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Ecological study on site selection for shifting cultivation by the Iban of Sarawak, Malaysia. A case study in the Mujong River area

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ABSTRACT **Site selection methods for shifting cultivation of the Iban were studied at five longhouses in the Mujong River area of Sarawak, Malaysia with special reference to their knowledge of secondary vegetation. Shifting cultivation practices in the area were more intense than reported in previous studies and were conducted with one-time cropping of upland rice followed by about a 2-10 year fallow period. In all, 42 sites of secondary forests were selected for the vegetation survey. They were classified into 25 suitable sites and 17 unsuitable sites for shifting cultivation by landowners, based on their perception through knowledge of vegetation. Interviews of farmers were also conducted to discover and assess indicator plants from plants encountered during the vegetation survey. In the first stage of decision-making for site selection, old secondary forests, especially with difficult access, were excluded. Secondly, the farmers took into consideration the composition and growth of secondary vegetation and, to a lesser extent, other environmental factors. During the early fallow period, less than about three years, some species such as *Lalang* (*Imperata cylindrica*) and *Kemunting* (*Melastoma polyanthum*) dominated. The farmers perceived such sites as unsuitable for shifting cultivation. Left fallow for several years (more than three years), tree species replaced small plants, e.g., grasses, ferns and shrubs, through vegetation succession. Farmers perceived the presence of many tree species as indicating fertile land, but some of them occurred more frequently or with higher density at unsuitable sites than at suitable sites. Nevertheless, tree size as measured by stem diameter at breast height was greater at suitable sites than at unsuitable sites, indicating that the farmers comprehensively grasp the growth condition of these plants for land fertility evaluation and site selection. Judging from the rice yield survey, the Iban farmers' site selection was appropriate for achieving sufficient rice production for their subsistence.**

Key words: indigenous knowledge, indicator plants, site selection, shifting cultivation, Sarawak, Iban

INTRODUCTION

Shifting cultivation has remained a common agricultural practice in tropical upland regions. However, it occasionally causes environmental deterioration because of inappropriate land management and the occurrence of natural disasters such as a prolonged drought (Kiyono & Hastaniah, 2000). Various agencies have examined many programs to develop sustainable agricultural methods with the intention of improving the economic status of local farmers and to conserve and manage forests appropriately. In this context, the importance of indigenous knowledge has recently received considerable attention (UNCED, 1992). It is now widely accepted that the indigenous knowledge of traditional shifting cultivators is applicable to forest conservation and management strategies on a community basis in collaboration with governmental or other outside programs (e.g. Eghenter et al. 2003).

Upland regions of Borneo Island have been inhabited by various ethnic groups (MacKinnon et al. 1997). These groups practice shifting cultivation to plant upland rice as their staple food. They possess profound knowledge of environments and agricultural practices because they use primary and secondary forests not only for farming but also for producing timber and collecting non-timber forest products. As part of that knowledge, many researchers have reported that these farmers investigate vegetation conditions of forests as an indicator of land suitability and fertility when selecting new farming sites. Such knowledge is incorporated into actual decision-making for site selection along with other factors such as topography, land accessibility, land tenure, labor availability, rituals, and taboos: the Benuaq as reported by Sardjono and Sansoedin (2001) and Gönner (2002); the Iban by Padoch (1982); the Kantu' by Dove (1981); and the Kenyah by Chin (1985), Mackie (1986), Inoue (1990), and Sindju (2003). For secondary forests in particular, because farmers can rarely be sure of the fallow duration in years and of the prior land-use history, vegetation composition and plant growth act as a readily perceptible chronological criterion for site selection. Many researchers have mentioned that farmers estimate soil fertility levels according to the presence of specific plants (indicator plants) and the health condition of trees as indicated by the leaf color and trunk straightness. Although various ethnic groups in Indonesian Kalimantan have been well studied, the knowledge of Malaysian Sarawak's largest ethnic group, the Iban, comprising 30% of the total population of the state, has been little reported: Padoch (1982) briefly noted that the Iban examine the species composition and the extent of secondary forest growth for site selection because of their ignorance of the fallow duration time and the prior land-use history. Furthermore, although the knowledge of the ethnic groups has been recorded and compiled mostly from an ethnographical viewpoint, it has rarely been verified ecologically.

The objectives of our ecological study are first to clarify the Iban's site selection method in relation to vegetation, and then to evaluate soil fertility under the vegetation and to correlate it with vegetation conditions or the presence of specific plants with special reference to the Iban's knowledge and perception. Our results will contribute to the development of appropriate land conservation and management strategies in upland regions of Sarawak. These upland regions are dissected topographically by undulating hills and mountains, rivers and streams, resulting in very wide variation in soil fertility. The farmers' knowledge of site selection, which reflects environmental conditions and fluctuations within small patches, can be incorporated into agricultural strategies and extension activities by governments, which usually administer a wide range of environments. In this paper, shifting cultivation practices in the study area will be described first. Then, the Iban site selection method will be discussed with special reference to secondary vegetation conditions and indicator plants. In a paper to follow (Tanaka et al. 2007), soil fertility under secondary forests will be analyzed in terms of the length of fallow

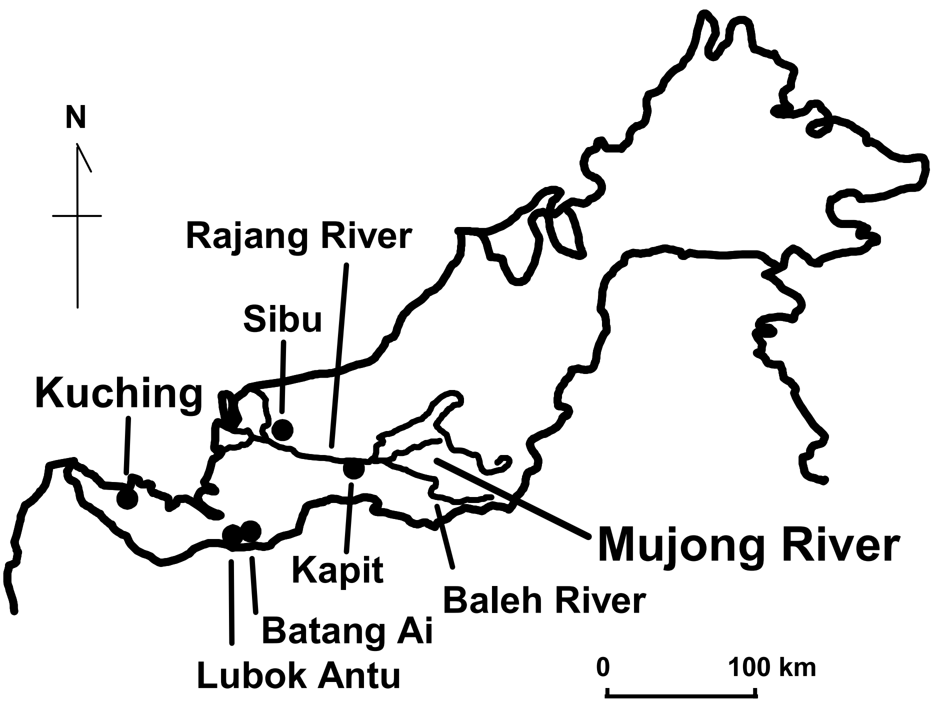

Fig. 1. Map of study area.

duration and vegetation.

