STRUCTURE AND COMPOSITION OF UNDERSTORY PLANT ASSEMBLAGES OF SIX LAND USE TYPES IN THE LORE LINDU NATIONAL PARK, CENTRAL SULAWESI, INDONESIA

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Abstract

In the present study the diversity and species composition of understory plants are examined in the submontane forest of Lore Lindu National Park, Central Sulawesi, Indonesia by comparing three rain forest types and three types of plantations of cacao differing in use intensity. The results showed that 376 understory plant species consisting of 140 species of tree seedlings, 162 herbs and shrubs, 29 terrestrial ferns and 45 climbers were collected in all land use types. The mean species numbers of herbs did not differ among three forest types but was significantly higher in cacao plantation with high use intensity, being about three times higher than in undisturbed rain forest and lightly disturbed rain forest. Urticaceae, Araceae, Hypoxidaceae and Acanthaceae were predominant in the forests, whereas Asteraceae and Poaceae in the cacao plantations. The number of species of ferns and climbers did not differ between forests and plantations. The study also recorded several invasive plant species at the cacao plantations such as *Piper aduncum* L.*, Bidens pilosa* L.*, Ageratum conyzoides* L.*, Sclerea purpuriens* Steud and *Paspalum conjugatum* Berg.

Introduction

Tropical rain forests are among the most species rich places on earth (Jacobs 1988). Many studies demonstrated high tree diversity of tropical rain forests (Proctor *et al.*1983, Kochummen *et al.* 1990, Phillips *et al.* 1994, Wright *et al.* 1997, Hamann *et al.* 1999, Kessler *et al.* 2005), especially economically important trees (Whitmore 1990). However, the studies on understory assemblages (Gentry and Dodson 1987), herbs, shrubs, lianas, and epiphytes (Laska 1997, Svenning 2000, Gradstein *et al.* 2005) are limited. Ecologically, understory plant species assemblages play a fundamental role in diversity, structure, and functional aspects of tropical forests (Svenning 2000). They may show different patterns of diversity than tree species due to different responses to light level, nutrient availability, and temperature (Laska 1997, Svenning 2000, Siebert 2002).

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Similar to other plant groups, data on understorey plant assemblages of Sulawesi, Indonesia are still limited and published data on the effects of habitat modification on such plant assemblages in the island are missing. This study, therefore, makes an attempt to address the question how the floristic composition, diversity, richness and density of understorey plant communities differ between three rain forest types and three cacao plantations types with different use intensity in submontane forest of Lore Lindu National Park, Central Sulawesi, Indonesia.

Materials and Methods

The study area was located in the surroundings of Toro, a village at the western margin of Lore Lindu National Park (longitude 01º22'52'' - 01º31'4'' S; latitude 120º1'37'' - 120º3'5'' E) about 100 km south of Palu, the Capital of Central Sulawesi, Indonesia. Research was carried out from April 2004 to December 2005. Detailed information on climate and soil conditions of this part of Central Sulawesi is not yet available (see Whitten *et al.* 1987). Falk *et al.* (2005), however, reported that mean annual rainfall in the study area varied between 1,500 mm and 3,000 mm, mean relative humidity 85.17%, and monthly mean temperature 23.40°C. The margin of the National Park is characterized in many parts by a mosaic of primary forest, primary less disturbed forest, primary more disturbed forest, secondary forests, and several land-use systems with cacao, coffee, maize and rice as the dominating crops (Gerold *et al.* 2004). The elevation of the selected sites is between 800 m and 1100 m, therefore belongs to the submontane forest zone (Whitten *et al.* 1987).

Understory plants were sampled in six different land use types differing in use intensity, including three types of rain forest and three types of agroforestry system, as follows:

1. Land use types A-C: Rain Forest

Land use type A ("*Wana*"): low use intensity / undisturbed rain forest. Natural forest with traditional use only; human activities restricted to collecting of medicinal plants and extensive hunting; rattan palms abundantly present.

Land use type B ("*Pangale 1*"): medium use intensity / lightly disturbed rain forest. Natural forest with rattan extraction, rattan palm removed.

