

Ferns as indicators of habitat quality in (agro)forest in Sumatra



Biodiversity research has to deal with an enormous diversity of plants, animals, fungi and other forms of life, which is often difficult and costly to measure. It helps to have tested indicators of habitat quality through species that are easily recognizable while marking specific ecological niches. Such indicators can be used in biodiversity conservation and habitat quality management. Ferns and related species (Pteridophyta) are proven to be indicators of habitat quality based on a detailed assessment in the rubber agroforests, natural forests and plantations of Sumatra.

Key Findings

- 1.** Jungle rubber is a forest-like land use which supports species diversity in an otherwise impoverished landscape increasingly dominated by monoculture plantations, although tree species conservation is limited by management practices and by a slash-and-burn cycle for replanting of about 40 years.
- 2.** Epiphytic ferns are found in jungle rubber agroforests, especially in older (less productive) plots that have more large, nonrubber trees.
- 3.** The understorey environment of jungle rubber supports intermediate numbers of 'forest fern species' and is much more forest-like than that of rubber plantations, but less so than primary forest.
- 4.** Several species of terrestrial pteridophytes can be used as indicator species for forest disturbance and forest regeneration.

Implications

- Maintaining older rubber agroforests can contribute to biodiversity conservation, in the near absence of effectively protected lowland forests.
- Economic incentives to maintain jungle rubber agroforests may be an effective way to conserve biodiversity.
- Species richness alone, without a priori ecological knowledge of the species involved, is not sufficient to indicate changes in ecological habitat quality.
- A number of species, described here, can be used as indicators of forest disturbance and of successful ecological restoration.

With the disappearance of undisturbed lowland rain forest habitat the question arises whether disturbed habitat maintains some of the characteristics and functions of the original forest, to what extent it can support survival and reproduction of primary rain forest species and how this function is influenced by management practices. We assessed the role of rubber (*Hevea brasiliensis*) agroforests in the conservation of lowland rain forest species in Sumatra. Primary forest and monoculture rubber plantations were included in this study to provide reference systems for biodiversity and rubber production values. The primary forest in this study was old growth forest without visible traces of timber cutting and without known history of logging or shifting cultivation, the only human use being limited collection of non-timber forest products and hunting.

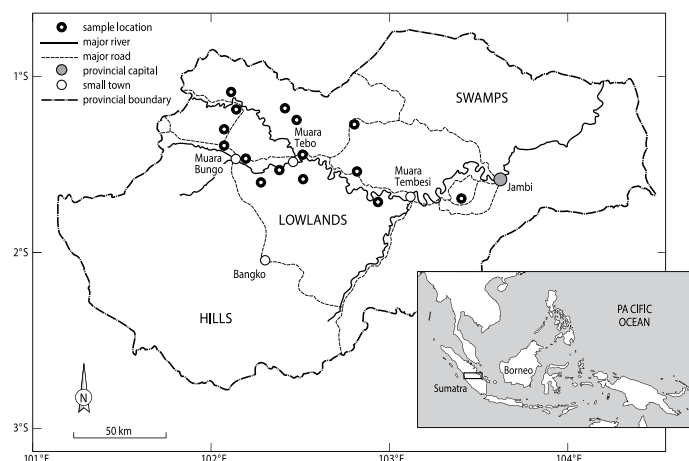


Figure 1. Sampling locations in the lowland area of Jambi province.

Method

The study was carried out in the lowlands of the peneplain area of Jambi province, a slightly undulating to flat area of about 200 by 150 km in the centre of Sumatra, Indonesia. Study plots were located in non-flooding areas at elevations ranging from 40 to 150 meters above sea level. Soils were predominantly well-drained, acid oxisols with low fertility. Annual rainfall in the study area was about 3000 mm per year. The original forests of this area are mixed Dipterocarp rain forests. New data was collected on terrestrial and epiphytic pteridophytes in 11 primary forest plots, 23 productive rubber agroforest plots, and 17 productive rubber plantation plots measuring 40 m x 40 m (0.16 ha/plot). Frequency of terrestrial pteridophyte species was assessed by counting species presence in 16 (10 m x 10 m) subplots in each plot, yielding a frequency score between 0 and 16 for each species in each plot. In addition, data was collected on the number of individuals of pteridophytes in the understorey, vegetation structure, litter layer, soil colour, slope steepness and position of the plot on the hill slope. Epiphytic ferns were collected in these plots from trees of at least 10 cm DBH using single-rope climbing techniques. Age of jungle rubber plots varied from 9 to 74 years, while the age of rubber plantation plots was 5–19 years old. Existing data on trees and birds was re-analysed for comparison with the pteridophyte results. Interviews were held to collect information on age and management history of the rubber plots.