MATERIALS AND METHODS

Study sites

According to Teng (2003), Sarawak can be divided into three physiographic zones, i.e. coastal lowland, central lowland and interior upland, accounting for 19.6, 33.3 and 47.1 % of the total land area (12.4 million ha), respectively. The greater part of the latter two regions is composed of a steep land with a slope gradient of more than 25°. The steep lands are covered mainly by the Red-Yellow Podozolic Soils and Skeletal Soils in the Sarawak classification system, corresponding roughly to Paleudults / Dystrudepts and Udorthents, respectively, in the USDA classification system (USDA, 1999). Main form of agriculture by local farmers on such upland area is shifting cultivation.

This study was conducted at the Mujong River basin in Kapit District, Sarawak (Fig. 1), which can be regarded as one of typical upland areas used for shifting cultivation in the state. The study area is located in the interior upland zone (Teng, 2003). The Mujong River is a branch flowing into the Baleh River, which is a tributary of the Rajang River, the longest river in Sarawak. This area was originally inhabited by the Penan, the Lugat, and other ethnic groups (Freeman, 1955). During the late 19th century, the Iban migrated from the Batang Ai area into the Baleh basin; later, in 1922, they settled down in that area under government supervision. Climate was classified into AA'r based on the Thornthwaite classification system (Thornthwaite, 1948). The mean annual temperature was about 26°C (Meteorological Department, 2003). The mean annual precipitation during 1994–2003 was 4,300 mm at the Nanga Mujong rainfall station (Department of Irrigation and Drainage, 2003). The monthly minimum precipitation was recorded in May-July: it was more than 200 mm. The dominant topography was undulating hills and mountains with a slope gradient ranging from 20° to 30°, occasionally exceeding 30°. Soils were derived from sedimentary rocks composed of shale, slate, phyllite, and sandstone with marlstone, calcareous sandstone, conglomerate and limestone lenses with weak regional metamorphism during the Paleocene to Eocene periods (Yin, 1992). The soils were classified into the Kapit Family of the Skeletal Soil Group based on the Sarawak soil classification system (Teng, 2003). Total population of Kapit District was 57,840 and the population density was 3.71 persons km^{-2} (Department of Statistics, 2002).

The longhouse is a community comprising several households of the Iban living together (Freeman, 1970). For this study, five longhouses (*Rumah*, Rh), i.e. Rh. Along (02°02′77″N, 113°19′77″E), Rh. Liok (02°02′66″N, 113°19′50″E), Rh. Peter (02°03′39″N, 113°17′71″E), Rh. Anding (02°03′37″N, 113°16′10″E) and Rh. Nawin (02°03′58″N, 113°15′15″E), were selected at the suggestion of members of the Forest Department Sarawak, who were Iban and were natives of the area. The longhouses were thought to be typical in this area because they have existed for about 100 years. They were located on the riverbank, at an altitude of about 100 m a.s.l.. When surveyed, 18–28 families or about 110–250 persons lived in each longhouse. All families cultivated upland rice by shifting cultivation on sloped land because of the scarcity of flat and wet (swampy) land available for lowland rice cultivation. The sole means of transportation between Kapit town, the district center and longhouses is a wooden boat, occasionally equipped with a 15–30 horsepower engine. Farmers visit adjacent longhouses or their farmland on foot through paths and trails or by using the boat.

Interviews

Three interviews of residents were conducted: The first interview, using questionnaires, was carried out in late March, 2003 with several residents gathered there. The interview was mainly intended to collect fundamental information about their longhouse community, families, and agricultural practices. Then, for deciding the interviewees for further interviews and the landowners whose secondary forests would be surveyed, we asked the heads of longhouses to introduce us to persons who have relatively accurate and adequate knowledge of secondary vegetation. The second interview was conducted during May-August, 2003, before carrying out the vegetation survey mentioned below. From the families of five longhouses, 24 interviewees were selected: they were household-heads or their wives, 30–80 years old. They were asked questions related to characteristics of fertile land and their site selection method. The final interview was conducted in May, 2004 to discover and assess indicator plants from among the plants encountered during the vegetation survey. The interview was administered to 33 household-heads or their wives out of the 38 landowners whose lands were surveyed for vegetation. The rest were absent during our visit to the longhouses for the interview. They were asked to classify the encountered plants into four categories, which we prepared to assess the importance of the plants as soil fertility indicators: plants indicating fertile land, plants indicating infertile land, plants indicating neither fertile nor infertile land, and plants that they do not know. By using a plant list made from the result of vegetation survey, we enumerated the plant names one after another to each interviewee to obtain the reply. In addition, the rice yields were recorded if they had cultivated the study sites after the vegetation survey. We were unable to measure the yield at the rice fields due to time limitation for survey. Therefore, the interviewees were asked to declare the rice yield based on the number of 50-kg fertilizer bags in which they usually kept rice before milling. We calculated the yield of brown rice using the average bag weight obtained from some measurements. Then, we asked questions concerning the sufficiency of rice production to accommodate the household needs for one year.

Vegetation survey

During May-August, 2003, 42 sites were selected from secondary forests with various fallow ages. These sites were managed by 38 households, including the 24 interviewees in the second interview. These sites were classified into 25 suitable sites and 17 unsuitable sites for upland rice cultivation by landowners, based on their perceptions through knowledge of vegetation. A 10 × 10 m^2 or 20 × 20 m^2 quadrat was established at each site. Based on the Iban nomenclature, the name, density and stem diameter at the breast height (DBH) of all woody plants were recorded. The name and density of all other smaller plants (grasses, ferns, tree seedlings, etc.) were also recorded at the quadrat or three sub-quadrates (2 × 2 m^2) established within it. Plant specimens were collected. The scientific names were identified at the Botanical Laboratory of the Forest Research Centre, Kuching with the assistance of a staff member of the Iban people. According to Tun Jugah Foundation (2001), although the Iban plant classification system shows a high degree of coincidence with the scientific classification system at a genus or family level, the relationship is not necessarily a one-to-one correspondence, especially at a species level. In some cases, the Iban names used for certain plants differ among persons, communities or regions. Therefore, we followed the plant names used by the landowners accompanying us to the field. In six cases, based on scientific identification and interviews, it was confirmed that they used different names for a single plant species, so that we treated them as the same plant: *Belian* with *Geriting* and *Teblian* (*Eusideroxylon zwageri*); *Belian Landuk* with *Teblian Landuk* (*Eusideroxylon melagangai*); *Deman* with *Resam* (*Dicranopteris sp.*); *Kejuru* with *Kemerlang* (*Scleria pupurescens*); *Sempan* with *Tempan* (*Ficus sp.*); and *Sukung* with *Tembusu* (*Fagraea crassipes*). Five plants which might be planted by farmers were also recorded in the survey: cocoa (*Theobroma cacao*), durian (*Durio sp.*), pineapple (*Ananas cosmosus*), para rubber (*Hevea brasiliensis*), and rambutan (*Nephelium spp.*). These plants were not excluded from data analyses because it was often difficult to discern whether the plants had been planted or were a natural regrowth. The Iban classify plants principally based on morphology, cultivation status and uses (Tun Jugah Foundation, 2001). Taking into account this fact and the responses of the farmers in the interviews, the plants observed in the survey were categorized into 11 groups: bamboos, ferns, gingers, grasses and herbs (excluding ginger), vines, palms, rattans, shrubs, trees, wild bananas, and unknowns. The vine group consisted of woody and non-woody vines, but the unknown group consisted of the plants that were unidentifiable by the farmers.