Land use type C ("*Pangale 2*"): medium use intensity / moderately disturbed rain forest. Selectively logged forest, containing small to medium sized gaps, disturbance of ground vegetation, and increased abundance of lianas following the selective removal of canopy trees and rattan.

2. Land use types D-F: Agroforestry System

Land use type D ("*Pahawa pongko 1*"): moderate use intensity. Cacao forest garden with natural shade trees (= remaining forest cover) in the forest margin.

Land use type E ("*Pahawa pongko 2*"): light use intensity. Cacao cultivated under mixed canopy planted shade trees in the forest margin.

Land use type F ("*Huma*"): high use intensity. Cacao cultivated under canopy of monospecific planted shade trees more distant from the forest margin.

For each land use type, four replicates were selected. At all sites understory vascular plants (including herbs, tree seedlings, ferns and climbers) less than 1.50 m high were sampled in ten 2 × 2 m subplots. Plots were selected similar to plots for tree diversity study. Plots of land use types A-C were located at slightly higher elevation (hill-tops) than land use types D-F (lower slopes).

All recognizable morphospecies of understory plants were collected. Plant collection was according to the "Schweinfurth method" (Bridson and Forman 1999). Additionally, fertile voucher specimens were collected for identification. Processing of the specimens was conducted at the Herbarium Celebense (CEB), Universitas of Tadulako, Palu, Indonesia. Identification was done in the field, in the CEB, in Herbarium Bogoriense (BO), Indonesia, and in National Herbarium of Netherland (L), Leiden. Vouchers were deposited in CEB, with duplicates in BO, L, Herbarium Gottingen, Germany, and Herbarium Biotrop Bogor, Indonesia.

Statistical analyses

Relative density, relative biomass, relative frequency and Importance Value Indices (IVI) were calculated according to the formulae of Dumbois-Muller and Ellenberg (Soerianegara and Indrawan 1998, Setiadi *et al.* 2001).

i) Relative density (%) = (No. of individuals of a family or species / Total no. of individuals in sample) × 100

ii) Relative biomass (%) = (Biomass of a species or family / Total biomass in sample) × 100

iii) Relative frequency (%) = (Sampling units containing a species/ Sum of all frequencies) × 100

iv) IVI for a species is the sum of its relative density, relative biomass, and relative frequency.

Additionally, we compared the taxonomic and structural composition between the land use types. Taxonomic composition was quantified on a family basis by calculating

the family relative density, relative diversity, relative dominance, and Family Importance Value (FIV) indices according to the formulae of Mori *et al.* (1983):

i)   Family relative density (%) = (No. of trees in a family / Total no. of trees) $\times$ 100
ii) Family relative diversity (%) = (No. of species in a family / total number of species) $\times$ 100
iii) Family relative dominance (%) = (Total basal area for all trees in a family / Total basal area of all families) $\times$ 100
iv) FIV is the sum of family relative diversity, relative density, and relative dominance.

The presence and absence data were used to calculate species similarity among all plots by application of Sörensen's similarity coefficient:

$$S = 2\,C\,(A + B)^{-1}$$

where A is the number of IV (important value) in Stage 1, B is the number of IV in Stage 2, and C is the number of IV common to both stages. Furthermore, dissimilarity index (1 - Sörensen similarity coefficient) among those plots where then clustered by using Biodiv 97 (Meßner 1996) and the program Statistica 5.5. Dissimilarity values were used to calculate a two-dimensional ordination of all samples using multidimensional scaling.

The program SYSTAT version 7.0 was used to perform statistical analyses. Arithmetic means are given $\pm$ 1 standard deviation (SD). ANOVA was of a one-way type. Tukey's Honest Significant Different Test was used for multiple comparisons of means.

Results and Discussion

Species richness

In total, 376 understory plant species consist of 140 species of tree seedlings, 162 herbs and shrubs, 29 terrestrial ferns and 45 climbers were collected in all land use types. Statistically, the mean species number of herbs did not differ among three forest types but was significantly higher in cacao plantation type F (high use intensity of cacao plantation) compared to all other five land use types (Fig. 1). The mean species number of herbs in cacao plantation type F (35.3 $\pm$ 5.8) was about three times higher than in undisturbed and lightly disturbed rain forests.

