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ORIGINAL PAPER

Mushroom diversity in sustainable shade tea forest and the effect of fire damage

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Abstract A survey of the biodiversity of wild macrofungi, including edible species yields, was carried out from 1 May to 30 September 2007 at four different forest types (in mainly *Miang* tea forest). The plots 100 m^2, comprised a tea garden with a few planted canopy tree species (37.2% canopy cover), a cultivated sustainable tea forest (80.2% canopy cover), an abandoned sustainable tea forest (89.8% canopy cover), and an abandoned sustainable tea forest that had suffered fire damage (72.9% canopy cover). All visible mushrooms were collected during weekly forays. Macro-characters of the fungi were annotated and photographed by digital camera and the fungi were identified to genera and morphospecies (e.g. *Agaricus* sp.1, *Agaricus* sp.2). The fresh weight of wild edible mushrooms produced in the plots was also recorded during this period. The biodiversity of macrofungi in abandoned sustainable tea forest was highest with 115 species in 47 genera, followed by cultivated sustainable tea forest with 85 species in 42 genera and fire damaged abandoned sustainable tea

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forest with 48 species in 25 genera, while only 19 species belonging to 15 genera were found in the tea garden. Twenty-one species belonging to nine genera with a total of 60.9 kg of edible fungi were collected throughout this study. The fresh weight of edible mushrooms was recorded with the highest fresh weight (25.3 kg) collected from the abandoned sustainable tea forest, followed by 18.2 kg in the cultivated sustainable tea forest, while in the fire damaged sustainable tea forest 16.4 kg were collected and only 1 kg was collected in the tea garden. Abandoned sustainable tea forest contained a greater shade tree biodiversity and higher canopy cover than other plots. This area has a generally higher humidity, a greater ground litter cover, a greater number of microhabitats, a greater number of trees that can form mycorrhizal associations and this probably accounts for the higher diversity of macrofungi and production of edible mushrooms. The fire damaged sustainable tea forest had lower mushroom diversity and edible mushroom production possibly due to the loss of litter and lower tree diversity. The tea garden supported a poor diversity of mushrooms and almost no edible mushrooms. Shade tea forest (*Miang* tea forest) is a good method to produce tea in a sustainable way as it maintains diversity of mushrooms and other organisms and could be developed as an alternative to shade coffee.

Keywords Basidiomycetes · Burning · Diversity · Sustainable forestry · Thailand

Introduction

The forests around Chiang Mai and Chiang Rai Provinces are in relatively good condition, partially because of the local tea industry, which occupies over 10,000 hectares. "*Miang* tea" is a fermented product of tea, grown under the forest canopy in a similar way to shade coffee (Keen 1972, 1978). "*Miang*" is the same tea plant as the one producing tea that people drink all over the world. If *Miang* forests could be developed from a local to a more profitable commercial type of tea in the same way as shade coffee, large tracts of forest could be saved from destruction. We need to establish and promulgate the high biodiversity maintained in *Miang* forest that retains a diverse tree over story so that we can use the data to influence policy makers to promote and conserve this sustainable way of life.

Tea (*Camellia sinensis*) is an important economic crop and is grown in monocrop plantations as well as sustainable forests, extensively in northern Thailand (Reichart and Phillipsen 1996). Many existing forests contain undergrowth tea and are the result of *Miang* tea production (Keen 1972, 1978). The *Miang* industry in northern Thailand is mainly a local industry based on individual family units. In 1967 there were about 100 factories producing *Miang*, in approximately 15 villages in Pa Pae sub-district of Mae Taeng District (Chotisukharat 1962), even though only the older generation indulge in *Miang* chewing. With the aging population dying there is reduced demand for *Miang*, and the *Miang* farmers are finding it harder to sell their products.

The existing *Miang* forests could be converted to producing green tea and other tea types in a sustainable way. If the forest were maintained in a sustainable way, and the under story *Miang* production converted to tea production, then the microbial, animal and plant biodiversity would presumably be maintained (Ambinakudige and Sathish 2009). Under story tea production is similar to under story coffee production and is known as "shade coffee" and is a multi million-dollar business (see: http://www.coffeehabitat.com/2009/03/nicaraguan-shade-coffee-finca-esperanza-verde.html). Therefore the term "shade tea" should be applied to tea produced in the under story of the forest and should be promoted, as it is both sustainable and desirable.