It should be noted that the term 'plant species' used in this study is not based on scientific classification but on the Iban's nomenclature system. For the Iban farmers, land evaluation and site selection are intended to provide adequate rice production for their subsistence. Therefore, the term *land fertility* or *soil fertility* is almost equivalent to the *suitability* of land for shifting cultivation (the Iban language *Tanah* means both land and soil). In this study, for convenience, *suitability* (*suitable* and *unsuitable*) is used for sites that we surveyed for vegetation and soils, whereas *land* or *soil fertility* (*fertile* and *infertile*) is used in contexts reflecting the farmers' perceptions.

Evaluation of plants as indicators

To evaluate the importance of plants encountered during the vegetation survey as indicators from an ecological viewpoint, the indicator value ($I_{ND}V_{AL}$), proposed by Dufrêne & Legendre (1997), was computed using the $I_{ND}V_{AL}$ 2.0 program (Legendre and Legendre, 1998). The $I_{ND}V_{AL}$ value gives an integrated measure of the relative mean abundance and the relative frequency of each species; it is calculated using the following equation:

$A_{ij} = N\ \text{individuals}_{ij} / N\ \text{individuals}_{+i}$

$B_{ij} = N\ \text{sites}_{ij} / N\ \text{sites}_{j}+$

$I_{ND}V_{ALij} = A_{ij} \times B_{ij} \times 100,$

where $I_{ND}V_{ALij}$ is the indicator value of species *i* in each cluster *j* (in this study, two clusters of suitable and unsuitable sites). In the definition of A_{ij} (relative mean abundance), N individuals$_{ij}$ is the mean number of individuals (log density = $\log_{10}$ (plants ha^{-1}+1)) of species i across sites pertaining to cluster j and N individuals$_{+i}$ is the sum of the mean number of individuals (log density) of species i in each cluster. In the formula for B_{ij}, N sites$_{ij}$ is the number of sites in cluster j where species i is present, whereas N sites$_{j+}$ is the total of the sites in the cluster j. Statistical significance of the $I_{ND}V_{AL}$ calculated for each species is tested between the two clusters using a randomization testing procedure at p = 0.05 in the program: the observed $I_{ND}V_{AL}$ is compared with 500 $I_{ND}V_{AL}$ values which are randomly generated with a random reallocation procedure between the two clusters. The program can give the output of the highest $I_{ND}V_{AL}$ value for each species between the two clusters and its significance.

Table 1. Average rice yield (Brown rice).

Respondents	No. of responses	Yield per family kg	Yield per capita kg
All	21	1388	362
Sufficient	15	1744* (414–6314)	484* (134–2115)
Insufficient	6	498 (238–1014)	78 (40–127)

Sufficient and insufficient: Answer to the question of whether rice production was sufficient for the household to live for 1 year or not. *Significantly higher in 'sufficient' than in 'insufficient' at $p < 0.05$ level using Student's t-test.

RESULTS

Shifting cultivation practices in the study area

In the study area, one-time cropping of upland rice is conducted at secondary forests with ages mainly of 2–10 years. Successive cropping is performed only when the rice yield in the previous year is very high. Primary forest was exhausted about 40 years ago. However, very old secondary forests with well-recovered vegetation sometimes remain near the longhouse in addition to those with difficult access from the longhouse and used only for timber production for domestic needs.

The use of chemical fertilizers and herbicides has become common. Farmers commonly apply a fertilizer named 'urea' or 'NPK', the latter of which contains N, P, K and trace elements, but at the rate of about one 50-kg bag per acre (0.407 ha) at most, when the rice plants grow to 30 cm height. Although they sometimes use herbicides (in most cases, paraquat dichloride) before sowing, weeding during the rice-growing season is mostly performed manually. Application of insecticides is not common.

The outline of farming calendar is as follows; the site-selection timing varies from early May to mid-June. Undergrowth is slashed within 2–3 days of the site selection and trees are felled, mostly using a chainsaw, after 1 month. Then, the field is burned at the end of July to August. The timing of sowing rice seeds depends on the use of herbicides to suppress weed germination after burning. Sowing without application of herbicides is conducted 2 days after burning, but that with the application is carried out 2–3 weeks after burning to await the emergence of weeds. The rice is harvested in February-April.

Results of the interview on rice production are summarized in Table 1. According to several farmers' comments, their primary concern in deciding the field size for rice cropping is to produce rice sufficient for their subsistence in a year because of difficult accessibility to Kapit town and lack of cash income. The farmers sometimes adjust the field size to be used in the current year depending on the rice production in the previous year or rice stocks. They commented that the production in 2003 before this study was normal. Therefore, the field size cropped during the study seemed to be normal for the farmers. Upland rice was planted at 21 suitable sites, but no unsuitable sites were cultivated. Of 21 households, 15 households (71%) answered that they were able to achieve rice yields sufficient to last them for one year. The average rice yield of those who answered 'sufficient' was significantly higher than that of those who answered 'insufficient' ($p < 0.05$).

Perception of the Iban farmers about characteristics of fertile land

Table 2 shows a summary of interviews concerning the characteristics of fertile land and the ecological component which farmers prioritize in the assessment of land fertility for site selection. For the question on the ecological component, the term 'indicator plants' is used when the interviewee mentioned specific plant name(s) (ex. *Tekalong*). The term 'trees' is applied to the answer '*Kayu* (tree)'.

The interviewees had rather common perceptions about topographical conditions: a fertile land is found on riversides or at the foot of hills with a gentle slope. However, some persons answered 'hillside' or 'hill top'. The soils in the fertile land are moderately clayey and are therefore able to retain an adequate amount of water

Table 2. Characteristics of fertile land and important ecological criteria for site selection.

