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Ground Cover Vegetation of Litchi Orchards in Relation to Land Use Intensity in Mountainous Northern Thailand

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Abstract: In mountainous northern Thailand, former swidden farming systems have become increasingly transformed into permanent agricultural land, which is mainly used for litchi (*Litchi chinensis* Sonn., Sapindaceae) cultivation. Plant species composition of the ground cover vegetation of litchi orchards was analyzed in the vicinity of two Hmong villages (Chiang Mai Province) implementing land use at different intensities. From the 49 litchi orchards (148 relevés) studied, a total of 275 plant species (predominantly annual pioneers) was recorded. Two major groups of orchard vegetation were separated by TWINSPAN classification, which corresponded with the sites related to the two villages. Further paired subdivisions were mainly related to the proportions of exotic and native species and life form composition among the species with the highest positive fidelity values. The differences between groups can largely be explained by factors of land use intensity and management, such as the duration of cultivation and the frequency of herbicide use and mowing. Knowledge on the relationships between management and composition of the ground cover vegetation in litchi orchards may contribute to the identification of appropriate strategies to promote ecological sustainability of land use in mountainous northern Thailand.

Key words: Management, succession, plant species composition, TWINSPAN

INTRODUCTION

The vegetation of Thailand has been influenced by human activities for millennia (White *et al*., 2004). According to a current estimation, only 15% of the original forest cover of the country now remains (Maxwell, 2004) whereas the area of agricultural land in Thailand almost doubled between 1961 and 2002. Former swidden farming systems are being increasingly transformed into permanent cropland due to limited land resources and shifts from small scale subsistence farming to market-oriented agriculture. In Chiang Mai Province, northern Thailand, arable land at elevations between 300 and 1300 m asl is now prevalently used for cultivation of litchi (*Litchi chinensis* Sonn.). About 80% of Thailand's litchi plantations are located in the mountainous regions in the northern provinces (Subhadrabandhu and Yapwattanaphun, 2001). Litchi orchards are characterized by permanent ground cover vegetation, which is influenced by various management practices. These include mowing, herbicide application, fertilization during the fruit growing season and irrigation in the dry season. A further factor is overhead shade, which is related to the size and stand density of the trees and to the extent of pruning.

Surveys of vascular plant associations have mainly focused on forest vegetation and croplands (Parnell *et al*., 2003), such as succession of rice based swidden farming systems (Schmidt-Vogt, 1999) or weeds of annual cropping systems such as soybean fields (Radanachaless and Maxwell, 1994).

Analyses of the vegetation of other land use systems such as fruit orchards were largely neglected in botanical surveys of Thailand. We, therefore, conducted a study to contribute to the knowledge of the ground cover vegetation of litchi orchards in mountainous northern Thailand. The specific objectives were to identify species composition and to classify the ground cover vegetation in litchi orchards of different management and land use intensity related to the practices of two Hmong villages.

MATERIALS AND METHODS

Study area: The study was conducted in the Doi Suthep-Pui National Park (18°50' N and 99°0' E, Chiang Mai Province, northern Thailand). The terrain is mountainous and much of the original forest cover has been degraded for subsistence and cash crop farming. The forest cover below c. 1000 m is mainly deciduous, while above this it is evergreen (Maxwell and Elliot, 2001).

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The climate of northern Thailand has three distinct seasons, viz., cool-dry (November-March), hot-dry (March-May) and rainy (May-October). Rainfall at the study sites is none to sparse during December-February and peaks to an average of 255 mm in September (The Uplands Program, 2005, unpublished data). The average annual rainfall in the area is 1334 mm (The Uplands Program, 2005, unpublished data). The warmest month is May with an average mean temperature of 25.0°C, while the coldest month is December with an average mean temperature of 17.4°C.

The soils in the study sites are mainly Acrisols and Cambisols (Schuler, 2005, unpublished data) and are generally characterized by medium to low fertility and a slightly acidic pH value (Vlassak *et al*., 1992). Soil quality has been degraded by land use practices and continuous cultivation.