In contrast, the mean number of species of tree seedlings was highest in moderately disturbed rain forest (type C: 36.5 $\pm$ 3.0), followed by rain forest of light use intensity and undisturbed rain forest, with the mean numbers of species being 25.5 $\pm$ 3.4 and 25.3 $\pm$ 5.3, respectively. The lowest number of tree seedling species (4.5 $\pm$ 3.7) was in the land use type F (high use intensity of cacao plantation).
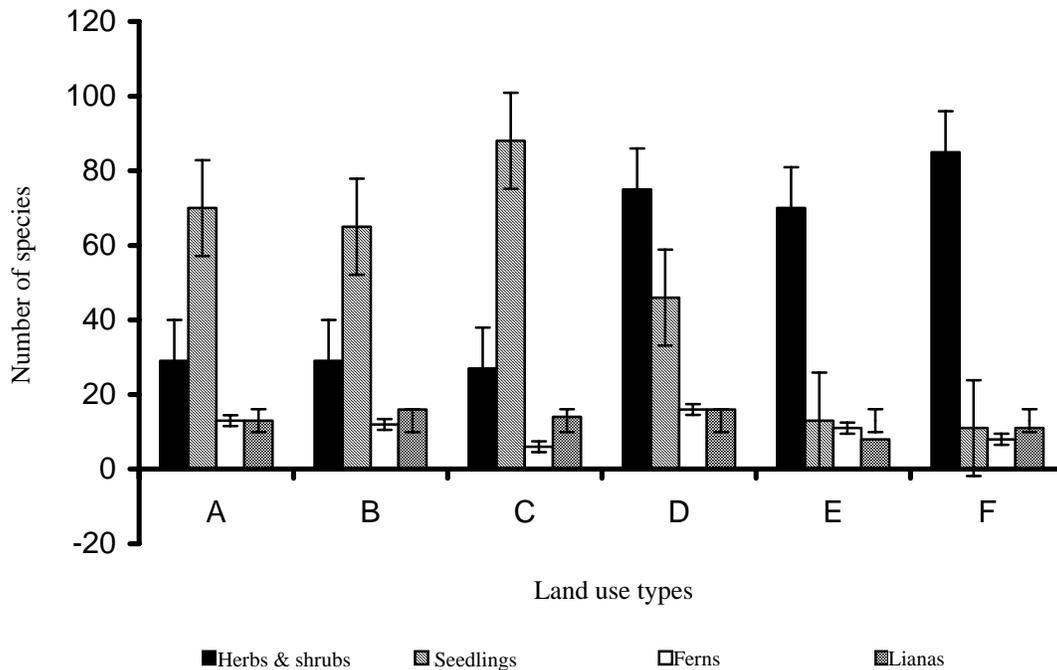
Fig. 1. Species richness (± standard deviation) of understory plants (herbs & shrubs, seedlings, ferns and liana) in six land use types at the Lore Lindu National Park, Indonesia. A = undisturbed rain forest, B = lightly disturbed rain forest, C = moderately disturbed rain forest, D = moderate use intensity of cacao plantation, E = light use intensity of cacao plantation and F = high use intensity of cacao plantation.

