Effect of Forest Use on Microhabitat Environment and Vegetation Structure in Sarawak, Malaysia

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Introduction

Tropical rain forests in Southeast Asia have been exposed to drastic and rapid deforestation because of an increasing human population and a rapidly developing economy. The annual deforestation rate in this region is 1.9%, whereas the average global rate is only 0.2 to 0.3% (Matthews 2001). Elucidation of the effects of forest use on plant biodiversity and on the microhabitat environment is an urgent subject for species conservation and proper forest management. Many studies have been performed on the effects of forest fragmentation on changes in tree species composition or abundance (e.g., Laurance et al. 2000). These studies have revealed that the structure of a forest remnant might be affected by its area, its distance from primary forest, and the elapsed time since fragmentation began (Laurance et al. 2002).

In Southeast Asia, forests are used for various purposes, including traditional ones. Slash-and-burn agriculture remains a widespread method of cultivation; local people (the Iban) abandon a field and shift to a new site after harvesting. As a result, secondary forests (fallows) at various developmental stages form a mosaic of landscape. Because rubber trees have been planted in abandoned fallows, particularly since the 1950s to produce crude rubber as a cash crop in Sarawak, Malaysia, rubber plantations operated by small holders are another widespread vegetation type (Ichikawa 2003). To understand the effect of forest use on a region’s vegetation structure, research must be conducted on the diverse vegetation types that form the forest mosaic. The alternation of vegetation structures may also be accompanied by changes in the microhabitat environment, such as canopy openness and soil-water content (Beaudet and Messier 2002). However, the effect of forest use on the microhabitat environment of various vegetation types remains unknown.

The objective of the present study was thus to compare the microhabitat environment and vegetation structure in fragmented primeval forests, abandoned fallows at three developmental stages, and rubber plantations, with those of primary forests so as to determine the effects of human forest use on the ecological traits of the vegetation in Sarawak, Malaysia. For fragmented primeval forests, the effects of the area, distance from a primary forest, and elapsed time since the fragmentation on vegetation structure were also examined.

Materials and methods

Study site and vegetation structure

A field survey was conducted in August 2003 in and around Lambir Hills National Park (LHNP), Sarawak, Malaysia (4°2'N, 113°5'E). The study site contained 32 plots (each 10×100 m) in six forest types: primary forests (four plots); fragmented primeval forests (nine plots); abandoned fallows at three developmental stages (i.e., new, 1 year after abandonment, four plots; young, 5 to 6 years after abandonment, four plots; and old, > 20 years after abandonment, six plots); and rubber plantations (five plots).

All trees in each plot ≥10 cm diameter at breast height (DBH, 1.3 m above ground) were tagged, mapped, measured DBH to the nearest mm, and identified to the species level. Voucher specimens were stored in the Herbarium of the Forest Research Center, Sarawak. Digitized satellite image was also used to identify the location of each plot, measure the shortest straight distance from the edge of each fragmented primeval forest plot to the primary forest of the park, and calculate the area of the fragmented primeval forest plots (Fig. 1). Since the exact date of fragmentation for each fragmented primeval forest was unknown, to estimate the date of fragmentation, we used the area of surrounding primary-forest-like vegetation within 200 m of each study plot calculated using a digitized aerial photograph of the region taken in 1977. The surrounding vegetation was classified into seven types: secondary forest (rubber plantation and fallow), open land (roads and grassland), wetland (wet rice fields and ponds), oil palm plantation, fragmented primeval forest, logged forest, and primary forest. The primary-forest-like vegetation included fragmented primeval, logged, and primary forest.