Jungle rubber and rubber plantations

Jungle rubber gardens are low-input rubber agroforests that structurally resemble secondary forest and in which wild species are tolerated by the farmer. In this study, jungle rubber agroforests consisted of a mixture of wild and planted vegetation dominated by rubber trees. These agroforests were usually only weeded for a few years after the rubber was planted. Rubber plantations were mostly monocultures, their vegetation structure and composition mainly determined by plantation management practices such as continued weeding and the use of herbicides. Length of the slash-and-burn production cycle was, on average, about 20 years for rubber plantations and about 40 years for jungle rubber agroforests. In rubber plantations, 98% of trees were rubber trees, whereas on average only 41% of trees in jungle rubber agroforests were rubber trees. Rubber trees were gradually replaced by other trees with increasing age of jungle rubber agroforests.

Micro-climatic variations in forest, rubber agroforest and rubber plantations

Shade increases with age in both jungle rubber agroforests and rubber plantations, which affect light conditions and humidity. These in turn determine habitat quality as to what species can survive and reproduce well, beyond weeding and other direct management that alter natural species composition. What happens at plot level also influences the surrounding landscape, especially through the contribution of seeds to neighbouring plots. However, it is hard to either: (i) conduct inventory of species in terms of presence-absence and abundance at the landscape level; (ii) monitor micro-climatic variations in space and time. Therefore, for practical purposes of biodiversity management, ground-layer ferns (terrestrial pteridophyte species) can serve as indicators of disturbance or forest quality, as many species show clear habitat differentiation with regard to light conditions and/or humidity. One can expect terrestrial pteridophyte species preferring sunny conditions to be replaced over time by species preferring shady conditions in all land use types.

Box 1. Fern species that indicate highly to moderately disturbed early successional situations



Pteridium caudatum
subsp. *yarrabense*



Adiantum latifolium



Blechnum orientale



Microlepia speluncae



Nephrolepis biserrata



Dicranopteris linearis var.
linearis



Asplenium pellucidum



Lygodium
microphyllum



Lygodium flexuosum

Box 2. Species indicative of moderate disturbance associated with secondary forest succession and forest regeneration. Some are also commonly found in natural forest



Selaginella willdenowii



Lygodium circinnatum



Dicranopteris linearis
var. *subpectinata*



Selaginella intermedia



Lygodium longifolium



Tectaria singaporeana



Lindsaea doryphora



Mesophlebion
chlamydophorum



Tectaria barberi

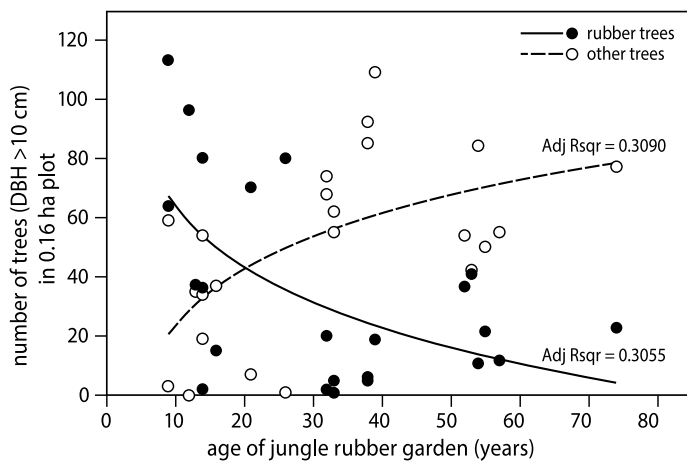


Figure 2. Number of rubber trees and other trees of DBH > 10 cm in jungle rubber plots of different age (H. Beukema)

Species diversity

Terrestrial pteridophyte species were grouped according to their ecological requirements into 'forest species' and 'non-forest species'. Species-accumulation curves were compiled for terrestrial and epiphytic pteridophytes, trees and birds, and for subsets of 'forest species' of terrestrial pteridophytes and birds.