During March through to April 2007 northern Thailand was extremely dry and forest fires were rampant. Some fires were reportedly started because the native population believes fires increase mushroom production. Another reason is traditional slash-and burn agriculture which does increase air pollution, but to a much lesser extent than widespread burning of the forests (Moore et al. 2002; Boonyanuphap 2005). This burning resulted in some of the worst air quality ever in Chiang Mai and caused severe health problems.

Much was written in newspapers on the subject and there was extensive government activity. The front pages of newspapers referred to the smoke haze (or smog) caused by forest fires in northern Thailand including Chiang Mai Province (news at Tuesday, March 13, 2007. see: http://www.irrawaddy.org/article.php?art_id=6813). People worried that smoke and haze from the fires would cause health problems (March 13, 2007. see: http://www.spacedaily.com/reports/Thailand_Considers_Declaring_Emergency_Over_Haze_999.html). Chiang Mai and the North suffer from a heavy haze at the outset of the hot season every year, from thousands of fires set by companies and farmers to clear their land for the imminent crop-planting. Similar hazes have occurred in March 2008 and 2009 (http://www.mathaba.net/news/?x=617818 accessed 30 May 2009).

With climate change the situation is likely to get worse and therefore the only way to prevent forests fires reoccurring on such a grand scale may be to develop forests in a sustainable and profitable way, so that villagers protect the forests from fires.

Shade tea forests are not only sustainable but also provide food for the farmers in the form of herbs, insects and edible fungi. The purpose of this study was to (1) compare the macrofungal diversity and edible fungi production in operational and abandoned shade tea forests as compared to a monocrop tea garden in the same region; and (2) establish the effect on burning on macrofungi diversity and edible fungi production in an abandoned burnt shade tea forest.

Materials and methods

Study sites and fungal collection

The study was carried out in Pha Deng Village, Pa Pae sub-district, Mae Taeng District, Chiang Mai Province, Thailand, N 19°07′ 13.7″, E 98°43′ 52, 9″, 850–905 m. (see Fig. 1). The sites were 100^2 plots and comprised an abandoned shade tea plantation, a utilized shade tea plantation, a burnt shade tea area and a monocrop tea plantation. All visible macrofungi were collected from each of the plots weekly during May to October 2007. Macro-characters of the fungi were annotated in the laboratory and fruiting bodies were photographed by digital camera. Fungi were identified to genera and morphotypes (see Hyde 1997) and herbarium specimens are deposited in the Mae Fah Luang University herbarium (MFLU). The fresh weight of edible fungi was also recorded for comparative purposes.

Tea trees was surveyed in each of the plots and calculated as density per 100 m^2. Five random sampling points (each point is 10 m^2) were surveyed in each site and average number of tea plants calculated. The large trees of the shade tea forest were surveyed and recorded using the field guide to forest trees of Northern Thailand (Gardner et al. 2000). Canopy cover was recorded by Forest Suppliers Spherical Crown Densiometers (Spherical Densiometer, Model-A) following the manufacturers instructions.