The study sites were located between 690 and 1300 m asl in the vicinity of two Hmong villages, which are (a) Doi Pui village in the relatively small Mae Tha Chang valley, c. 11.5 km from Chiang Mai in the southern part of the National Park and (b) Mae Sa Mai village in the larger Mae Sa valley, c. 16.5 km from Chiang Mai in the northern part of the National Park.

Rotational agriculture is no longer practiced by farmers of the two Hmong villages and both do not have any significant sustainable subsistence cropping. The villagers of Doi Pui rely on litchi production for their main cash crop, whereas litchi, cabbage varieties, carrot and white radish are the main cash crops at Mae Sa Mai. Due to size and population differences, the intensity of agricultural land use and management of Doi Pui village is considerably lower compared to Mae Sa Mai village. The extent and quality of the forest cover is better, i.e., more diverse and less fragmented, at Doi Pui village than at Mae Sa Mai village.

Field methods: Field studies were conducted in two separate surveys near the two villages. At Mae Sa Mai village, vegetational studies were conducted at 21 different plots from November -December 1998 and at Doi Pui village at 45 different plots from September- November 2000. The locations included a total of 49 litchi orchards which differed according to a variety of factors, such as the frequency of herbicide application (none to two times per year), manual mowing (one to three times per year), the age of the orchards and the surrounding land use types. For comparisons, a total of 17 other vegetation plots were studied. These included two jackfruit (*Artocarpus heterophyllus* Lmk.) orchards at Mae Sa Mai village and three abandoned litchi orchards, two abandoned tea (*Camellia sinenesis* (L.) Kuntze) fields, one abandoned corn field, one ruderal site between two litchi orchards, one ruderal site adjacent to a planted *Pinus keysia* Roy. *ex* Gord. forest as well as 7 locations in differently structured hardwood forests at Doi Pui village.

The appropriate size for vegetation samples (relevés) was determined by consideration of the recommendations by Ellenberg (1956) and with help of species-area curves (Cain, 1938), resulting in relevé sizes of 20-25 m². Three stochastically distributed and homogeneous relevés were analyzed per location (exception: one litchi orchard with four relevés). In order to avoid inhomogeneous and partially scarce vegetation cover, only areas outside the crown cover of the trees were selected as relevé sites. Species quantities were measured with cover-abundance scales of the Braun-Blanquet method (Müller-Dombois and Ellenberg, 1974). All plants were identified by J.F. Maxwell (CMU Herbarium, Chiang Mai University, Chiang Mai, Thailand). Species names and authorities are given according to the nomenclature of the CMU Herbarium, Chiang Mai University, Chiang Mai, Thailand. Specimens collected by Wehner and Chamsai are deposited in the CMU Herbarium.

Data analyses: Preparation of synoptic tables and calculation of fidelity measures was performed by JUICE 6.3 (Tichý, 2002). For comparisons of fidelities calculated in datasets of different size, phi coefficient (Sokal and Rohlf, 1995) was implemented for species-specific measure of fidelity (Chytri *et al*., 2002). Random values in the data array were excluded by Fisher's exact test (Sokal and Rohlf, 1995). Levels of significance were $p<0.001$ for the condensed TWINSPAN dendrogram of Fig. 1 and $p<0.05$ for species included in calculation of Table 2.

TWINSPAN (Two-way indicator species analysis; Hill, 1979) function of JUICE was applied to obtain distribution patterns of the ground cover plant species. Relevés (n = 199) from all locations were included in the analysis and fidelity measures were used to identify characteristic plant species. Species with a frequency of less than 3% were excluded from the analysis (289 remaining species). Six pseudo species cut levels of 0, 2, 5, 20, 50, 75 were established in order to maintain the Braun-Blanquet categories in TWINSPAN. Cover-abundance scales r and + were combined, because rare species were of low significance for vegetation characterization. All remaining setting possibilities of TWINSPAN were set to default values.

