of tree (and seedling) species among sites (1-year, 3-year, and 6-year fallows, and natural forest).

Site	Fallow age	Karen			Lawa			
		1-year	3-year	6-year	1-year	3-year	6-year	Forest
Site 1	1-year	–	71 (41)	57 (39)	57 (35)	64 (31)	65 (39)	51 (24)
	3-year		–	71 (54)	49 (36)	62 (29)	59 (30)	58 (21)
	6-year			–	54 (33)	66 (37)	67 (58)	60 (41)
Site 2	1-year				–	71 (44)	72 (47)	62 (39)
	3-year					–	71 (51)	71 (72)
	6-year						–	64 (52)

Table 6
Number of tree species of each traditional use type in fallows and natural forest.

Traditional uses	Fallow		Forest	
	Site 1	Site 2	Site 1	Site 2
Edible	20	37	20	31
Medicine	5	5	2	4
Firewood	2	4	7	7
Construction	9	8	4	4
Other	3	2	2	3
Total uses species	30	45	20	36
Multiple uses species	10	18	11	16

Table 7
Percentage of species recorded for traditional uses and percent similarity of uses.

Traditional uses	Percentage of species used		Percent similarity (Sørensen's index)
	Site 1	Site 2	
Edible	17.54	35.24	48
Medicine	1.39	4.76	20
Firewood	1.75	3.81	29
Construction	7.89	7.62	21
Other	2.63	1.90	0
Total uses species	26.32	42.86	50
Multiple uses species	6.14	9.52	12

similarities among paired-plots were lower for seedlings than for trees. However, the 3-year fallow of site 2 and the natural forest showed a high similarity for both tree and seedling species.

Thirty plant species from the fallows and twenty species from the natural forest plot were used in site 1, and 45 and 36 species from site 2, respectively (Tables 6 and 7). Traditional uses include edible food plants, construction timber, medicine, firewood and other uses. Multiple uses species, *i.e.* species that can be used for more than one purpose were also recorded. A comparison of the indigenous knowledge of plant uses by the two villages and other studies is shown in Appendix A.

4. Discussion

4.1. Vegetation in fallow field plots

Cattle browsing on trees and seedlings in the 1-year plot of site 1 created gaps that were invaded by herbaceous weeds such as *Eupatorium adenophorum*, *E. odoratum*, and *Pteridium aquilinum*, which consequently prevented seedling establishment. While tree species richness and diversity decreased in the 3-year plots, tree density was not noticeably higher, despite the fact that the plot was fenced to keep away the cattle. Seedling density was slightly lower, suggesting the effect of invasive weeds filling in gaps in the plot. Another 3-year plot was without any sign of cattle grazing, *i.e.* absence of cattle may be the possible cause of the higher tree and seedling densities. The 6-year fallow plot was characterized by canopy closure, and was dominated by *Mitragyna hirsuta*, and *L. polystachyus*. Site 2 showed many signs of human use. Tree cutting had created gaps favorable for seedling establishment and is most possibly the reason for the higher seedling diversity and density when compared to the 1 and 3-year plots. Tree density, on the other hand, was lower.

4.2. Natural forest

The plot is located close to cultivated fields and fallows of various ages and the forest was found to share many species with the fallows of site 2. *M. kurzii*, which was dominant in these fallows, was also abundant in the natural forest plot. The tree diversity in the natural forest plot was lower than in the 6-year fallow plot, suggesting a higher species accumulation on fallows due to the combination of sprouting trees and trees growing from seeds. This is in agreement with the study of Kennard (2002), who found that tree species richness and stem density in the Bolivian tropical forest was almost twice as much in a successional forest 50 years after shifting cultivation than in a mature forest stand.

4.3. Traditional uses of tree species

The most commonly used tree species belong to the families Euphorbiaceae, Fagaceae, Lauraceae, Myrtaceae, Rutaceae and Theaceae. During sampling, we observed villagers collecting wild food or wood near or inside the study plots. Use indicators (tree stumps, stripped-off bark, broken-off branches) were found more frequently in the older than in the younger fallows. Cutting wood for construction or fuel has a stronger effect on the abundance of useful species in the fallows than uses that involve only the removal of plant parts. This includes the collecting of nuts of tree species from family Fagaceae, including *Castanopsis* spp. and *L. polystachyus* as fodder for cattle and pigs. Collecting and preparing plant medicines is an important component of traditional use of tree species. The traditional use of plants for medicinal purposes has been reported by many studies (Winijchaiyanan, 1995; Schmidt-Vogt, 1999; Yaso, 2000; Trisonthi and Trisonthi, 2009, see Appendix A).

Fewer species from natural forest were used for traditional purposes than from fallows. The exception was firewood, for which 7 species were used from forest and 4 from fallows. This indicates that some usable species can still be found only in natural forest which, therefore continues to play an important role in the livelihood of hill people.

4.4. Traditional ecological knowledge of fallow secondary forest

In the context of our study and due to our focus on forest restoration, we were mainly interested in traditional knowledge relating to regeneration of trees on fallows. Sprouting is considered as the most effective and most common tree regeneration process in shifting cultivation systems. Repeated cycles of cultivation and fallowing, which are characteristic of swiddening favors tree species capable of sprouting over trees that can regenerate only from seeds. Tree species capable of sprouting have an advantage regenerating over most of the seed bearing tree when felled. Regenerating sprouts may substitute for seed dispersal, especially when seed dispersal and seedling establishment is limit (Sakai et al., 1995). Moreover, sprouts often have a higher survival and a faster regrowth rate after fire than seedlings (Bond and van Wilgen, 1996; Miller and Kauffman, 1998; Kennard et al., 2002). Nearly all tree species found in this study had regenerated from stumps, underground stems or rootstocks. Exceptions were *B. asiatica*, *M. denticulata*, and *M. kurzii*. The conspicuous absence of *M. kurzii* in the fallows of site 1 is probably due to lack of sprouting ability combined with human pressure since the tree and its leaves are used for roofing the house and for making containers. Sprouting of trees was particularly dense in 1-year plots, which were still quite open and exposed to sunlight (Everham and Brokaw, 1996).