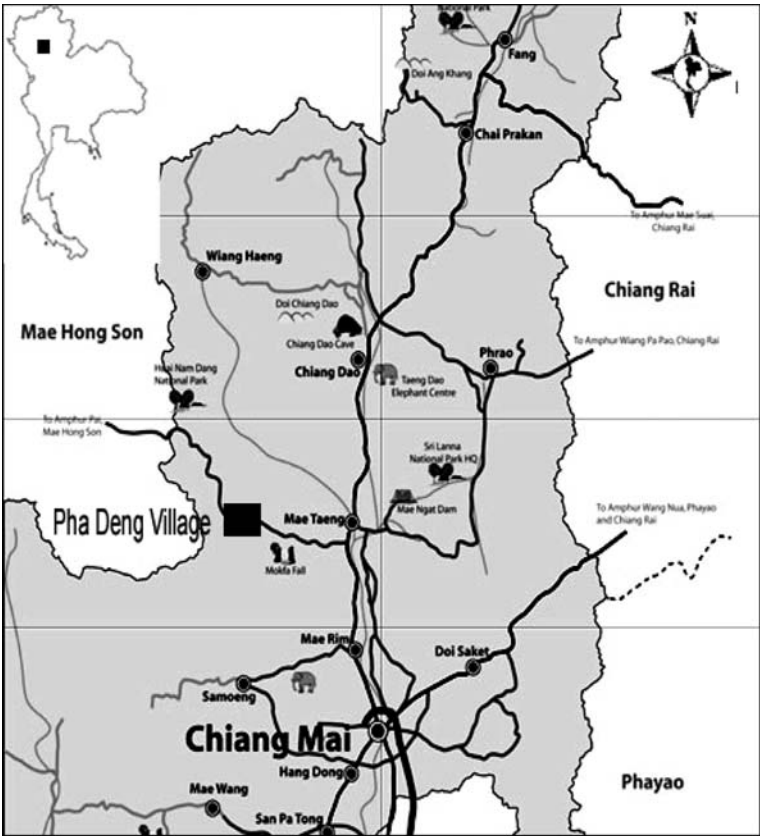

Fig. 1 Map of study area (■ Pha Deng Village, A. Mae Taeng. T. Pa Pae, Chiang Mai, Thailand), the figure from http://www.maps-thailand.com/maps-thailand-files/map_north730x740.gif

The four study plots are *Miang* tea forests and comprised similar plant diversity other than tea garden which had a few planted tree species and was within 700 m of each other.

(1). Tea garden: this area has low tree diversity and canopy cover with 37.2%. This area had been cultivated for more than 10 years, the large trees had been cut and tea trees and few other economic trees were instead cultivated (Fig. 2, Table 1).

(2). Cultivated sustainable tea forest (*Miang* forest): this area comprised under story tea and a few other small trees species. The tea trees were small as they were continually harvested. They were numerous large shade trees with high diversity and high canopy cover (80.2%) as the area was relatively unlogged (Fig. 3, Table 1).

(3). Abandoned sustainable tea forest (*Miang* forest): this area comprised regrowth *Miang* forest which had grown tall since it had been abandoned. There were numerous large shade trees with high diversity as the area was relatively unlogged and had high canopy cover (89.8%). The tea trees had grown tall due to lack of harvesting (Fig. 4, Table 1).

4. Fire damaged sustainable tea area (*Miang* forest): In this area the density of tea had decreased as it had suffered from fires almost yearly during the previous 5 years. Forest

Fig. 2 Tea garden containing tea and economic fruit trees cultivated for more than 10 years comprising Ma-Kwaen (*Zanthoxylum limonella*), mango (*Mangifera indica*), lychee (*Litchi chinensis*) and a few large trees

floor litter such as grass, dead leaves, wood, small trees and soil were burnt, but the larger trees had survived the fire. Canopy cover was 72.9% (Fig. 5, Table 1).

Statistical analysis

Species index was calculated to compare the number of macrofungi from each site. Every species of macrofungi occurring at each site was recorded. The percentage of species occurring at one site was calculated as total species collected at one site multiplied by one hundred and divided by the total species collected at all sites.

Results

The large shade trees of sustainable tea forest (*Miang* forest) surveyed in this study comprised 34 species (Table 1), but the dominant species were *Castanopsis tribuloides, Diospyros glandulosa, Heynea tijuga, Lithocarpus thomsonii, L. elongan, Melia toons-endan, Microcos paniculata, Schima wallchii* and *Toona ciliata*. The greatest diversity of shade trees occurred in the abandoned sustainable tea forest with 27 species, followed by the cultivated sustainable tea forest and fire damaged sustainable tea forest with 25 and 19 species respectively. In the tea garden only 6 canopy species were present and these were not native species and included Ma-Kwaen (*Zanthoxylum limonella*), mango (*Mangifera indica*), lychee (*Litchi chinensis*) and small number of large trees such as *Toona ciliata* and *Zanthoxylum limonella.* Tea tree distribution in 4 plots also differed with 700 t/100 m^2 in the tea garden, 310 t/100 m^2 in abandoned sustainable tea forest, 194 t/100 m^2 in the fire damaged sustainable tea forest and 164 t/100 m^2 in the cultivated sustainable tea forest (Table 2). The small tea trees in the fire damaged sustainable tea forest died following the fire, but the larger tea trees had survived.