RESULTS

A total of 275 plant species of 65 families were recorded from the 148 relevés of litchi orchards. The most

Table 1: Characteristics, percentage constancy and frequency of dominance of plant species with percentage constancies of >10 recorded from the 49 litchi orchards

Plant species	Family	Characteristics	Percentage constancy (%)	Frequency of dominance (%)
Ageratum conyzoides L.	Asteraceae	a/h/pi	95	41
Crassocephalum crepidioides (Bth.) S. Moore	Asteraceae	a/h/pi	78	11
Mitracarpus villosus (Sw.) DC.	Rubiaceae	a/h/pi	77	20
Conyza sumatrensis (Retz.) Walk.	Asteraceae	b/h/pi	77	12
Digitaria setigera Roth *ex* Roem. & Schult.	Poaceae	a/gp/pi	76	11
Bidens pilosa L.	Asteraceae	a/h/pi	69	9
Spilanthes paniculata Wall. *ex* DC.	Asteraceae	a/h/pi	64	12
Borreria laevis (Lmk.) Griseb.	Rubiaceae	a/h/pi	57	0
Imperata cylindrica (L.) P. Beauv.	Poaceae	pe/gp/pi	55	21
Euphorbia hirta L.	Euphorbiaceae	a/h/pi	55	1
Eupatorium odoratum L.	Asteraceae	a/h/pi	47	5
Synedrella nodiflora (L.) Gaertn.	Asteraceae	a/v/pi	43	11
Melinus repens (Willd.) Zizka	Poaceae	a/gp/pi	43	8
Cyperus cyperoides (L.) O.K.	Cyperaceae	a/gc/pi	41	1
Pennisetum polystachyon (L.) Schult.	Poaceae	pe/gp/pi	39	6
Torenia violacea (Aza. *ex* Blanco) Penn.	Scrophulariaceae	a/h/pi	36	1
Arthraxon lancifolius (Trin.) Hochr.	Poaceae	a/gp/pi	28	14
Cyperus kyllingia Endl.	Cyperaceae	a/gc/pi	28	4
Eleusine indica (L.) Gaertn.	Poaceae	pe/gp/pi	28	0
Cyrtococcum accrescens (Trin.) Stapf	Poaceae	a/gp/pi	26	7
Murdannia nudiflora (L.) Bren.	Commelinaceae	a/h/pi	24	1
Dioscorea glabra Roxb.	Dioscoreaceae	pe/v/sg	22	0
Euphorbia heterophylla L.	Euphorbiaceae	a/h /pi	22	0
Salvia riparia Kunth	Lamiaceae	pe/h/pi	21	5
Fimbristylis dichotoma (L.) Vahl	Cyperaceae	a/gc/pi	20	1
Oxalis corniculata L.	Oxalidaceae	a/h/pi	20	0
Paspalum scrobiculatum L.	Poaceae	pe/gp/pi	18	3
Peperomia pellucida (L.) H.B.K.	Piperaceae	a/h/pi	18	3
Lysimachia peduncularis Wall. *ex* Hk. f.	Primulaceae	a/h/pi	18	0
Digitaria bicornis (L.) Roem. & Schult.	Poaceae	a/gp/sg	15	4
Spilanthus iabadicensis A. H. Moore	Asteraceae	a/h/pi	14	2
Paspalum conjugatum Berg.	Poaceae	a/gp/pi	14	1
Emilia sonchifolia (L.) DC. *ex* Wight	Asteraceae	a/h/pi	14	0
Lygodium flexuosum (L.) Sw.	Schizeaceae	pe/fe/sg	13	0
Pteris biaurita L.	Pteridaceae	pe/fe/sg	13	0
Adiantum philippense L.	Pakeriaceae	pe/fe/fo	12	0
Digitaria violascens Link	Poaceae	a/gp/pi	12	0
Dioscorea bulbifera L.	Dioscoreaceae	pe/v/sg	12	0
Eragrostis amabilis (L.) Nees	Poaceae	a/gp/pi	12	0
Crotalaria dubia Grah. *ex* Bth.	Fabaceae	a/h/fo	11	1
Mucuna bracteata A. DC.	Fabaceae	a/v/pi	11	1
Chloris nodosa Sw.	Poaceae	pe/gp/pi	11	0
Cyperus cuspidatus Kunth	Cyperaceae	a/gc/pi	11	0
Lindernia crustacea (L.) F. Muell.	Scrophulariaceae	a/h/pi	11	0
Paederia pallida Craib	Rubiaceae	a/v/sg	11	0
Commelina paludosa Bl.	Commelinaceae	pe/h/pi	10	2
Blumea lacera (Burm. f.) DC.	Asteraceae	a/h/pi	10	0
Dioscorea alata L.	Dioscoreaceae	pe/v/sg	10	0
Spatholobus suberectus Dunn	Fabaceae	pe/wc/fo	10	0