Taxonomic composition

The species composition of understory plants was different among land use types. In the undisturbed forest (type A), dominating tree seedling species were *Acer laurinum* Hassk. (Aceraceae), *Areca vestiaria* Giseke (Arecaceae), *Calophylum soulattri* Burm.f. (Clusiaceae), *Aglaia argentea* Bl. (Meliaceae), *Ardisia celebica* Scheff. (Myrsinaceae). *Syzigium accuminatisimum* Miq. (Myrtaceae), *Lasianthus* sp. (Rubiaceae) *Meliosma sumatrana* (Jack.) Walp (Sabiaceae), *Palaquium quercifollium (*de Vriese) Burck (Sapotaceae). Herb and shrub species were presented by *Alpinia galanga* (L.) Swartz.*, Costus speciosus* (Koen.) J.E. Smith*, Elletaria* sp. (Zingiberaceae), four unidentified species of *Elatostema* spp. and *Pauzolzia zeylanica* Benn. (Urticaceae). Ferns were mostly represented by *Christella dentata* Forst (Thelypteridaceae), *Cyathea amboinensis* (Aldew.) Merr. (Cyatheaceae), *Davalia trichomanoides* Bl. (Davaliaceae), *Diplazium crenatoserratum* (Bl.) Moore (Athryriaceae), *Nephrolepis bisserata* (Sw.) Schott and *Selaginella* sp. (Selaginellaceae), whereas liana and vine species were four juvenile endemic rattans, namely *Calamus inops* Becc. ex Heyne*, Calamus minahassae* Becc.*, Calamus ornatus* Blume ex Schult. var. *celebicus* Becc., and *Calamus zollingerii* Becc. (Arecaceae)*,* an endemic scrambler bamboo *Dinochloa barbata* S. Dransfield (Poaceae),

Freycenetia angustifolia Bl. (Pandanaceae), *Stephania japonica* (Thunb. ex Murr.) Miers (Menispermaceae), and *Ziziphus angustifolius* (Miq.) Hatus. (Rhamnaceae).

In the lightly disturbed rain forest (type B), dominant tree seedling recorded were *Areca vestiaria, Arenga pinnata* (Wurmb) Merr., *Pinanga aurantiaca* Mogea (Arecaceae), *Callophyllum soulattri* (Clusiaceae), *Leea indica* (Burm.f.) Merr. (Leeaceae), *Pandanus sarasinorum* Lauterb (Pandanaceae), *Meliosma sumatrana* (Jack) Walp (Sabiaceae), *Palaquium quercofollium* (Giff.) Engler and *Chionanthus laxiflorus* Blume (Oleaceae). Whereas herb species recorded were *Staurogyne elongata* (Blume) Kuntze (Acanthaceae), *Curculigo orchioides* Gaertn. (Amaryllidaceae), *Homalomena humilis* (Jack) Hook.f. (Araceae), *Begonia aptera* Bl. (Begoniaceae), *Elatostema* cf. *macrophylla, Elatostema* sp. 1*, Elatostema* sp. 2 (Urticaceae), *Spathyphyllum canaefollium* Schott (Araceae) and *Tacca palmata* Bl. (Taccaceae). There were only two juvenile rattans species, namely *Calamus zollingerii* and *Calamus minahassae*, but the other common lianas species were *Ziziphus angustifolius* (Rhamnaceae), *Alyxia celebica* D.J. Middleton (Apocynaceae), *Medinilla* sp. (Melastomataceae), *Gnetum cuspidatum* Bl. (Gnetaceae) and *Centrosema* sp. (Fabaceae). *Christella dentata*, *Diplazium esculentum* (Retz.) Sw., *Cyathea amboinensis*, *Nephrolevis biserrata* and *Helminthostachys zeylanica* (L.) Hook. (Ophioglosaceae) were the co-dominant fern species in this land use type.

The herb species in moderate use intensity forest (type C) were mostly presented by *Elatostema* sp. 2 (Urticaceae), *Homalomena humilis* (Araceae), *Curculigo orchioides* (Amarylidaceae), *Elatostema* sp. 1, *Elatostema* sp. 3 and *Tacca palmata*. There were only six species of ferns in this habitat and again we recorded *Lindsaea lucida*, *Christella dentata*, *Cyathea* sp. and *Helmintostachys zeylanica* as seedlings. The dominant liana seedlings were *Stephania japonica* (Menispermaceae)*, Dinochloa barbata* L. (Poaceae)*, Arcangalesia flava* (L.) Merr. (Menispermaceae), *Piper miniatum* L. (Piperaceae), *Calamus inops* and an endemic rattan *Korthalsia celebica* Becc. (both Arecaceae).