Longhouse	Respondent	Sex	Topography		Soil properties						Vegetation			Ecological component prioritized
			Location	Slope	Color	Texture	1	2	Moisture	Gravel	Diameter	Undergrowth	Litter fall	
Along	1	M	R	M	Bl	M	F	I	Md	N	T	M	M	*Tanah*, size of indicator plants
Along	2	F	R, F, S, T	G	Bl	R	F	I	W	M	W	M	M	Size of trees
Along	3	F	R, F, S, T	G	Bl	S	F	I	W	F	W	M	M	Size of trees
Liok	4	F	R	G	Bl	S, M	F	I	Mi	M	W	N	M	Size of indicator plants
Liok	5	M	F	S, M, G	Bl, R	S	F	I	W, Mi, Md	M	W	M	M	*Tanah*, size of trees
Liok	6	M	R, F, T	G	Bl	S	F	I	W	F, N	W	M	M	Size of trees
Liok	7	F	F	G	Bl	M	F	I	W	M, C, F	W	M	M	*Tanah*, size of trees
Liok	8	M	R, F	G	Bl	M	F	I	Md	M	W	F	M	Size of indicator plants
Liok	9	M	S	G	Bl	–	F	I	Md	C	T	F	L	Size of indicator plants
Liok	10	F	R, F	G	Y	S	I	I	W	N	W	M	M	*Tanah*
Liok	11	M	R, F	G	Bl	–	I	I	Mi	M	W	M	M	–
Liok	12	M	R, F	S, M, G	Y	S	F	I	W, Mi	M	W	M	M	Size of trees
Peter	13	M	R, F	G	Bl	M	F	I	Mi, Md	N	W	F	L	Size of indicator plants
Peter	14	M	T	G	R	M	F	I	D	N	W	F	M	*Tanah*
Peter	15	F	F	G	Bl	M	F	I	W	N	W	M	M	Size of trees
Peter	16	F	F	G	Br	M	I	-	W	M	W	M	M	Forest condition
Peter	17	M	S	G	Bl	M	F	I	Mi	M	W	M	M	Presence of indicator plants
Peter	18	M	R, F	G	Bl	M	F	I	W	N	W	F	M	*Tanah*
Peter	19	M	F	G	R	M	F	I	Md	N	W	F	M	Size of indicator plants
Peter	20	M	S	G	R	M	F	I	W	F	W	F	M	Presence of indicator plants
Anding	21	M	F	G	Bl	S	I	I	W	F	W	M	M	Size of indicator plants
Anding	22	M	F	G	Bl	M	I	I	W	M	W	M	M	Size of indicator plants
Nawin	23	M	R, F, S, T	S, M, G	Bl	S	F	I	W	M	W	M	M	*Tanah*, many rocks is better
Nawin	24	F	R, F	G	Bl, Y	S	F	I	W	M	W	M	M	Presence of indicator plants, *Tanah*

Location: R, riverside; F, foot of hills; S, hillside; T, hill top; O, other.
Slope gradient: S, steep; M, moderate; G, gentle, O, other.
Color (free answer): Bl, black, Br, brown; R, red; Y, yellow.
Texture: S, sticky; M, moderate; R, rough.
1. The land where soils become slippery after rainfall is: F, fertile; I, infertile
2. The land where rainfall penetrates rapidly is: F, fertile; I, infertile.
Moisture content: W, wet; Mi, moist; Md, moderate; D, dry.
Gravel content: M, much; C, common; F, few gravel stones; N, none.
Diameter = Stem diameter of woody plants are larger than the size of: F, finger; A, arm; T, thigh; W, waist.
Undergrowth: M, much; C, common; F, few plants; N, none.
Litterfall: M, much; C, common; L, little; N, none.
Ecological component prioritized by farmers in assessment of land fertility for site selection: open answer; *Tanah*, land or soil condition.
'–' indicates no idea.

Table 3. Number of plant species encountered in a field survey (based on Iban nomenclature).

	Whole survey (at suitable and unsuitable sites, n = 42)	at suitable sites (n = 25)	at unsuitable sites (n = 17)	plants occurring at more than 5 sites out of 42 sites
Bamboos	2	1	1	0
Ferns	11	10	11	8
Gingers	10	7	7	2
Grasses and herbs	18	7	18	6
Vines	41	33	19	9
Palms	4	4	1	1
Rattans	2	2	1	1
Shrubs	20	14	12	4
Trees	136	110	80	39
Wild bananas	2	1	1	0
Unknowns	6	5	2	0
Sum	252	194	153	70

Vine group includes woody and non-woody vines.

although water permeability is good. The black soils, *Tanah chelum* (*tanah*, soil; *chelum*, black), are inferred to be the most fertile because of their high contents of soil organic matter and good moisture conditions. According to elderly interviewees, the black soils had been found under primary forests. Somewhat less fertile soils are yellow or red soils (*Tanah kuning*, *Tanah mirah*, respectively) which are clayey, whereas infertile soils are grey or white soils with a sandy texture. Two classes are applied to sandy soils, i.e. *Tanah pasir* (sand) and *Tanah kerangas* (heath forest). Some of farmers commented that cultivation in sandy soils would cause severe land degradation and that such cultivation should be avoided.

Perceptions about vegetation in fertile lands were also similar among the interviewees. The stem diameter of trees must be greater than a person's waist size. The bigger the diameter, the more fertile the land is. They assumed that trees would grow to the girth of a man's waist when left fallow for 20 years, after which the field is suitable for another round of rice cultivation. The answers on the amount of undergrowth varied in spite of the agreement on the requirement of litter fall. Some persons who answered 'much' for the amount of undergrowth considered the undergrowth and litter fall to be good fuel for burning, whereas persons answering 'few plants' considered undergrowth as an obstruction to rice growth.

The ecological component prioritized in the assessment of land fertility was related to secondary vegetation condition, i.e. the tree size in stem diameter and the presence or size of indicator plants, followed by the condition of *Tanah* (soil or land). Many respondents pointed out that the vegetation of fertile land is dark green and that the trees grow straight.

Plant species, densities, and DBH

Table 3 shows the species number of plants encountered in the field survey while Fig. 2 depicts the species numbers of the tree, grass and herb, and fern groups at the study sites along with fallow length. At the 42 study sites, 252 plant species were recorded, including 194 and 153 species at suitable and unsuitable sites, respectively. The rattan, bamboo, and wild banana groups were not classified properly because of confusing answers from interviewees. Although these groups comprise many species and have sub-order names (Tun Jugah Foundation, 2001), the farmers often recognized and called the plants only by their group names: *Wi* or *Rotan* for rattan (*Calamus spp*., etc.), *Buloh* for bamboo, and *Gentu'* or *Lengki* for wild banana.