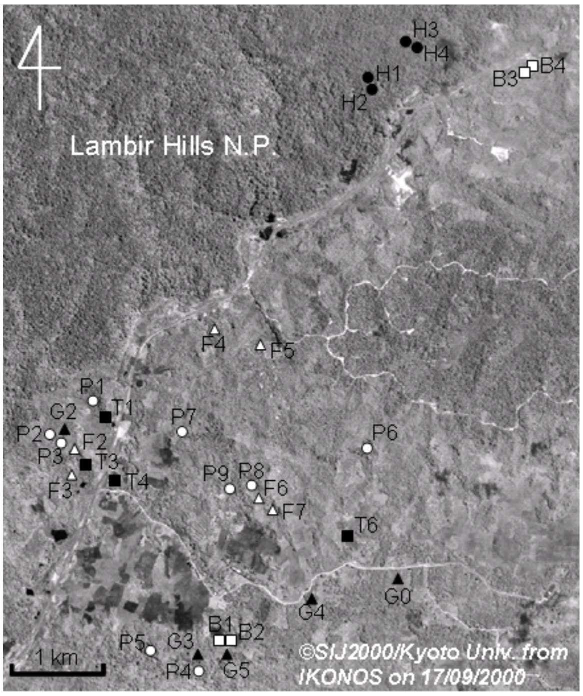

Fig. 1 Location of the study plots in and around Lambir Hills National Park, Sarawak, Malaysia. Symbols indicate the vegetation types: solid circle, primary forest; open circle, fragmented primeval forest; solid square, young fallow; open square, new fallow; solid triangle, rubber plantation; open triangle, old fallow. See Table 1 for plot codes.

Microhabitat environment

To characterize the light conditions at the forest floor, we measured the percent canopy openness using a digital camera with a fisheye lens (CoolPix 910, Nikon). Ten images were taken from the ground in each plot at 10-m intervals and analyzed using the CanopOn2 software (CanopOn 2003).

The soil-water potential was quantified using the method of Deka et al. (1995) in each study plot. Soil samples were taken on 20 February 2005, after a relatively dry spell during which no rain fell for six consecutive days. We sampled 10 soil cores to a 10-cm depth (3-cm in diameter) at 10-m intervals after removing the surface litter. Each soil sample was sealed in a plastic box for 8 days with filter paper (No. 42, Whatman) placed in the middle of the soil. On 1 March 2005, the filter paper was then weighed to within 1 mg after quickly removing the soil with a small paintbrush, and the soil-water potential was calculated (Deka et al. 1995).

Data analysis

We calculated the Shannon-Wiener *H'* parameter as a species diversity index using basal area data for each plot. Analysis of variance (ANOVA) was used to compare the effects of forest use on vegetation structure and microhabitat environment among the vegetation types, after log (absolute values) or arcsine (percentage values) transformation. For plots of fragmented primeval forest, we evaluated the relationships between vegetation structure traits (density, number of species, basal area, and H') and the area, distance to primary forest, or area of surrounding primary-forest-like vegetation within 200 m of each study plot using a Pearson's correlation coefficient. All statistical analyses were performed using the JMP 6.0 software (SAS Institute 2005).

Results

Vegetation structure and microhabitat environment

Since no trees ≧10 cm in DBH were found in the new fallow plots, we excluded this category from the ANOVA for vegetation structure. All variables that described vegetation structure and microhabitat environment differed significantly among vegetation types (Table 1). Primary forest and fragmented primeval forest had similar vegetation structures and dominant trees (Dipterocarpaceae), and they showed high tree density, number of species, basal area, and *H'*. Young fallow and rubber plantation plots had significantly low number of species and *H'*, though the density and basal area in young fallow were similar to those of old fallow, which had intermediate vegetation structure traits. The dominant trees were *Vitex pinnata* (Verbenaceae) in young fallow plots, *Artocarpus elasticus* (Moraceae) in old fallow plots, and *Hevea brasiliensis* (Euphorbiaceae, rubber tree) in rubber plantation plots (Table 1). In new fallow plots, grasses (Cyperaceae) grew thickly, mixed with small *Macaranga* and *Artocarpus* trees. Canopy openness and soil-water potential were highest in new fallow and fragmented primeval forest, respectively.

Table 1 Vegetation structure and microhabitat environment of six vegetatoin types studied in and around Lambir Hills National Park. Average variables of each vegetation type were shown.

Vegetation type (plot code)	*N*	Density (/0.1ha)	Species no (/0.1ha)	BA (m^2/ha)	H'	Canopy openness (%)	Water potential	Dominant tree[a]
Primary forest (H)	4	58	44.0	43.1	3.2	7.3	1.5	Dipterocarp trees
Fragmented primeval forest (P)	9	70	47.0	40.1	3.0	7.9	2.4	Dipterocarp trees
New fallow (B)	4	-	-	-	-	20.5	1.9	-
Young fallow (T)	4	40	15.5	7.9	2.0	9.8	1.9	*Vitex pinnata*
Old fallow (F)	6	53	32.7	20.9	2.8	8.2	1.9	*Artocarpus elasticus*
Rubber plantation (G)	5	60	19.2	20.6	1.8	10.8	1.9	*Hevea brasiliensis*

[a] Based on basal area.