Production of wild mushrooms in the plots

The end of April or early May is the beginning of rainy season in northern Thailand (Table 3) and soon after the rains begin, mushrooms proliferate and macrofungi could be collected from every plot. During the survey we identified 150 taxa of macrofungi

Table 1 Shade trees occurring in the study plots

Trees species	Fire damaged sustainable tea forest	Cultivated sustainable tea forest	Abandoned sustainable tea forest	Tea garden
Adenanthera microsperma	+	+	+	−
Alangium kurzii	+	+	+	−
Bacaurea ramiflora	+	+	+	−
Canthium glabrum	+	+	+	−
Castanopsis tribuloides	+	+	+	−
Chionanthus ramiflorus	+	+	+	−
Cinnamomum iners	+	+	+	−
Clausena excavata	−	−	+	−
Cratoxylum formosum	−	−	+	−
Diospyros glandulosa	−	+	+	−
Elaeocarpus floribundus	+	+	−	−
Fernandoa adenophylla	−	+	−	−
Ficus benjamina	+	−	+	−
Ficus tonanatoria	−	−	+	
Gnetum leptostachyum	+	+	+	+
Gluta obolata	+	+	+	−
Heynea tijuga	+	+	+	+
Lagerstroemia tomentosa	−	+	+	−
Litchi chinensis	−	−	−	+
Litrocarpus thomsonii	+	+	+	−
Lithocarpus elongan	+	+	+	−
Mangifera indica L.	−	−	−	+
Melia toonsendan	+	+	+	−
Mallotus paniculatus	−	+	−	−
Microcos paniculata	+	+	+	−
Michelia baillonii	+	+	+	−
Markhamia stipulata	−	+	−	−
Prunus arborea	−	−	+	−
Rhus rhetsoides	−	+	+	−
Schima wallchii	+	−	+	−
Sapidus rarak	−	+	+	−
Suregata multiflora	−	+	+	−
Toona ciliata	+	+	+	+
Zanthoxylum limonella	−	−	−	+
Total species	19	25	27	6
Canopy cover (%)	72.9	80.2	89.8	37.2

belonging to 55 genera in 29 families. The biodiversity of macrofungi in the abandoned sustainable tea forest was highest with 115 species in 47 genera, followed by cultivated sustainable tea forest with 85 species in 42 genera. There were 48 species in 25 genera in the fire damaged sustainable tea forest and 19 species belonging to 15 genera in the tea garden, the latter being far lower than the other plots. The diversity of macrofungi

Fig. 3 Cultivated sustainable tea forest (*Miang* forest) which comprises mostly small and a few large tree species)

Fig. 4 Abandoned sustainable tea forest (*Miang* forest) with tall tea trees under larger canopy trees

Fig. 5 Fire damaged sustainable tea area (forest floor with dead wood and small living trees are burnt and include tea trees)

identified each month was consistently higher in the abandoned sustainable tea forest, followed by the cultivated sustainable tea forest and the fire damaged sustainable tea forest, and always lowest in the tea garden with 46, 36, 31 and 7 species identified respectively in May, 60, 36, 24 and 7 species in June, 53, 27, 15 and 7 species in July, 44, 32, 11 and 5 in August and 26, 16, 3 and 3 species in September (Table 2, Fig. 6).

Comparison of wild mushroom production in different plots and the diversity indices

The most common genera in all sites were *Agaricus, Amanita, Auricularia*, *Leucoagaricus*, *Laccaria*, *Microporus* and *Schizophyllum*, while *Amanita*, *Amanitopsis*, *Boletus, Boletinus*,

Table 2 Macrofungal diversity during the experimental period compared with number of tea trees, tree species and canopy cover

Items	Fire damaged sustainable tea forest					Cultivated sustainable tea forest					Abandoned sustainable tea forest					Tea garden				
	M	Jun	Jul	Aug	Sep	M	Jun	Jul	Aug	Sep	M	Jun	Jul	Aug	Sep	M	Jun	Jul	Aug	Sep
Number of species identified	31	24	15	11	3	36	36	27	32	16	46	60	53	44	26	7	7	7	5	3
Total collections (species)	63	42	18	11	2	70	49	36	45	20	94	104	81	58	30	10	13	7	6	3
Percent of occurred species (%)	17.85					28.87					48.16					5.118				
Canopy tree species (species)	19					25					27					6				
Canopy cover (%)	72.9					80.2					89.8					37.2				
Tea density (t/100 m^2)	194					164					310					700				