Categories of species characteristics are: a = annual, b = biennial, pe = perennial, h = herbaceous, fe = fern, gc = graminaceous (Cyperaceae), gp = graminaceous (Poaceae), v = vine, wc = woody climber, pi = pioneer, sg = secondary growth species, fo = forest species. Percentage constancy expresses the species specific frequency in relation to the number of relevés. Frequency of dominance values represent the percentage frequency of relevés, in which the species cover exceeded the 10% dominance threshold (Mühlenberg, 1993)

species rich families were Poaceae (42 species), Asteraceae (26 species) and Fabaceae (25 species). Along with Rubiaceae (15 species), Cyperaceae (11 species) and Euphorbiaceae (11 species), theses families included nearly half (47%) of all recorded species. The major species of ground cover vegetation in the selected litchi orchards, their characteristics, constancy and frequency of dominance are listed in Table 1. Mainly annual herbaceous and some graminaceous (Cyperaceae and Poaceae) plant species reached high percentage constancy levels (>50%). *Ageratum conyzoides* L. reached the highest constancy level (95%) and was by far most prevalently dominant (degree of cover >10% according to Mühlenberg, 1993). Although showing mostly percentage constancy levels of <50%, some graminaceous species such as *Imperata cylindrica* (L.) P. Beauv. and *Arthraxon lancifolius* (Trin.) Hochr. reached high frequencies of dominance. Most vines and woody