The tree species accounted for more than 50% of the 252 species. For unsuitable sites, the species number of the tree group increased with increasing fallow duration (Fig. 2; r = 0.69, significant at p < 0.01 if the outlying data from one site with the age of 20 years was excluded). The species number of the tree group in suitable sites varied widely among the sites and no relationship was observed in terms of fallow duration. The total species number of the grass and herb group at the unsuitable sites was more than twice as much as that at the suitable sites (Table 3). The average species numbers of the grass and herb and

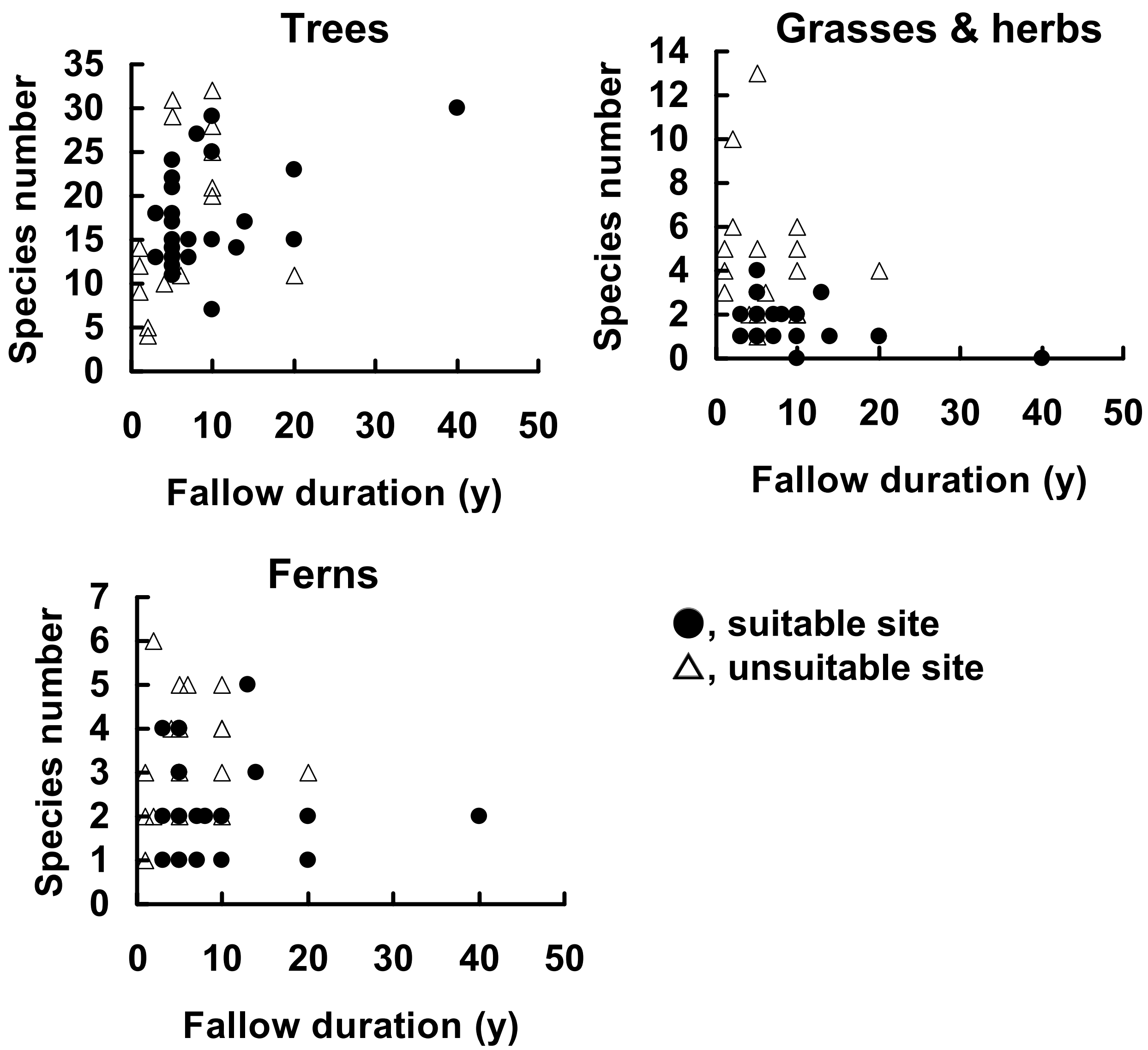

Fig. 2. Relationship between species number of plants and fallow duration of the study sites.

fern groups at the unsuitable sites were 4.5 and 3.4. They were significantly higher than those of 1.6 and 2.4 at the suitable sites, respectively ($p < 0.01$ and 0.05). However, both for the suitable and unsuitable sites, there were no correlations between the species number of the grass and herb group and the fallow length or between that of the fern group and the fallow length (Fig. 2).

The plant densities of the tree, grass and herb, and fern groups at the sites are shown along with fallow length in Fig. 3. There were no clear tendencies in the plant densities in terms of fallow length. However, the average density of the grass and herb group at the unsuitable sites was significantly higher than that at the suitable sites ($p < 0.01$). At some of the suitable sites, in particular, a density of the grass and herb group was less than 1,000 plants ha^{-1}. Among the unsuitable sites, the average density of the tree was significantly lower at the early fallow stages than at the later fallow stages of more than 5 years ($p < 0.05$) while that of grass and herb groups was higher at the early fallow stages ($p < 0.01$).

Thus, in the unsuitable sites, especially at the early stages of fallow, the plants of the grass and herb group, and the fern group to a lesser extent, was dominant in species number and density, compared with the suitable sites. Other plant groups showed no clear tendencies in species number and density in terms of fallow duration and site suitability.

Figure 4 shows the average DBH of the tree group at each study site. The DBH was clearly larger at suitable sites than at unsuitable sites ($p < 0.01$), especially after