The understory plants species composition was significantly different between cacao plantations and forests. The number of native species of forest climbers and herbs decreased in land use types D, E and F, where they were replaced by the weedy herb species. Although there were *Elatostema* sp. 1 (Urticaceae), *Tacca palmata* (Taccaceae), *Elatostema* sp. 2, *Curculigo orchioides* and *Impatiens platypetala* Lindl. (Balsaminaceae), all typical for the herb layer of the forest, we collected a large number weedy species in land use type D such as *Ageratum conyzoides* (Asteraceae), *Elephantopus mollis* L. (Asteraceae), *Crassocephalum crepidiodes* (Benth.) S. Moore (Asteraceae), *Paspalum conyugatum*, *Setaria palmifolia* (J. Koenig) Stapf, *Panicum repens* L., *Eragrostis tennella* (L.) Beauv. ex R. & S. (Poaceae), *Cyathula prostata* (L.) Bl. (Amaranthaceae), *Coleus* sp. (Lamiaceae), *Hyptis capitata* Jacq. (Lamiaceae), *Commelina diffusa* Burm.f., *Pollia secundiflora* (Bl.) Bakh.f. (Commelinaceae), *Blumea*

lacera (Burm.f.) DC. (Asteraceae), and *Scleria purpurascens* Steud. In land use types E and F, the herb species layer was entirely composed of the weedy species.

At the family level, the understory plant composition was different among six land use types (Table 1). Urticaceae was dominant in land use types A, C and D, but Taccaceae in B. Whereas Poaceae was dominant family in land use type E and Asteraceae in F.

Similarity of understory plant assemblages

The result of similarity analyses of understory plant assemblages among the six land use types showed that there was a high degree of similarity percentage among land use types A, B and C. The value of similarity between A vs B was 67%, A vs C was 63% and between B and C was 67%. On the other hand, the taxonomic composition between land use types E and F also showed a high degree of similarity, with a Sörensen index 0.82. Similarity percentages of understory plant between forests and cacao plantations showed low values of Sörensen index. The value of similarity between A vs D was 28%, A vs E was 9%, and between A and F was 7%, whereas between B vs D, E and F were 34%, 14% and 10%, respectively.

The cluster analysis and two dimensional scaling based on Sörensen indices for all possible pair wise combinations of understory plant species assemblages showed a clear separation between the three types of forests and the cacao plantation types (Figs 2 and 3). There is a high degree of overlapping between land use types A (natural forest) and B (lightly undisturbed forest). The cacao forest garden (type D) represented a relatively distinct group. Both land use types E (cacao cultivated under mixed canopy of shade tree) and F (cacao cultivated under monospecific canopy of shade tree) showed a high degree of overlapping.