Species richness in jungle rubber was slightly higher (terrestrial pteridophytes), similar (birds) or lower (epiphytic pteridophytes and trees) than in primary forest. For subsets of 'forest species' of terrestrial pteridophytes and birds, species richness in jungle rubber was lower than in primary forest. For all groups, species richness in jungle rubber was generally higher than in rubber plantations.

Terrestrial pteridophytes

Terrestrial pteridophyte species can serve as indicators of disturbance or forest quality, as many species show clear habitat differentiation with regard to light conditions and/or humidity. The 65 species of terrestrial pteridophytes in the dataset were classified in five groups according to apparent ecological similarity with respect to presence and abundance in plots of different land use types and ages, while a sixth group was formed containing those species that were only found in primary forest. This grouping based on field data was compared to a previous species classification derived from literature that focused primarily on light requirements of species ('forest species' and 'non-forest species'). The two classifications were generally in agreement. Groups found mostly in rubber plantations and (young) jungle rubber consisted predominantly of species that according to the literature preferred open or lightly shaded conditions. Species found mostly in jungle rubber appeared as an intermediate group, with half of the species preferring open or lightly shaded conditions and the other half preferring more shady conditions. The species that were found mostly in jungle rubber and primary forest all preferred shady conditions. The agreement between the grouping based on field data and the literature-based classification indicated that an *a priori* classification of terrestrial pteridophyte species into two groups based on light requirements may be used to interpret data in biodiversity and succession studies at the community level.

Box 3. Species found mostly or exclusively in natural forest



Trichomanes javanicum



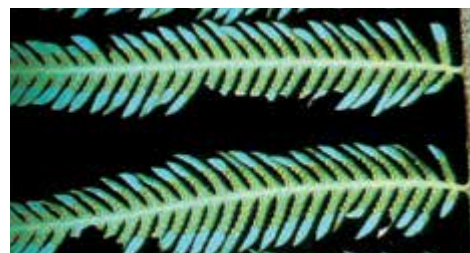
Trichomanes obscurum



Trichomanes singaporeanum



Lindsaea cultrata



Cyathea moluccana

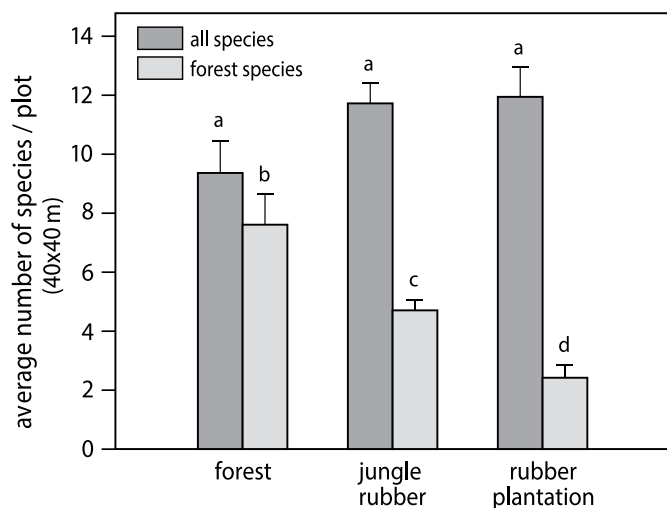


Figure 3. Number of terrestrial pteridophyte species per 0.16 ha plot. Means and their standard errors for three land use types forest (n=11), jungle rubber (n=23) and rubber plantations (n=17). Dark bars: all data; light bars: 'forest species' subset. Different letters indicate significant differences between land use types (Turkey's HSD test, $P<0.005$)