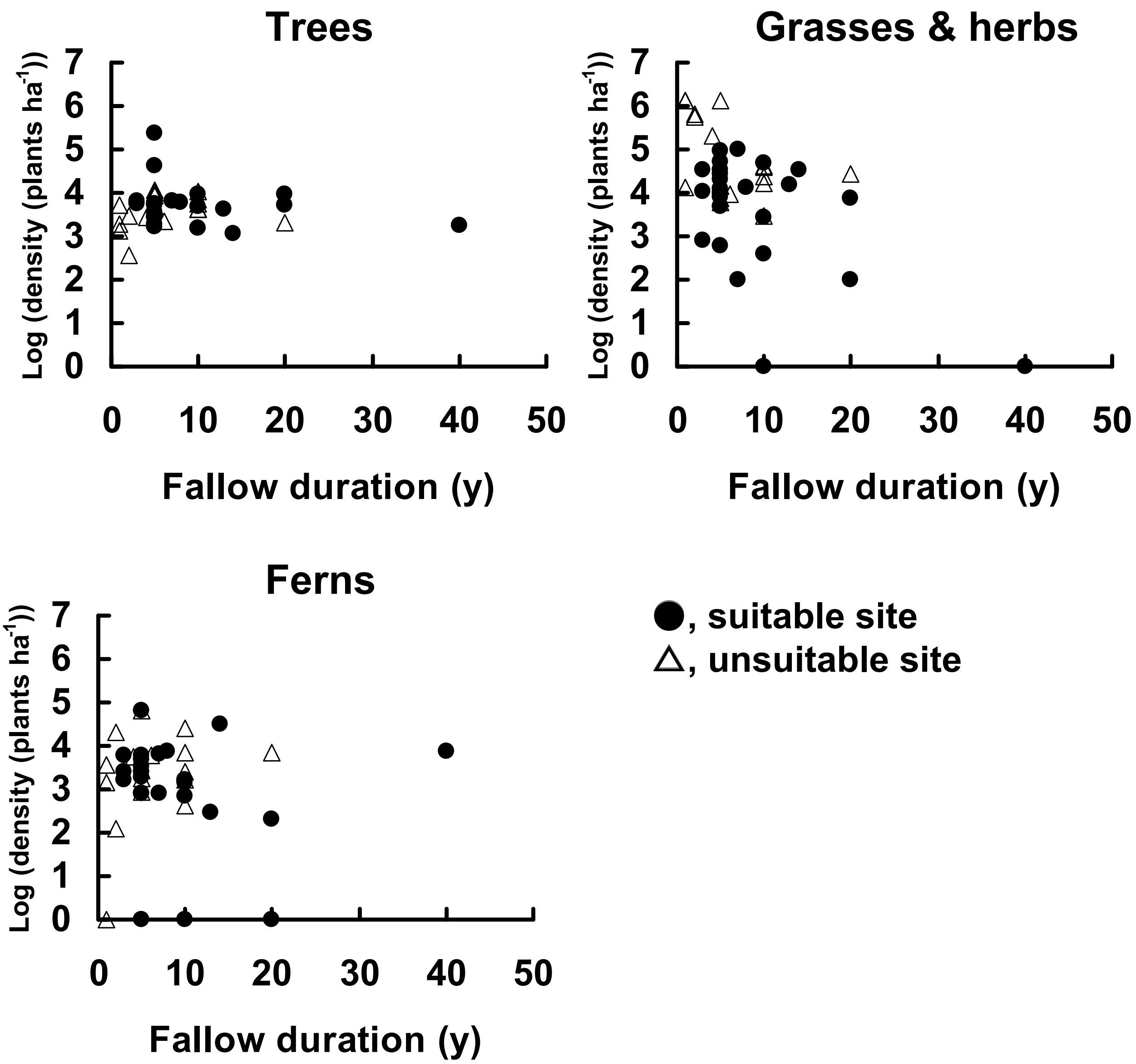

Fig. 3. Relationship between plant density and fallow duration of the study sites. Density is transformed to log (density (plants ha^{-1})).

about 5 years left fallow. This result was also true when the DBH of respective species are compared (data not shown), except for *Getah, Durian* and *Rambutan*.

$I_{ND}V_{AL}$ values and its relationship with the Iban's perception

Only 70 plant species were common at more than 5 sites out of the 42 sites (i.e., 10% of the study sites) (Table 3). Therefore, the results for those species were used for detailed analyses. Table 4 shows the $I_{ND}V_{AL}$ values calculated for these 70 species and the farmers' perception of them as indicators for land fertility. Thirty-three species scored higher $I_{ND}V_{AL}$ values for the cluster of suitable sites (cluster S) than for the cluster of unsuitable sites (cluster U). Among these species, the $I_{ND}V_{AL}$ values of seven species of the tree group, two species of the vine group and one species of the ginger group were statistically significant for the cluster S. On the other hand, 37 species showed higher $I_{ND}V_{AL}$ values for the cluster U. The values of six species of the tree group, two species of the shrub group, one species of the vine group, four species of the grass and herb group, and three species of the fern group were significant for the cluster U.

Most plants in cluster S were perceived as indicating fertile land by most farmers, irrespective of the significance of the $I_{ND}V_{AL}$ values. In the tree group,

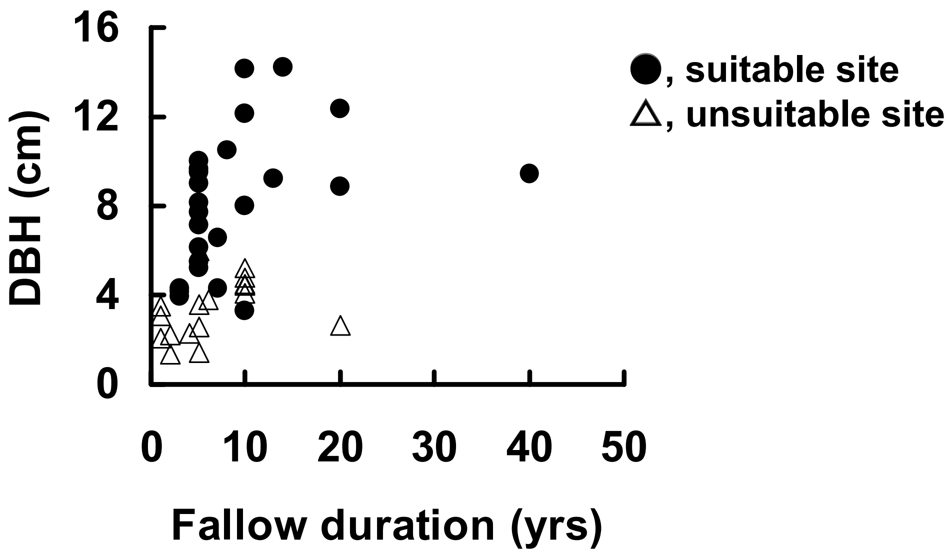

Fig. 4. Relationship between average DBH of trees taller than breast height and fallow duration of the study sites.

only one species *Entali* was oppositely evaluated by the farmers. In contrast, in cluster U, the farmers' perception for only seven species were consistent with the $I_{ND}V_{AL}$ values, including two species of the fern group (*Selap padi, Kemiding*), two species of the shrub group (*Kemunting, Sempulut babi*), and three species of the grass and herb group (*Lalang, Rumput belanda, Berang empeliau*). In contrast to these seven species, many other species which were perceived to indicate fertile land showed higher $I_{ND}V_{AL}$ values for the cluster U oppositely.

DISCUSSION

Alteration of shifting cultivation and socio-economic factors relating to site selection

According to Freeman (1955, 1970), the Iban of the Baleh area in the middle 20th century had usually practiced successive cropping of upland rice after clearing primary forests. The Iban's customary law provides that land tenure is established by a household by felling primary forests. Therefore, the Iban farmers had enthused over looking for primary forests to expand their land holdings. However, our study depicted that the shifting cultivation at present was conducted with relatively short fallow periods while primary forest had been exhausted. This system resembles that in the Batan Ai area of Sarawak, where the Iban had settled for more than 300 years, with the fallow duration of 4 to 15 years (Padoch, 1982).

While secondary forests with young ages were used for shifting cultivation, very old secondary forests still remained within the longhouse territory. The tree sizes of these forests were likely to conform well to the criteria for site selection. This fact indicates that some very old secondary forests are excluded from sites that have been proposed for shifting cultivation. Two practical factors are likely to relate to this first stage of decision-making for site selection: accessibility of the field and labor availability. Farmers preferred sites that were located within a one-hour walking distance from their longhouse because of advantages of time saving and avoidance of carrying heavy loads such as harvested rice and fertilizers. This locational consideration lead to the frequent use of farming sites near the longhouse and shortened fallow duration. Labor availability for rice farming is another important factor. Labor division between the sexes is common for various tasks that are inherent to the shifting cultivation practice (Freeman, 1955). Farming in old secondary forests requires high labor input for felling (mostly done by men) but low input for weeding (mostly done by women), whereas that in young secondary forest requires high input for weeding (Padoch, 1982). In addition, cash-crop planting, such as that for para rubber and pepper, requires much family labor input. However, in the study area, the family member(s), mostly males, were often away from the longhouse to engage in off-farm wage work. Therefore, limitations of labor availability of a household also influence the preference for short fallow periods and for farming sites near the longhouse.