Table 3 Temperature (°C) and rainfall (mm) of Chiang Mai Province 2008

Statistic	Month											
	Jan	Feb	Mar	Apr	M	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max-Temperature (°C)	29	32	34	36	34	32	31	31	31	31	30	28
Min-Temperature (°C)	13	14	17	22	23	23	23	23	23	21	19	15
Rainfall (mm)	7	5	13	50	158	132	161	236	228	122	53	20

http://www.wordtravels.com/Cities/Thailand/Chiang+Mai/Climate

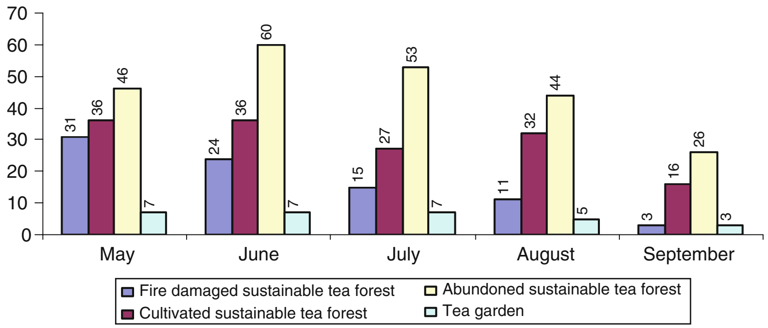

Fig. 6 Diversity of macrofungi (species) collected during May to September

Filoboletus, *Ganoderma*, *Inocybe*, *Laccaria*, *Lentinus*, *Russula*, *Scleroderma*, *Strobilomyces* and *Termitomyces* were common genera found in the fire damaged sustainable tea forest, cultivated sustainable tea forest, the abandoned sustainable tea forest, but absent in the tea garden. The genera *Alpova, Bolbitus, Chlorophyllum, Greastum, Macrolepiota, Psathyrella* and *Volvariella* were only identified in cultivated sustainable tea forest. *Camarophyllus, Heimiomyces, Hypholoma Hygrocybe, Hygrophorus, Marasmius, Oudemansiella, Pulverobolitus* and *Xerula* were only collected in the abandoned sustainable tea forest.

The diversity index for macrofungi was highest in undisturbed tea forest, followed by disturbed tea forest, burnt tea forest and tea garden being 4.47, 4.14, 3.64 and 2.76 (Shannon Index) and 0.98, 0.97, 0.96 and 0.91 (Simpson index) respectively (Table 4). The highest percentage of occurrence frequency of ten species was *Auricularia* sp.1, *Auricularia* sp.2, *Laccaria* sp.1, *Boletinus* sp., *Russula* sp.13, *Leucocoprinus* sp.1, *Russula* sp.2, *Trogia* sp.1, *Laccaria* sp.2 and *Filobolitus* sp.1 being 5.51, 4.46, 2.62, 2.49, 2.36, 2.23, 1.97, 1.97, 1.84 and 1.84 percent respectively (Table 5, Fig. 7).

Table 4 Data analysis of Shanon and Simpson Index of 4 sites

Plots	Fungi species	Individuals	Shannon index	Simpson index
Fire damaged sustainable tea forest	49	136	3.64	0.96
Cultivated sustainable tea forest	83	220	4.14	0.97
Abandoned sustainable tea forest	116	367	4.47	0.98
Tea garden	19	39	2.76	0.91

Table 5 Highest percentage of occurrence frequency of ten species

Species	Total of occurrence time throughout study	Occurrence frequency (%)
Auricularia sp.1	42	5.51
Auricularia sp.2	34	4.46
Laccaria sp.1	20	2.62
Boletinus sp.	19	2.49
Russula sp.13	18	2.36
Leucocoprinus sp.1	17	2.23
Russula sp.2	15	1.97
Trogia sp.1	15	1.97
Laccaria sp.2	14	1.84
Filoboletus sp.1	14	1.84