The richness and composition of understory plant species are presumably due to their different responses to abiotic factors such as differential light levels, nutrient availability, water availability, wind and temperature (Marquis *et al.* 1986, Denslow 1987, Laska 1997, Svenning 2000, Siebert 2002). The abundance and diversity of understory plants are also influenced by biotic factors. For example, birds, mammals and bats are known to be important dispersers of pioneer and forest climax tree species, shrub, herb and epiphytic species (Galindo-Gonzales *et al.* 2000, Siebert 2002). In the present study, herbs showed highest species richness in cacao cultivated forest gardens (type F), which is in accordance with the findings of Siebert (2002). The higher light levels and more open canopy in this land use type may explain the observations.
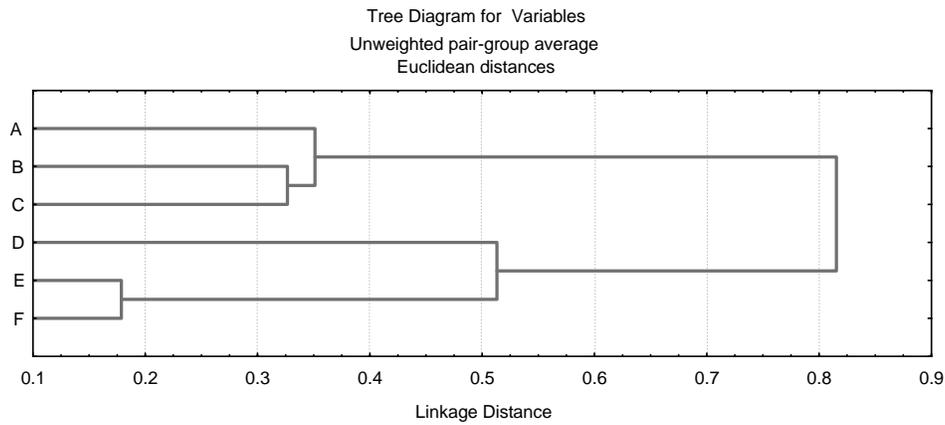
Table 1. The ten main understory plant families under each of six land use types based upon family important value (FIV). A = undisturbed rain forest, B = lightly disturbed rain forest, C = moderately disturbed rain forest, D = moderate use intensity of cacao plantation, E = light use intensity of cacao plantation, and F = high use intensity of cacao plantation.
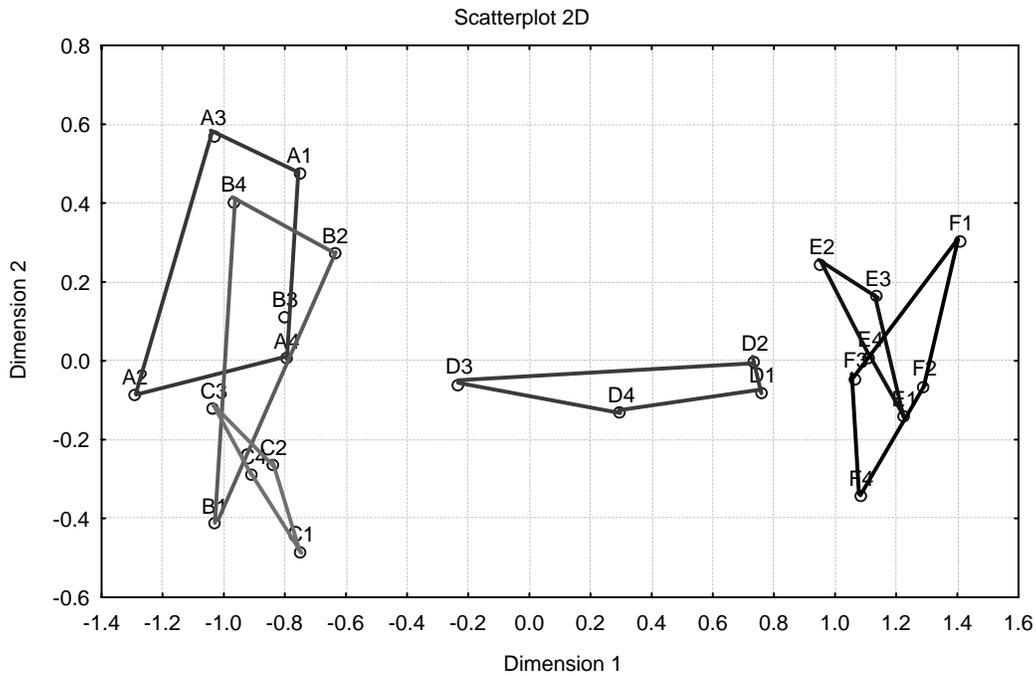
No.	Land Use Types											
	A		B		C		D		E		F	
	Families	FIV	Families	FIV	Families	FIV	Families	FIV	Families	FIV	Families	FIV
1	Urticaceae	92.80	Taccaceae	24.35	Urticaceae	106.60	Urticaceae	72.84	Poaceae	89.84	Asteraceae	86.95
2	Araceae	55.50	Acanthaceae	20.96	Araceae	62.92	Poaceae	54.29	Asteraceae	56.13	Poaceae	80.74
3	Hypoxidaceae	40.10	Urticaceae	17.42	Hypoxidaceae	35.49	Asteraceae	39.10	Acanthaceae	29.31	Caryophyllaceae	29.26
4	Acanthaceae	14.60	Araceae	16.16	Taccaceae	16.98	Araceae	21.60	Lamiaceae	22.00	Amaranthaceae	13.33
5	Zingiberaceae	7.48	Hypoxidaceae	14.38	Gesneriaceae	15.26	Taccaceae	18.60	Caryophyllaceae	16.73	Lamiaceae	12.53
6	Gesneriaceae	7.22	Gesneriaceae	4.83	Acanthaceae	13.41	Lamiaceae	17.42	Rubiaceae	11.74	Cyperaceae	11.18
7	Orchidaceae	5.52	Zingiberaceae	2.91	Zingiberaceae	13.17	Hypoxidaceae	13.31	Cyperaceae	10.24	Urticaceae	8.07
8	Commelinaceae	2.68	Orchidaceae	2.75	Balsaminaceae	9.54	Balsaminaceae	10.88	Urticaceae	9.03	Commelinaceae	7.69
9	Araliaceae	2.30	Begoniaceae	2.35	Maranthaceae	8.39	Acanthaceae	8.05	Malvaceae	8.97	Euphorbiaceae	6.62
10	Taccaceae	2.05	Balsaminaceae	1.16	Commelinaceae	6.84	Comelinaceae	7.73	Verbenaceae	8.10	Rubiaceae	5.25
	Remaining families	69.80	Remaining families	192.75	Remaining families	11.41	Remaining families	36.18	Remaining families	37.91	Remaining families	38.38
	Total	300	Total	300	Total	300	Total	300	Total	300	Total	300