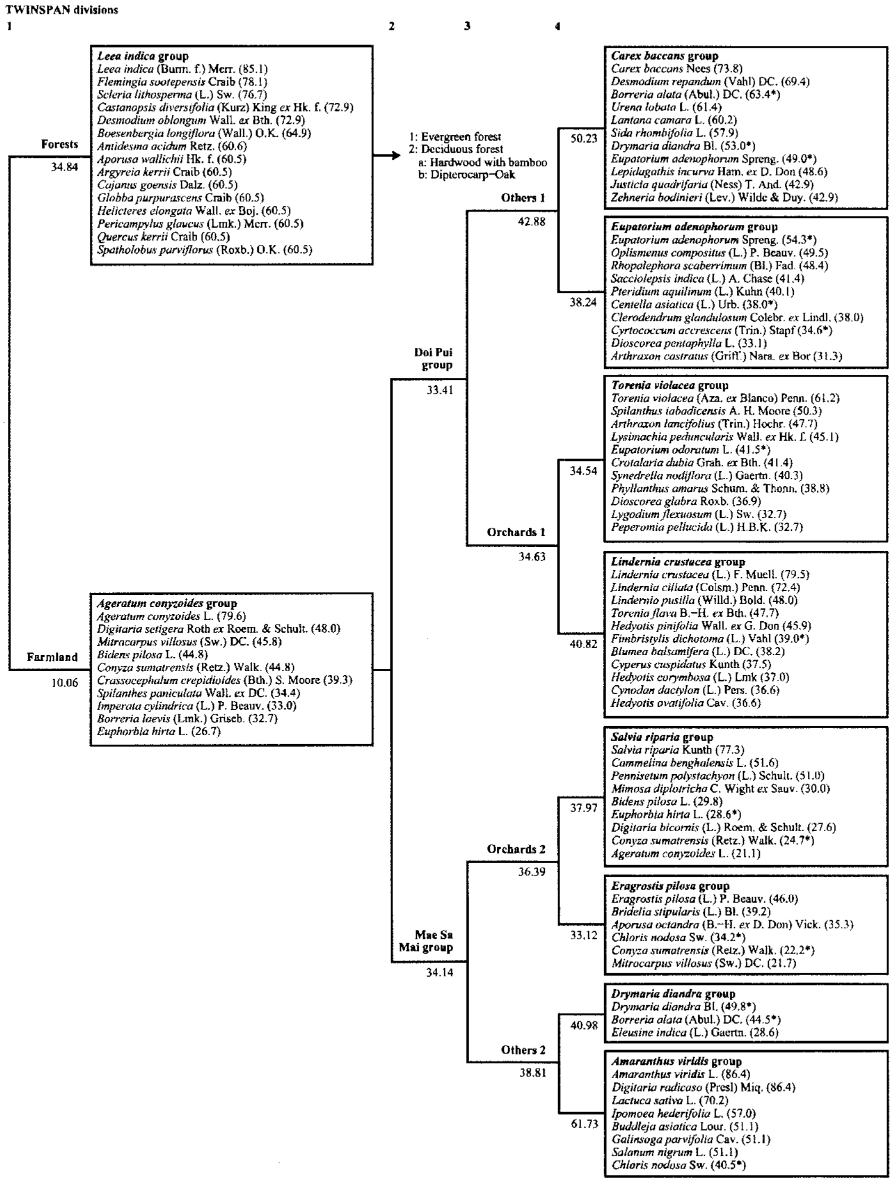

Fig. 1: Condensed dendrogram of TWINSPAN divisions (1 - 4, header of the figure). All relevés (n = 199) and species with a minimum frequency of 3% (n = 289) were included in the analysis. The boxes represent the plant species groups including names of up to 15 species with the 10 highest positive fidelity values (>20, in brackets after the species name) within the respective group (Fischer's exact test, p<0.001). Species with high positive fidelity values (>20) in other plant groups of the same division level are marked with *. The numerical values in front of each bifurcation and group boxes indicate the average of positive fidelity values from all plant species of the respective group

climbers reached only percentage constancy values below 15% and a negligible frequency of dominance. The only exceptions were *Synedrella nodiflora* (L.) Gaertn. (43% constancy) and *Dioscorea glabra* Roxb. (22%). Forest tree or shrub species were also sparsely present (percentage constancy below 10%) in the ground cover vegetation of litchi orchards.

Groups of ground cover vegetation resulting from TWINSPAN are shown in a condensed dendrogram in Fig. 1. The first TWINSPAN division level 3 clearly

Table 2: Proportions of the major categories of species characteristics in the final groups subdivided by TWINSPAN

		Proportion (%)						
	n	a	pe	h	g	pi	s/f	w
Orchards 1	81							
Torenia violacea group	61	72.2	27.8	44.4	30.6	75.0	25.0	0.0
Lindernia crustacea group	20	92.9	7.1	64.3	21.4	82.1	14.3	3.8
Orchards 2	62							
Salvia riparia group	44	66.7	33.3	53.3	33.3	86.7	13.3	0.0
Eragrostis pilosa group	18	33.3	66.7	33.3	26.7	46.7	46.7	26.7

The proportions refer to HF species (positive fidelity values >20, Fisher's exact test $p<0.05$). Categories are: n = number of relevés, a = annual, pe = perennial, h = herbaceous, g = graminaceous, pi = pioneer, s/f = secondary growth and forest, w = woody plant species

separated plant species typically associated with forest habitats (Forests) and similar vegetation units from those of agricultural related habitats (Farmland). The second TWINSPAN division level of Farmland (181 relevés) divided the ground cover vegetation and relevés explicitly according to the two Hmong villages (Doi Pui group and Mae Sa Mai group) with very few exceptions (13 of all Farmland relevés). TWINSPAN division level 3 divided the Doi Pui group and the Mae Sa Mai group each into plant groups which were exclusively found in relevés of orchard sites (Orchards 1 and Orchards 2) and those of mixed relevés comprising orchards and other sites (Others 1 and Others 2). These were further subdivided into two groups each at TWINSPAN division level 4. Although Fisher's exact test was applied to all groups of this division level, considerable numbers of species in one group also occurred in neighbouring groups.