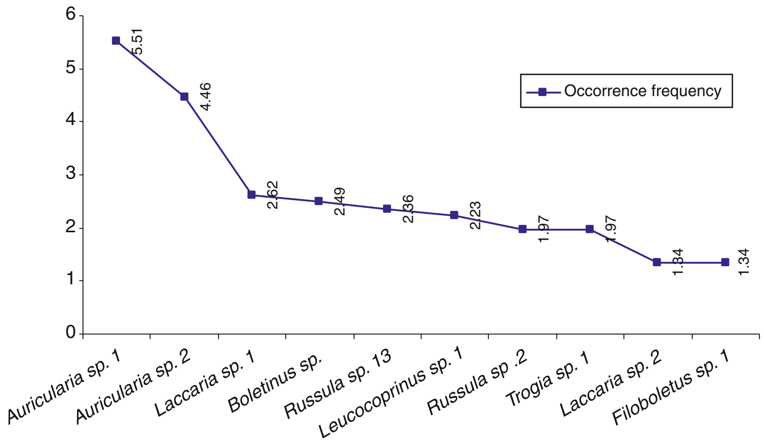

Fig. 7 Percentage occurrence of ten most frequent species (%)

Production of edible fungi in the plots

The occurrence of edible fungi over the wet season varied from month to month. In late May, Hed Torp (*Astraeus hygrometricus*) appears in large numbers but as they occur underground they were not reported in this study. Twenty-one species of edible fungi belonging to 9 genera were collected throughout this study, yielding a total of 60.9 kg. The fresh weight of edible fungi (25.3 kg) was highest in the abandoned sustainable tea forest, followed by 18.2 kg in the cultivated sustainable tea forest, while 16.4 kg were collected from the fire damaged sustainable tea forest and only 1 kg was collected from the tea garden. In May the fresh weight of macrofungi was highest (9.5 kg) from the abandoned sustainable tea forest, followed by 9 kg in the cultivated sustainable tea forest, 7 kg in the fire damaged sustainable tea forest, with no collections from the tea garden. Similar trends occurred throughout July to August although fewer edible macrofungi were collected and in September edible fungi were rarely collected (Table 6, Fig. 8).

Some species occurred throughout the rainy season (e.g. *Auricularia* sp.1, *Auricularia* sp.2, *Lentinus* sp.2) while some species were found at the beginning to middle of the

Table 6 Fresh weight of wild edible fungi collected in this study (kg)

Fungi	Fire damaged sustainable tea forest (kg)						Cultivated sustainable tea forest (kg)						Abandoned sustainable tea forest (kg)						Tea garden (kg)					
	M	J	JL	AU	Sep	Total	M	J	JL	AU	Sep	Total	M	J	JL	AU	Sep	Total	M	J	JL	AU	Sep	Total
Alpova sp.							0.5				0.1	0.6												
Amanita sp.2	0.4					0.4		0.1				0.1	1.1	0.4				1.5						
Amanita sp.3							0.8			1		1.8	1	0.2		0.6		1.8						
Amanita sp.4							1.2					1.2												
Auricularia sp.1	0.9	1.3	0.9	0.3		3.4	0.9	1.1	1.4	0.4	0.1	3.9	1.1	1.7	1	0.6	0.1	4.5			0.3			0.3
Auricularia sp.2	0.7	1	0.4	0.2		2.4	1	1.2	0.4	0.5		3.1	1.1	1.2	0.6	0.4	0.1	3.4						
Boletus sp.2		0.9				0.9	1,6		0.8	0.5		2.9												
Citocybe sp.	0.3	0.3				0.6							1.4	0.6				2			0.2			0.2
Lentinus sp.1	0.5					0.5																		
Lentinus sp.2														2.8	1.4	0.4		4.6						
Lentinus sp.3	0.2	0.2				0.4							0.2	0.2				0.4						
Russula sp.2	1.9	0.7				2.6	1.2	0.3				1.5	1.4	0.6				2						
Russula sp.3	0.4					0.4	1.6					1.6	0.6					0.6						
Russula sp.4	0.7	0.1				0.8		0.1				0.1	0.9	0.2				1.1						
Russula sp.6	1	0.7				1.7							0.7					0.7						
Russula sp.8		1.2				1.2																		
Schizophyllum sp.		0.9				0.9		0.8				0.8		1.6				1.6		0.2				0.2
Termitomyces sp.1							0.2					0.2												
Termitomyces sp.2			0.2			0.2			0.2						0.4			0.4			0.2			0.2
Termitomyces sp.3				0.1		0.1				0.3		0.3				0.3		0.3						
Termitomyces sp.4										0.1		0.1				0.1		0.1			0.1			0.1
Total	7	7.3	1.5	0.6	0	16.4	9	3.6	2.8	2.8	0.2	18.2	9.5	9.5	3.4	2.4	0.2	25.3	0	0.2	0.8	0	0	1

