Tree stand floristic dynamics in secondary forests of different ages in Sarawak, Malaysia

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Abstract. *Karyati, Ipor IB, Jusoh I, Wasli ME. 2018. Tree stand floristic dynamics in secondary forests of different ages in Sarawak, Malaysia. Biodiversitas 19: 767-773.* Succession is a series sequential processes of the development of floristic community which involves changes in community structure, species composition and diversity over time. The information on tree stand floristic dynamics of various stages of succession in secondary forests in Malaysia is currently lacking. This study was conducted to determine tree stand structure, floristic composition, and species diversity in various stages of secondary forest development in the study areas. A total of 997, 1,842, and 834 tree stems with diameter at breast height (DBH) of ≥ 5 cm were recorded in one-hectare-plots of 5, 10, and 20 year old secondary forests, respectively. The ten most common species in 5 and 10 year old of secondary forests consisted mostly of light demanding species. In the 20 year old secondary forest, these species did not exist. *Macaranga gigantea* was the most dominant tree species in the 5 and 10 year old secondary forests in terms of basal area and volume per hectare. The most common species, based on density, basal area, volume, and Importance Value Index (IVi), in the 20 year old secondary forest was *Adinandra dumosa*. The diversity and richness indices of the 10 year old secondary forest were the highest among all study sites.

Keywords: Floristic composition, diversity, secondary forest, vegetation structure, succession

Abbreviations: DBH: Diameter at Breast Height; BA: Basal Area; V: volume; H': Shannon-Wiener's diversity index; D_s: Simpson's dominance index; J': Pielou's evenness index; R: Margalef's richness index; ISS: Sørensen similarity index

INTRODUCTION

The primary forests of Sarawak are shrinking due to the combination of logging and shifting cultivation. They are replaced by secondary forests with lower stature and altered species composition (Primack and Hall 1992; Jomo et al. 2004). Human disturbances bring negative effects to forest and cause lower species diversity and simplified community structure (Dianpei et al. 2004). Following field abandonment, secondary forest develops naturally (Van Do et al. 2010). Secondary forests are identified by their structure and extent of vegetative cover, as well as their composition in terms of dominant and secondary species (Mittelman 2001; Van Breugel et al. 2006). Without additional disturbances, secondary forests will undergo succession and develop into forests with structure similar to that of the original forests (Kartawinata et al. 2001). The dynamics at several temporal periods of forest disturbances determine plant diversity within a regenerating fallow (Lawrence 2004). Brearley et al. (2004) stated that fifty-five years of succession is insufficient for the recovery of the most primary forest species. The secondary forests are especially vital in conserving biodiversity because they provide the last remaining corridors (Mittelman 2001). Karyati et al. (2013) reported that plant seedlings and saplings in 3 and 5 year old secondary forests in Sabal area of Sarawak were dominated by light demanding and fast growing species, such as *Melastoma malabathricum* L.,

Ploiarium alternifolium Melchior, and *Ficus aurata* Miq. as well as *Dillenia* spp. and *Macaranga* spp. *Dillenia suffruticosa* Martelli was also a common species in both 10 and 20 year old secondary forests.

Information on the capability of abandoned land after forest disturbance in providing ecological functions is vital in order to ease the pressure on the natural forest ecosystem as an ecotone for balancing the tropical forest ecosystem. Many studies had been done on the floristic composition and stand structure of the tropical forest in Borneo Island, but few similar studies have been done in various stages of secondary forests in Sarawak.

This study was conducted in order to determine the community structure, floristic composition, and species diversity of tree stand in secondary forests of different ages during early secondary succession process at abandoned lands.

MATERIALS AND METHODS

Study sites

The study was carried out in three stages of fallows (period of abandonment), namely 5 year old, 10 year old, and 20 year old secondary forests in Sabal, Sri Aman, Sarawak, East Malaysia (Figure 1). The geographic locations of these sites are 01°04'43.3"N 110°59'02.0"E, 01°03'55.9"N 110°55'51.4"E, and 01°03'59.3"N

110°53'34.4"E, respectively. The same sites had been studied previously for composition and diversity of seedlings and saplings (Karyati et al. 2013) as well as their soil properties (Karyati et al. 2014). The study plots at Sabal were located approximately 110 km southeast of Kuching along the Kuching-Sri Aman Road and 5 to 15 km from the Sabal Agroforestry Centre. The study sites had similar histories of abandonment after shifting cultivation, as told by the land owner and confirmed by Sabal Agroforestry Centre staff. The original vegetation at Sabal site was lowland mixed dipterocarp forest with heath forest (kerangas) (Kendawang et al. 2007). In the study sites, the soil was categorized as acidic soil, indicated by the pH (H_2O) values of lower than 5 and the low content of T-C, T-N and exchangeable bases (Karyati et al. 2014).