Species with the highest ranking fidelity values (>20, in the following termed as HF species) in Orchards 1 were dominated by annual pioneers (Table 2). The *Torenia violacea* group included 75.3% of all relevés of litchi orchards of Doi Pui village. The most characteristic group of ground cover vegetation in the litchi orchards of Mae Sa Mai was the *Salvia riparia* group, which represented 71% of relevés of Orchards 2. Although the proportions of major life form categories were similar, the compositions of HF species in the predominant groups of ground cover vegetation of the two villages were completely different (Fig. 1). In both groups of Orchards 1, the majority of HF species is native to South or Southeast Asia, e.g., *Torenia* spp., *Spilanthus iabadicensis* A.H. Moore, *Arthraxon lancifolius* (Trin.) Hochr., *Lysimachia peduncularis* Wall. ex Hk. f., *Lindernia* spp. and many others. In contrast, most HF species in the *Salvia riparia* group of Orchards 2 are exotics, which mainly originate from tropical America. Examples are *Salvia riparia* Kunth, *Pennisetum polystachyon* (L.) Schult., *Mimosa diplotricha* C. Wight ex Sauv., *Bidens pilosa* L., *Euphorbia hirta* L., *Conyza sumatrensis* (Retz.) Walk. and *Ageratum conyzoides* L.

A comparison of the proportions of relevés from litchi orchards with and without herbicide application showed that the *Torenia violacea* group and the *Salvia riparia* group comprised a relatively lower percentage of relevés with herbicide application (37.9 and 36.8%, respectively) than those of the *Lindernia crustacea* group (85%) and the *Eragrostis pilosa* group (52.6%).

The ground cover vegetation groups of Others 1 (25 relevés) and Others 2 (13 relevés) were generally characterized by higher proportions of perennials and species of forest secondary growth among the HF species than the major groups of Orchards 1 and Orchards 2. The different groups represented relevés beyond the typical range of litchi orchard ground cover vegetation types, such as a young litchi orchard (the *Amaranthus viridis* group) on the one hand and several abandoned plantations and ruderal sites on the other (the *Eupatorium adenophorum* group).

DISCUSSION

The basic division of ground cover vegetation types resulting from TWINSPAN analyses was clearly attributed to the successional stage of the selected sites. The *Leea indica* group was mainly composed of shade tolerant species typical for the understorey vegetation of different forest climax stages. In farmland habitats, such species were only found in low densities, or were absent. On the other hand, the *Ageratum conyzoides* group is mainly composed of plant species tolerating artificially maintained open conditions, which are characteristic of cultivated land and partially for disturbed areas and secondary growth (Maxwell and Elliot, 2001). A similar separation of the vegetation into two groups of distinct successional stage was also shown in a study of weedy fields and forests in the Peruvian Amazon (Fujisaka *et al*., 2000).

The factors accounting for differences in the vegetation of the major groups of Orchards 1 and Orchards 2 are less apparent, because both were dominated by annual pioneer species and represented a similar stage of vegetational succession. However, the clear differences in the proportions of exotic and native species in these two groups of orchard vegetation can be interpreted by land use intensity and site history. The high proportion of exotic HF species in Orchards 2 of Mae Sa Mai indicates a higher intensity and a longer history of cultivation. In that area, exotic pioneer species became well established in the short fallows of the annual cropping systems over time and were able to displace native species. Such sites probably represented the main source of plant colonization into the ground cover vegetation of the litchi orchards nearby. In contrast, the high proportion of native HF species in Orchards 1 of Doi Pui can be related to a later initiation of land cultivation and a lower degree of landscape transformation in the surroundings of the orchards compared to Mae Sa Mai. Both factors may account for advantages of native pioneers over exotics in the colonization of the orchard vegetation. Especially the prevailing forests in that area might act as barriers for the invasion of exotics by large distances, resulting in ground cover vegetation types dominated by native plants.