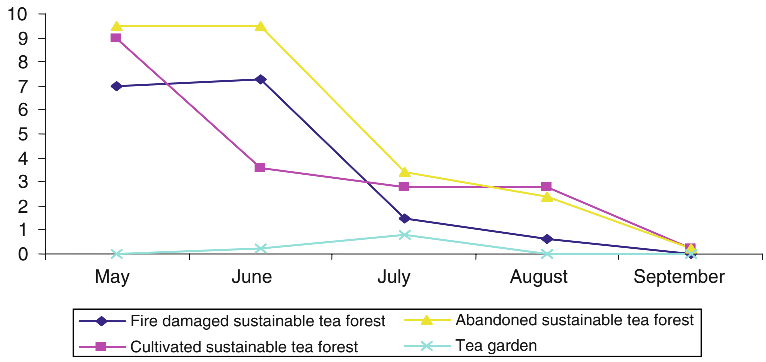

Fig. 8 Fresh weight of wild edible fungi collected during May to September 2007

season (May to July) such as *Amanita* sp.2, *Boletus* sp.2, *Lentinus* sp.3 and *Russula* spp., and some species only occurred in the middle of the season, such as *Termitomyces* spp. (Table 6).

Discussion

There are limitations to the methodology used in this study. Firstly it was impossible to select sites with identical shade tree species and the history and use of each plot would not have been identical. However, the overall trend in results can be used to show the effects of the tea tree numbers, shade tree diversity, canopy cover and land use on macrofungal diversity in the plots and the yields of edible fungi.

Abandoned sustainable tea forest contained a greater number of tea bushes than the cultivated sustainable tea forest. The tree canopy in the abandoned sustainable tea forest was much better developed with 27 shade tree species and 89.8% canopy cover as compared to 25 shade trees in the cultivated sustainable tea forest with 80.2% canopy cover. The reason for the higher diversity of macrofungi in the abandoned sustainable tea forest is likely to be because (1) there are more substrates on forest floor such as dead leaves and decaying wood that can support saprobic fungi (Orchard 1996), (2) the humidity is higher because of the greater canopy cover which will enhance fungal growth (Svrček 1977), and (3) the number of hosts that can form mutualistic associations with mycorrhizal fungi is higher (Svrček 1977). Most new species of fungi in the area of the cultivated sustainable tea forest (Mushroom Research Centre) have been described from relatively undisturbed forest (Le et al. 2007a, b; Stubbe et al. 2008; Lodge and Ovrebo 2008; Sanmee et al. 2008; Kerekes and Desjardin 2009; Wannathes et al. 2008a, b). The fire damaged sustainable tea forest supported 19 shade tree species with 72.9% canopy cover and had been accidentally burnt most years during the previous 5 years. Forest floor litter such as grass, dead leaves, wood, small trees and soil were burnt, but the larger trees had survived. For the above three reasons fungal diversity here was lower. Finally the tea garden had poor canopy cover (37.2%) and almost no shade tree diversity and thus a very low fungal diversity was observed.

Shade tree diversity and forest canopy cover is therefore important in maintaining high fungal diversity and high production of edible fungi and therefore important in providing a food source and income to the local villagers. Similarly the high shade tree biodiversity and high canopy cover will provide habitats for most wildlife and plants ranging from microorganisms to mammals and birds (Johnson et al. 2006; Balia et al. 2007; Sekercioglu et al. 2007; Ukmar et al. 2007). A higher organism biodiversity is maintained with high tree diversity and canopy cover as has been shown in the case of shade coffee (López-Gómeza et al. 2007).