Tree Diagram for Variables
Unweighted pair-group average
Euclidean distances

Fig. 2. Dendrogram of cluster analysis of understory assemblages based on dissimilarity index (1 - Sörensen similarity indices) among six land use types differing in use intensity. A = undisturbed rain forest, B = lightly disturbed rain forest, C = moderately disturbed rain forest, D = moderate use intensity of cacao plantation, E = light use intensity of cacao plantation, and F = high use intensity of cacao plantation.

Scatterplot 2D

Fig. 3. Two dimensional scaling of understory species assemblages similarity based on Sörensen indices in the six land use types. Sites belonging to the same habitat type are connected by lines. A = undisturbed rain forest, B = lightly disturbed rain forest, C = moderately disturbed rain forest, D = moderate use intensity of cacao plantation, E = light use intensity of cacao plantation, and F = high use intensity of cacao plantation.

The cacao forest garden, known as a traditional forest farming system (Siebert 2002), is an important land use type in the margins of Lore Lindu National Park. The high species diversity and complex structure of traditional forest farming systems maintain many of the ecosystem functions and processes found in primary forests. These include low ground-level light intensities, low transpiration rates of understory plants, reduced wind speed, diurnal temperature and humidity fluctuations, large and continuous organic matter inputs, efficient nutrient cycling, and a diverse habitat for forest flora and fauna (Perfecto *et al.* 1996, Beer *et al.* 1998, Siebert 2002). Traditional forest farming system may also provide connectivity between isolated primary forest fragments (Galindo-Gonzales *et al.* 2000).

In this study, a mix of native and exotic weed species was recorded in the cacao forest garden (type D). The composition of herbs in this forest type agrees with the results of Siebert (2002) who found both native and exotic weed species occurring in traditional forest farming systems. At the family level, Asteraceae and Poaceae were the dominant families of exotic weeds in cacao plantation areas. Probably, the invasion by species of these two families is due to the excellent dispersal capacities of their species.

Interestingly, the dominant tree seedling species in three cacao plantation types was *Piper aduncum* (Piperaceae), with important value indices more than 75%. Weber (2003) stated that *Piper aduncum* is one of invasive alien species widely distributed in the tropics including Malesia, Polynesia and Melanesia. Tjitrosoedirdjo (2005) who inventoried the invasive alien species in Indonesia pointed out that this species is originally from South America but it has recently invaded some islands in Indonesia including Sulawesi.

Despite the differing levels of disturbance, the three forest types (A, B and C) showed significant similarities among themselves suggesting resilience of the occupying species towards disturbance. On the other hand, although the overall species assemblages of types E (light use intensity) and F (high use intensity) were similar, type D (moderate use intensity) remained different from them probably due to the presence of high tree seedlings and weedy species.

Acknowledgements

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