Shade increases with age in both jungle rubber agroforests and rubber plantations. Therefore, one can expect terrestrial pteridophyte species preferring sunny conditions to be replaced over time by species preferring shady conditions in both land use types. Species composition of terrestrial pteridophytes was studied in the undergrowth of chronosequences of productive jungle rubber agroforests, aged 9 to 74 years old, and productive rubber plantations, aged 5 to 19 years old, while species composition in primary forest served as a reference for the undisturbed situation. Change in species composition with plot age was more pronounced in jungle rubber than in rubber plantations. With increasing age of jungle rubber plots, species found mostly in rubber plantations and (young) jungle rubber – such as *Blechnum orientale*, *Microlepia speluncae*, *Nephrolepis biserrata*, *Stenochlaena palustris*, *Dicranopteris linearis* var. *linearis*, *Asplenium pellucidum*, *Lygodium microphyllum*, *Lygodium flexuosum*, *Christella subpubescens* and *Lygodium salicifolium* – became generally less abundant, especially after about 30 years, when some of these species disappeared altogether. In rubber plantations, some species found usually in jungle rubber and primary forest appeared in older plantations, but with lower abundance

than in jungle rubber plots. Older rubber plantations were increasingly dominated by two ground-covering species, namely *Nephrolepis biserrata* and *Stenochlaena palustris*. Frequencies of individual species were modeled with respect to plot age to detect successional patterns for a subset of 29 species that were common in the dataset. Patterns identified by modeling helped characterize individual species as either transient or climax species in secondary forest succession in the study area.

Epiphytic ferns

To assess the importance, by logistic regression, of land use, tree size, and tree type for colonization and reproduction of epiphytic ferns, the occurrence and fertility status of ferns on rubber trees and other trees in three size classes (DBH 10–20 cm, 20–40 cm, >40 cm) was recorded. A total of 3983 trees were checked for epiphytic ferns, of which 949 trees were in primary forest (1.6 ha), 1953 in jungle rubber agroforests (3.68 ha), and 1081 in rubber plantations (2.72 ha). The availability of large trees, the suitability of rubber trees as host trees, and habitat differences caused by land use practices were expected to influence habitat suitability. For the occurrence of epiphytic ferns on trees, only tree size was significant as a main effect. Larger trees were colonized by epiphytic ferns more often than smaller trees. A less important significant interaction indicated that medium sized trees in rubber systems were colonized more often than trees in the same size class in primary forest. For the occurrence of fertile epiphytic ferns on trees, both tree type and tree size were significant as main effects. Rubber trees had fertile epiphytic ferns less often than other trees. Tree size was the most important significant factor, with larger trees having fertile epiphytic ferns more often than smaller trees. Large trees (>40 cm DBH) had the largest odds ratio (8.27) of any of the factors in the models, indicating an important role for large trees in the reproduction of epiphytic ferns. Primary forest was a significant factor when compared to a reference class of jungle rubber and rubber plantation land use types taken together, indicating that trees in primary forest carried fertile epiphytic ferns more often than trees in the other land use types.

Box 4. Epiphytic ferns found in both natural forest and rubber agroforests



Davallia triphylla



Vittaria ensiformis



photo: H. Beukema

Outlook

Sustainability of the jungle rubber land use type depends primarily on the choice by individual farmers to keep cultivating rubber in a low-input, low-management manner. The outcome of individual choices for a plantation-style monoculture (of rubber, oil palm, or fast-growing trees) or a jungle rubber agroforest will eventually determine the importance in terms of area of jungle rubber in the landscape. In addition, there will likely be changes in the nature of the jungle rubber system, such as shortening of the life cycle through shortening of pre-productive and post-productive periods. Vegetation dynamics in jungle rubber may also change as a result of land use trends in the area. For instance, cultivating jungle rubber on previously cultivated land rather than on forest land may increase weed problems and the need for investment in herbicides, while the lack of nearby forest may lead to poor regeneration of useful woody species in jungle rubber. In places where primary forest is still present, priority should be given to conservation of remaining primary forest patches.

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Correct Citation

Beukema H, van Andel J, Werger MJ, van Noordwijk M. 2013. *Ferns as indicators of habitat quality in (agro)forest in Sumatra*. ASB Policybrief No. 37. Nairobi: ASB Partnership for the Tropical Forest Margins. 6p.

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