Rice yields (brown rice) obtained from the Iban's

Table 4. *IndVal* values of the plants occurred in the field survey and the Iban's perception of them to indicate land fertility.

Plants with higher IndVal values for the cluster of suitable sites						Plants with higher IndVal values for the cluster of unsuitable sites					
	Iban name	Scientific name	IndVal	No. respondents			Iban name	Scientific name	IndVal	No. respondents	
				Fertile	Infertile					Fertile	Infertile
Tree	*Engkerebai*	*Psychotria aurantiaca*	52*	27	1	Tree	*Kepapa*	*Vitex longipes*	63*	31	2
	Entemau	*Ficus semicordata*	50	31	2		*Getah*	*Hevea brasiliensis*	51*	33	0
	Tekalong	*Artocarpus elasticus*	42	31	2		*Sempan*	*Ficus* sp.	47*	17	3
	Empitap	*Nauclea borneensis*	41	33	0		*Kayu Ara'*	*Ficus racemosa*	46*	29	4
	Entali	*Macaranga costulata*	39	13	16		*Patuk Tilan*	*Cratoxylum cochinchinense*	45*	30	0
	Mata Ikan	*Saurauia amoena*	38	31	1		*Manyam*	*Glochidion arborescens*	42	27	5
	Purang	*Macaranga trachyphylla*	37	33	0		*Mulung Udok*	*Timonius billitonensis*	31	32	0
	Serang	*Euodia alba*	32*	30	2		*Bilau*	*Callicarpa pentandra*	27	33	0
	Kumpang	*Horsfielda grandis*	29*	32	1		*Lengkan*	*Ficus grossularoides*	25*	29	2
	Belian	*Eusideroxylon zwageri*	28	33	0		*Bintangor*	*Calophyllum blancoi*	24	31	1
	Maba	*Crypteronia paniculata*	28*	22	0		*Medang*	*Cratoxylum cochinchinense*	22	33	0
	Manding	*Erythroxylum cuneatum*	28*	31	0		*Ubah Ribu*	*Anisophyllea disticha*	19	20	2
	Leban	Vitex sp.	24*	24	1		*Pudu*	*Artocarpus nitidus*	19	33	0
	Aras	*Ilex cissoidea*	24	22	11		*Durian*	*Durio* sp.	18	33	0
	Kedang Belum	*Milletia vaeta*	23	32	1		*Meregang*	*Commersonia bartramia*	18	22	2
	Puak	*Baccaurea macrocarpa*	20*	31	1		*Rambutan*	*Nephelium lappaceum*	17	31	0
	Entapung	*Vernonia arborea*	19	30	2		*Engkala'*	*Litsea garciae*	13	32	0
	Terentang Tikus	*Buchanania sessilifolia*	18	32	1	Shrub	*Kemunting*	*Melastoma polyanthum*	46*	8	25
	Rengas	*Semecarpus rufovelutinus*	13	29	3		*Lemba*	*Curculigo latifolia*	36	31	1
	Kandis	*Garcinia eugeniifolia*	13	29	2		*Sempulut Babi*	*Hibiscus* sp.	26*	15	17
	Beringin	*Dillenia excelsa*	13	32	0	Vine	*Nyalin*	*Xanthophyllum* sp.	41*	29	2
	Semukau	*Monocarpia marginalis*	8	32	1		*Akar Melebu*	*Ventilago malaccensis*	25	33	0
Rattan	*Rotan*	Unid.	16	32	0		*Akar Bandars*	*Smilax* sp.	21	19	12
Palm	*Aping*	*Arenga brevipes*	7	31	1		*Akar Malam*	*Merremia peltata*	18	33	0
Vine	*Akar Bebai*	*Unid.*	44*	27	6		*Akar Kemedu*	*Spatholobus ferrugineus*	14	32	1
	Akar Remat	*Lycopodium borneense*	40	23	10	Grass &	*Lalang*	*Imperata cylindrica*	57*	5	28
	Akar Kelait	*Uncaria ferrea*	24*	29	3	herb	*Kejuru*	*Scleria pupurescens*	55*	19	13
	Akar Kemudang	Smilax sp.	12	22	11		*Rumput Belanda*	*Paspalum conjugatum*	45*	13	20
Ginger	*Kemuyang*	*Homalomena sagittifolia*	30*	32	1		*Berang Empeliau*	*Isachne albens*	41*	13	19
	Tepus	*Etlingera timbracteata*	11	32	0		*Rumput Melebap*	*Cyrtandra bracheia*	24	30	2
Fern	*Paku Kerejai*	*Tectaria crenata*	29	29	4		*Rumput Tukol*	*Jacquemontia tomentella*	21	26	7
	Paku Pait	*Christella arida*	11	27	6	Ginger	*Kechala*	*Etlingera elatior*	11	33	0
	Kelindang	*Blechnum orientale*	11	20	13	Fern	*Paku Remat*	*Lygodium microphyllum*	43*	23	10
							Selap Padi	*Lycopodiella cernua*	40*	15	18
							Paku Kubok	*Cyslopettis presliana*	40	30	2
							Paku Lang	*Selenodesmium obscurum*	29*	26	5
							Kemiding	*Stenochlaena palustris*	9	16	17

IndVal values with a * symbol are significantly higher in one cluster than others at $p = 0.05$ by a randomization testing procedure. Fertile: the number of respondents who answered that the plant indicates fertile land. Infertile: the number of respondents who answered that the plant indicates infertile land.

shifting cultivation practices was reported to be about 1,000 kg ha^{-1} or 300 kg per capita (Freeman, 1970; Padoch, 1982). The rice consumption per capita was estimated as 211 kg per year (Freeman, 1970). The average yield of the households who answered that they had self-sufficiency in rice production reached these values (Table 1). Freeman (1970) stated that in normal years, 70 to 80% of the Iban households would attain their requirements of rice for subsistence. The value of 71% in this study was comparable to his reported value in spite of the difference in methodology used for survey.

Compared to the Iban in the Lubok Antu area (Kendawang et al. 2005b), those in the Mujong River area in this study used chemical fertilizers and agrochemicals to a lesser degree, probably because of the difficult access to markets.

Ecological interpretation of farmers' perception about topography and soils in relation to land fertility

Many of interviewees answered that topographical locations where fertile land is located are riversides or the foot of hills with a gentle slope. This perception is understandable because such lower land generally shows high soil fertility attributable to the deposition of surface soils eroded from upper to lower slopes. Moisture conditions of the lower land are also likely to be better than those of hillside land, even during a drought. For the black soils, in general, soil organic matter plays important roles of nutrient and moisture retention. Furthermore, higher contents of soil organic matter can be an important source of nutrients, especially nitrogen, for crops through heat decomposition at burning time and subsequent decomposition during cropping period (Kendawang et al. 2005a).