The characteristics of the ground cover vegetation of litchi orchards were also influenced by frequencies of herbicide application. The vegetation groups with high proportions of herbicide treated orchards (*Lindernia crustacea* group and *Eragrostis pilosa* group) showed lower proportions of graminaceous and higher proportions of woody HF species than those with lower proportions of herbicide-treated orchards. These results are partly in accordance with the findings of Wentworth *et al*., (1984) from the ground cover vegetation of apple orchards in North Carolina, USA. They showed that orchards dominated by woody plants had received significantly more frequent broad-spectrum herbicide applications than grass-dominated orchards. This was similar in the *Eragrostis pilosa* group, which showed the highest proportion of woody species of all orchard groups, but not to the same extent in the *Lindernia crustacea* group. Additional management factors, such as the frequency of mowing, probably account for such differences.

Comparisons between the ground cover vegetation of litchi orchards and fallows of traditional rice-based swidden farming systems of northern Thailand are offered by data from Schmidt-Vogt (1999). He analyzed the vegetational succession of fields from villages practising different intensities of land use, related to the duration of fallow and cultivation periods. Independent of land use intensity, all swidden fallows were clearly dominated by exotic weeds (mainly *Eupatorium adenophorum* Spreng., *E. odoratum* L.) up to about four years after cultivation. None of the ground cover vegetation groups from litchi orchards showed similar associations of plant species. However, Schmidt-Vogt (1999) found that *Ageratum conyzoides* L. was more abundant in fallows of intensive land use systems than in those of lower land use intensity. Similarly, *A. conyzoides* was a more important species in the ground cover vegetation of orchards at Mae Sa Mai compared to Doi Pui.

In the swidden fallows, the dominance of exotic weeds is terminated after around four years by the emergence of coppicing trees as the first stage of forest succession. The further development depends on site history and on the decision of farmers whether or not to interfere with the course of secondary succession (Schmidt-Vogt, 1999). The ground cover vegetation types of litchi orchards represent a later successional stage than those found within the first four years of swidden fallows. They are also different from early stages of forest succession, because tree regrowth is suppressed by mowing. Rather, the litchi orchard vegetation can be considered as a transitional stage of succession from a young weedy swidden fallow towards a permanent cultivation system, which has no analogy in natural succession sequences. Differences in ground cover species composition can largely be explained by the duration of cultivation, the intensity of land use of the surrounding landscape and management practices such as herbicide application and the frequency of mowing. Relationships between plant species composition and the duration of cultivation were also recorded by De Rouw (1991) from upland rice fields in Côte d'Ivoire (Africa).

Taken together, the vegetation data on land use systems of northern Thailand indicate that differences in land use intensity in relation to village practices are found in swidden farming systems as well as in permanent cultivation systems such as litchi orchards. The present study adds further evidence to the conclusion drawn by Schmidt-Vogt (1999), that the human impact on vegetation of land use systems in northern Thailand is strongly affected by differences of cultivation practice between villages as well as by historical processes. These are related to farming traditions of the ethnic groups, to the conditions they found upon arrival in northern Thailand and to changes of such conditions in recent times.

In the upland farming systems of northern Thailand, major production constraints are related to increasing land pressure and include erosion, fallow and soil degradation, weed pressure and pest problems (Turkelboom *et al*., 1996). Other studies from subtropical Asia demonstrated that erosion as well as soil fertility in orchards is affected by the composition and diversity of the ground cover vegetation (Tian *et al*., 2003; Chen *et al*., 2004). Furthermore, ground cover vegetation management of orchards can have significant effects on beneficial arthropods (Horton *et al*., 2003). Such results indicate that the ground cover vegetation occupies a key position in the orchard agroecosystem in relation to various ecological functions and services. Knowledge on the relationships between management and composition of the ground cover vegetation may contribute to the identification of appropriate strategies to promote ecological sustainability of land use and fruit tree production.

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