Miang forest is representative of several regions in northern Thailand such as Chiang Rai and Mae Hong Son Provinces and Chiang Dao, Doi Saket, Fang, Mae Ey, Mae Jam, Mae On, Mae Rim, Mae Taeng, Prao and Sa Muang district of Chiang Mai Province (Reichart and Phillipsen 1996). There were about 100 factories producing Miang, in approximately 15 villages in Pa Pae sub-district of Mae Taeng district, with one factory in Pha Deng Village where this study was carried out (Chotisukharat 1962). Disturbance and damage to each plot differed, however, the diversity of fungi and yield of edible fungi did not depend on tea concentration, but depended upon shade tree species diversity and canopy cover. The land use patterns of *Miang* tea forests has been recognized as a form of sustainable forestry by Sasaki et al. (2005), who examined *Miang* land use, recognized the *Miang* village as an indigenous agroforestry system that is well suited to high altitude areas of northern Thailand. Highly diverse and healthy forest with high animal and plant diversity have also been maintained, unlike in some other areas of Thailand where forest has been destroyed due to agriculture (Sathaporn 1999).

Local villagers' depend on the forest for food resources and it is believed that fires stimulate the growth of mushrooms and wild vegetables (Nugen 1999). However, there are also many detrimental affects to burning forest. These include decreasing vegetation and wildlife in the ecologically diverse and rich forest environments (Perlis et al. 2002). This study does not support the hypothesis that burning forests stimulates the growth of edible fungi as the yield of edible fungi in the fire damaged site throughout the study was much lower than in the cultivated and abandoned sustainable tea forest (Table 6, Fig. 8). It is thought that burning forests may stimulate the formation of some fungal species (e.g. *Astraeus hygrometricus*), but overall it reduces the yield and biodiversity of mushrooms and should be discouraged. There is also no evidence that burning increases the yield of *Astraeus hygrometricus*. The ectomycorrhizal fungi might be able to survive under the soil with the tree roots, however the saprobic fungi are killed when the substrate on which they grow are burnt (Svrček 1977).

One phenomenon that may account for the belief that a greater yield of edible fungi are produced after burning forests, may be that it is more easy to observe and collect samples on the ground of burnt forest. For example, collectors can find *Astraeus hygrometricus* more easily. These dark brown mushrooms are half-hidden in the soil and it is difficult to find them on the ground especially when litter is present (Ruksawon et al. 2001). *Astraeus hygrometricus* are not grown commercially and are favored by many northern Thai and thus command a high price in the market (http://www.apafri.org/8thdip/Session%203/S3_Dell.doc). This species is ectomycorrhizal and associated with higher plants including *Alnus*, *Castanea*, *Eucalyptus* and *Pseudotsuga* and grow in the forest floor and proliferate up at beginning of rainy season (Phosri et al. 2004; Trappe 1967; Molina 1979; Malajczuk et al. 1982; Nouhra and Dominguez De Toledo 1998). If collectors raked away the leaf litter they can more easily locate the fungi and we suspect yields of *Astraeus* would be higher. More importantly if collectors raked the ground litter back above the exposed ground, the yield of other fungi including edible fungi should be much higher than if the forest was burnt. Luoma et al. (2006) compared mushroom numbers and wet weight yield of *T. magnivelare* (American Matsutake) among treatments where leaf litter was raked above Matsutake fairy rings and not replaced, areas where mushrooms were harvested with minimal disturbance and non-harvested, non-disturbed controls. It was significant that the number and wet weight yield of Matsutake in control treatments was higher than raked and replaced treatments, and raked and non-replaced treatments respectively.

Conclusion and recommendations

This study has shown that the diversity of shade tree species, the extent of canopy cover and land use directly influences macrofungal diversity and edible mushroom yield in the following ways.

1) If tea is grown without canopy cover the diversity of macrofungi is low and the yield of edible fungi is very low.
2) If forests suffer fire damage the diversity of macrofungi and the yield of edible fungi is lower.
3) If the shade tree diversity is higher then the diversity of macrofungi and yield of edible fungi is also higher.
4) If the canopy cover is higher then the diversity of macrofungi and yield of edible fungi is also higher.

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