Some persons answered that fertile land is located on 'hillside' or 'hill top'. They commented that sandy soils are often deposited on a riverside and a foot of hills. These sandy soils seemed to correspond to *Tanah pasir*. On the other hand, another classification of sandy soil, *Tanah kerangas* is podozol composed of white silica sand and is distributed patchily on dip hills, and *kerangas* (heath) forests grow there (Mackinnon et al. 1997; Whitmore, 1998). Once cleared for cultivation, nutrient levels in such sandy soils decline rapidly, resulting in very low rice yields and the poor subsequent vegetation recovery (Kendawang et al. 2004; Tanaka et al. 2004; Kendawang et al. 2007) in agreement with the farmers' comments about cultivation on sandy soils.

These views about topography and soil condition are similar among ethnic groups in Borneo (e.g., Dove, 1981; Gönner, 2002; Sindju, 2003). Although the Benuaq and Kenyah examine soil texture by inserting the blade of a bush-knife into the soil (Sardjono and Sansoedin, 2001 for Benuaq; Chin, 1985 for Kenyah), the Iban in the study area did not use this testing method.

Ecological evaluation of indicator plants and the Iban's perception

Dufrêne and Legendre (1997) defined indicator species as the most characteristic species found mostly in a single group of a typology and present at most sites belonging to that group. They proposed the $I_{ND}V_{AL}$ value, which is an integrated measure of the relative abundance and relative frequency of species occurrence. In this sense, all plants that showed significant $I_{ND}V_{AL}$ values for either cluster S or cluster U can be regarded as useful indicator plants to evaluate land suitability for shifting cultivation. However, while most plants in cluster S were perceived as indicating fertile land by most respondents, many species with higher $I_{ND}V_{AL}$ values for the cluster U were oppositely perceived to indicate fertile land. This inconsistency is explainable using data depicted in Fig. 4. Irrespective of the $I_{ND}V_{AL}$ values, most tree species in the unsuitable sites showed smaller DBH than at the suitable sites. It is indicated that although the Iban perceived the presence of many plants (mostly tree species) as indicators for fertile land, they investigated the size of these plants comprehensively when evaluating land fertility and selecting sites for shifting cultivation. *Getah*, *Durian* and *Rambutan* did not follow the tendency in DBH. These plants are commercially valuable or edible for domestic consumption. Therefore, the farmers might answer about them to indicate fertile land with a preconceived preference.

In general, species composition and growth during the fallow period result from complex interactions among a number of conditions and factors which occur before and during the fallow period, i.e., land management such as fire intensity and the number of cultivations, seed sources in soils or from the surrounding forests, soil fertility, and light conditions (Kendawang et al. 2007). The higher $I_{ND}V_{AL}$ values of tree species for the cluster U and the smaller DBH at unsuitable sites suggest that although the sprouts or germinating seeds of these tree species were more abundant at unsuitable sites than at suitable sites because of the interaction of these conditions and factors, growth was restricted at unsuitable sites. This difference in tree size is ascribable to soil nutrient status, as discussed in the paper to follow (Tanaka et al., 2007).

On the other hand, seven species showed higher $I_{ND}V_{AL}$ values in cluster U, which were consistent with the farmers' perception (Table 4). These plants occurred at unsuitable sites with a high relative density and a high relative frequency at the early stages of fallow period. The plants accounted for major parts of the density of each group at each site (data not shown). Other researchers also reported that these plants dominated the vegetation at the early stages of the fallow period (Mackie, 1986; Ipoh and Tawan, 2004). *Lalang*, in particular, is a predominant species in the extensive grasslands that are created from the combination of forest fires, drought, and human impacts in Indonesian Kalimantan (Kiyono & Hastaniah, 2000). It complicates rice cropping because of the difficulty in eradicating its fibrous root system. These views on *Lalang* are probably reflected by its predominant perception as an indicator for infertile land. However, it is noteworthy that some farmers stated that *Lalang* would disappear after several years if left fallow; subsequently, the field is useful for shifting cultivation. Some other species and related genera are also perceived by other ethnic groups to indicate infertile land: *Juten* (*Melastoma malabathricum*) and *Siet* (*Scleria spp.*) by the Lepo Ga', a subgroup of Kenyah (Chin, 1985) and *Lio fade* (*Lycopodium cernuum*, *Selap padi* in the Iban) by the Lun Dayeh (Padoch, 1986).

However, judging from the number of respondents in Table 4, the farmers did not always evaluate four species, i.e. *Sempulut babi*, *Berang empeliau*, *Selap padi* and *Kemiding* to be the indicators for infertile land in contrast to high evaluation for *Lalang* and *Kemunting*. It could be assumed that these plants are less important for farmers to assess land fertility although they dominate in unsuitable sites.

Some species of the vine group scored higher $I_{ND}V_{AL}$ values for the cluster U (Table 4), but this was inconsistent with the Iban's perception. We could not find appropriate explanation.

Site selection method of the Iban

We can summarize the site selection method of the Iban for shifting cultivation as follows: Based on deliberation about accessibility and labor availability, the Iban farmers first exclude secondary forests with difficult access from the longhouse and those which have a vegetation condition that is beyond their management capacity as the candidate for farming, even if the forest has recovered well. After that stage of decision-making, the criteria of land fertility are incorporated into the consideration. The ecological component prioritized in assessment of land fertility was related to secondary vegetation condition, although the topography and soil conditions are also considered. Indicator plants such as *Lalang* and *Kemunting*, which indicate infertile land, seem to serve important roles as criteria. These species occur with higher frequency and higher density at sites in the early stages of fallow less than about 3 years. Therefore, the farmers perceive these sites as unsuitable for shifting cultivation. At such sites, the N availability is low; moreover, nutrient input to the soil surface through ash addition at burning time is expected to be slight because of poor aboveground biomass (Tanaka et al. 2007). With increasing length of fallow periods, tree species replace the pioneering small plants, such as grasses, ferns, and shrubs, through vegetation succession. At that stage, the farmers investigate the stem diameter of trees and select a site where the trees recover well. Judging from results of interviews concerning the fallow duration and the measurement of the DBH as shown in Fig. 4, the minimum requirement of the tree size for site selection in the current shifting cultivation system is about 5 cm in diameter, although after 15–20 years, the trees are likely to grow to more than 20 cm in diameter, i.e., the ideal value in the farmers' perception. Burning a large amount of aboveground biomass can ameliorate acidic conditions of soils and improve the nutrient status of the soils through ash input (Tanaka et al. 2004, 2005). It can also release NH_4–N into the soil through heat decomposition processes of soil organic matter (Kendawang et al. 2005a).

Taking into account the influence of topography, microclimate or other incidents such as the occurrence of diseases and insect damage under lighter applications of fertilizers and agrochemicals, the ratio of 71% that the respondents could produce sufficient rice seemed to be high. In other words, it can be concluded that the Iban site selection was appropriate for achieving adequate rice production.

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