Fragmented primeval forest

No significant correlations between forest area and vegetation structure were found for fragmented primeval forest. Tree density and species richness were significantly and negatively correlated with the distance to primary forest (Fig. 2). In contrast, we found significant and positive correlations between the area of the surrounding primary-forest-like vegetation within 200 m of each plot and tree density, species richness, and basal area.

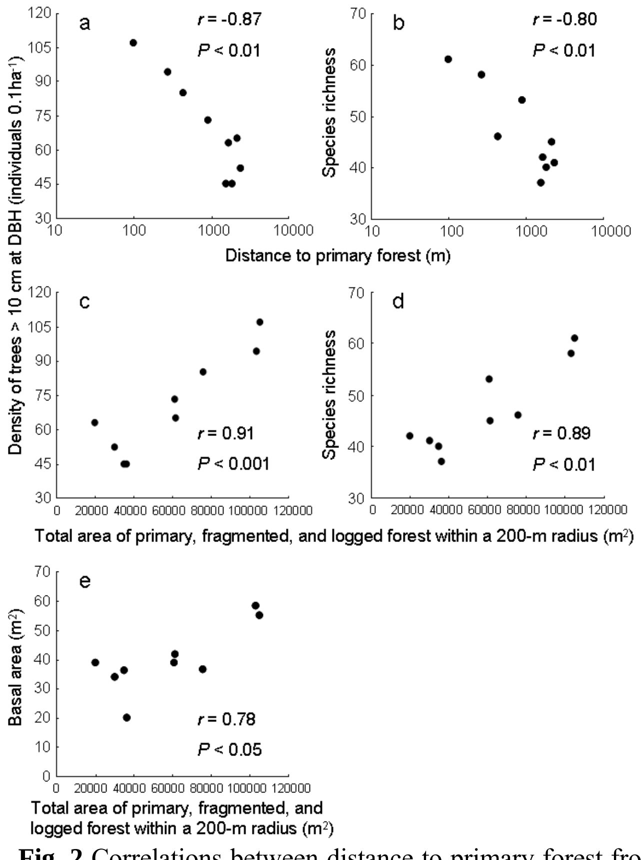

Fig. 2 Correlations between distance to primary forest from each fragmented primeval forest plot and (a) tree density (individuals $0.1ha^{-1}$) and (b) species richness (species numbers $0.1ha^{-1}$), and between area of surrounding primary-forest-like vegetation within 200 m of each fragmented primeval forest plot and (c) tree density, (d) species richness, and (e) basal area (m^2 ha^{-1}).

Discussion

Characteristics of the vegetation structure and microhabitat environment differed obviously among the vegetation types. Primary forest and fragmented primeval forest had larger and denser trees, with higher species richness and a darker forest floor (i.e., reduced canopy openness). However, the soil-water potential was highest in fragmented primeval forest. This might be because these forests are located mainly on ridges. Old fallow had the third-highest species richness, though the trees were smaller than those of primary forest or fragmented primeval forest and the dominant trees were also different. The differences in density and basal area between the young fallow and rubber plantation plots may have been caused by the planting of rubber trees. The vegetation structure and canopy openness in new fallow were distinctive, our results indicate that trees were able to recover from the disturbance and begin growing again relatively quickly, within several years after slash-and-burn agriculture. The alternation of the vegetation structure and microhabitat environment might affect not only the regeneration success of plants and forest dynamics (Bruna 1999; Cascante et al. 2002; Takeuchi et al. unpublished data) but also the biodiversity of fauna and the interactions between plants and animals (Medellín and Equihua 1998; Ferraz et al. 2003; also see several papers in this report).

Although species-area relationships have been widely used both to predict the effects of habitat loss on extinction rates and to guide conservation design (e.g., Wilson 1989), we observed no effects of the area of remnant forest on vegetation structure. Tree density, species richness, and basal area were instead affected by the characteristics of the surrounding vegetation, and particularly by the distance to primary forest and the area of surrounding primary-forest-like vegetation. This indicates that a small-scale mosaics composed of a range of forest types may be important because it enables trees to regenerate or immigrate to neighboring remnants by means of seed dispersal, thereby mitigating otherwise drastic habitat alterations. Gascon et al. (1999) also suggested the importance of a matrix of modified habitats surrounding forest fragments in terms of its effects on the dynamics or composition of vertebrate communities in tropical forest remnants. To practice proper land-use management, it will thus be necessary to consider the distribution of various vegetation types at the landscape level.

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