Our study shows that the abundance of seedlings in the understorey increases as the age of the plot increases, with a small amount of pioneer and climax seedlings in the younger fallows and a higher amount of climax but less pioneer species in the older fallows. This may be successional species turnover similar to the study of van Breugel et al. (2007) where both pioneer and climax species are present in the first phase of succession, but where pioneer species are more abundant. After canopy closure, recruitment of the dominant pioneer species becomes limited, while recruitment of shade-tolerant climax species continues. However, we found indigenous knowledge about understorey seedlings to be less than expected, despite the high density of seedlings in the older fallows. This may be due to the fact that villagers prefer to use older trees that produce resources which can be harvested rather than small seedlings that are shaded by coppicing trees. Villagers identified only a few tree seedling species and described their mechanism of dispersal.

4.5. The role of wildlife in vegetation succession following shifting cultivation

Wildlife, especially birds and small mammals, are connected with trees in many ways, as reported by informant villagers and as discussed in the relevant literature on vegetation succession following shifting cultivation. Especially, birds have been mentioned in many studies to be associated with vegetation succession following shifting cultivation (Raman et al., 1998; Blake and Loiselle, 2001; Raman, 2001; Metzger, 2003; Borges, 2007). Bulbuls, according to our local informants are common frugivorous birds, and we observed them frequently in the plots. Black Bulbul, (*Hypsipetes madagascariensis*) Black-crested Bulbul (*Pycnonotus melanicterus*), Red-whiskered Bulbul (*Pycnonotus jocosus*), and Sooty-headed Bulbul (*Pycnonotus aurigaster*), which occur in a wide range of habitats can eat many kinds of fleshy fruits (Chanthorn, 2002; Sanitijan, 2002; Sanitijan and Chen, 2009). Other species observed and reported by villagers as frugivorous are Barbet (*Megalaima* spp.), Green Pigeon (*Treron* spp.), Junglefowl (*Gallus* spp.), Parakeet (*Psittacula* spp.), and Oriole (*Oriolus* spp.). These birds promote seed dispersal and can speed up the development of structurally complex vegetation (Wunderle, 1997; Clark et al., 2001; Corlett, 2002; Cordeiro and Howe, 2003; Cagan, 2006). Common tree species found in fallow successions, which are eaten by frugivorous birds include *Callicarpa arborea*, *E. fruticosa*, *E. accuminata* var. *wallichiana*, *Macaranga denticulata* and *Rhus chinensis*. Large animal such as elephant and wild cattle have been extirpated from the research sites for many decades. From among mammals, Barking deer, Flying lemur, Wild pig, Squirrels and other rodents were reported by villagers as common fruit-eating wildlife in fallows (see Appendix B).

4.6. Combining traditional knowledge with forest restoration science: implications for participatory forest management

One of the tree species capable of providing both economic and ecological benefits in shifting cultivation systems and forest restoration in Northern Thailand is *M. denticulata* (*Pada*, the name in Skaw Karen, *Tong Coab* in Lawa or *Tong Taeb*, *Tao Maew*, *Por Khee Haed*, in Thai). This small evergreen species has been described in various studies as a fallow-enrichment species (Padoch et al., 2009), mainly on account of its symbiotic association with mycorrhizal fungi, which are essential for soil nutrient accumulation (Youpensuk et al., 2005; Yimyam et al., 2008). Fields established on fallow land with a dense cover of *M. denticulata* support a high productivity of upland rice because of the concentration of nutrients in the fallow biomass, particularly N and K which are released and made available by burning (Yimyam et al., 2003). *M. denticulata* is also an outstanding framework species, which is planted to accelerate forest regeneration and biodiversity recovery by FORRU-CMU. The species is fast-growing and has a wide crown that shades out weeds and creates suitable understorey conditions for seedling recruitment. Its small fruit attract frugivorous birds to promote seed dispersal (FORRU-CMU, 2005).

5. Conclusion

Our study shows that, at least in some areas, where the traditional land use practices of the Lawa and Karen are followed, older fallows have considerable potential for natural forest recovery, provided they are protected from fire and cattle browsing, are close to seed sources and seed dispersal mechanisms across the landscape remain operative. In order to determine how widely our conclusions may apply, further studies and more replication at other locations are needed. There were some similarities between seedling species found in the rotational swidden cultivation fields and those found in the forest restoration plots of FORRU-CMU as the original evergreen forests surrounding them were similar due to similar elevations. This implies that the method of planting pioneer tree species in forest restoration can lead to similar results as the semi-natural regeneration mechanism of the rotational shifting cultivation system practiced by the Karen and Lawa. Farmers of both groups reported also that seed dispersal by frugivorous birds and sprouting ability of trees are crucial for plant regeneration and secondary succession. FORRU-CMU has been restoring degraded areas through the assisted natural regeneration (ANR) method which relies on the sprouting ability of tree species. Information on this ability provided by farmers can be utilized in ANR for selected forest restoration species. Indigenous knowledge focused mainly on edible species, followed by species for medicinal, construction and firewood, respectively. In summary, areas formerly under rotational swidden cultivation to be managed for restoration of the original forest cover, could be achieved by protecting existing fallow forests. Forest restoration of degraded areas through ANR may, on the other hand, benefit from local knowledge on tree regeneration mechanisms of swidden cultivators.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.foreco.2010.07.042.

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