Data collection

The surveys of vegetation were conducted in 5, 10, and 20 year old secondary forests. Twenty five sub plots each measuring 20 m × 20 m were established within each study site. The diameter at breast height (DBH) and total height of all woody trees with DBH of $\geq$ 5 cm within the plots were enumerated and their species were identified. Nomenclature was checked in the flora records of the study area (Anderson 1980; Jawa and Chai 2007).
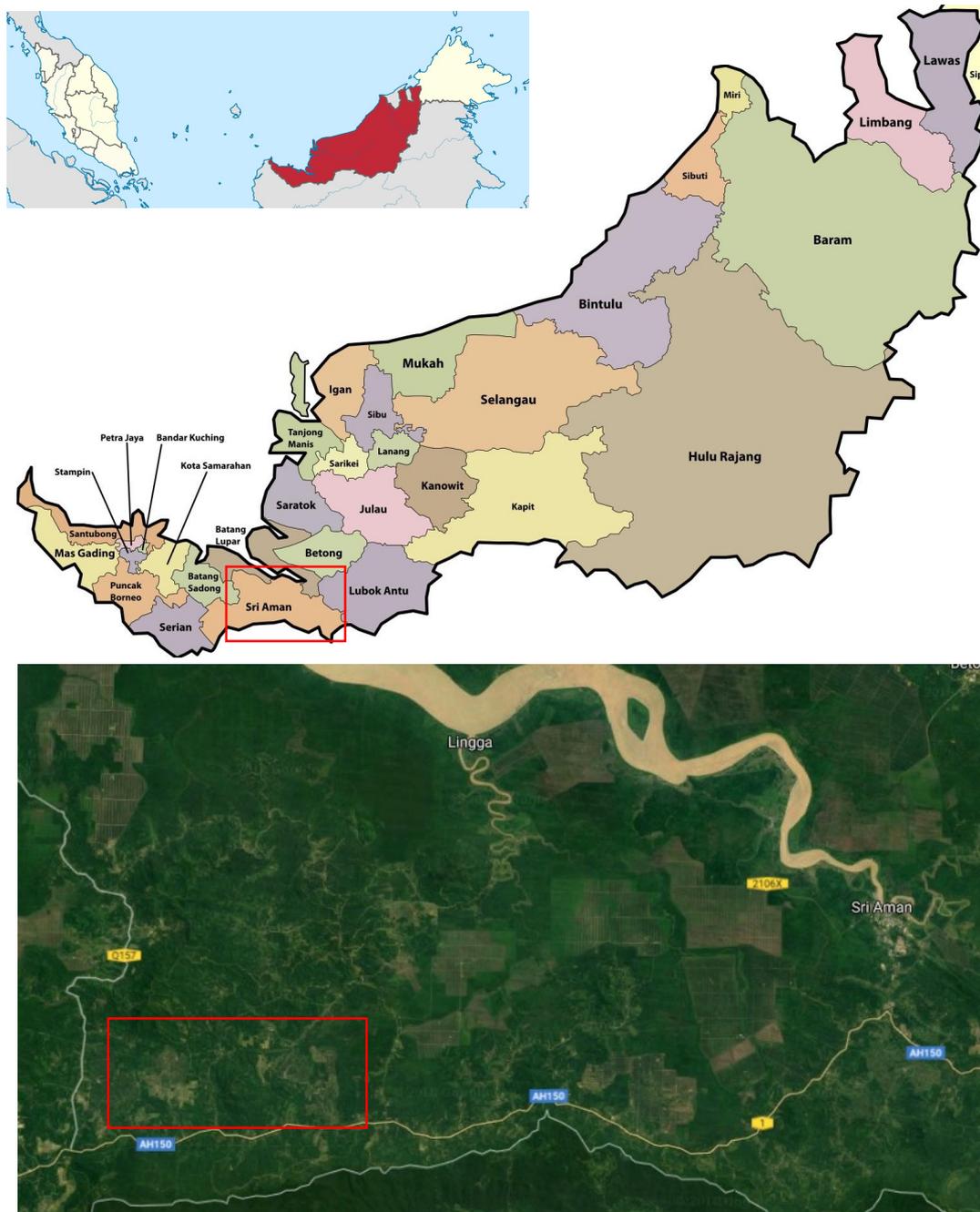

Figure 1. Map of the study area in Sabal, Sri Aman, Sarawak, East Malaysia

Data analysis

The dominant species of forest community were determined by importance value index (IVi) of species within the plots (Fachrul 2007). The similarity of species composition among different communities was determined using Sørensen similarity index (ISS) (Fachrul 2007). The diversity indices of Shannon-Wiener's diversity index (H'), Simpson's dominance index (D_s), Pielou's evenness index (J'), and Margalef's richness index (R) were used to measure species diversity of standing trees in each community (Odum 2005). The mean values of H', Ds, J', and R for each site were compared with one-way analysis of variance (ANOVA) by Tukey's tests. All statistical tests were conducted using SPSS version 18 for Windows (SPSS Inc. 2012).

RESULTS AND DISCUSSION

Stand structure
Diameter at Breast Height (DBH) and Height Distributions

The density of trees among DBH classes differed among three succession stages of secondary forests. The total number of trees decreased as the DBH increased, and generally forms L-shaped distribution as shown in Figure 2. The tree DBH distribution in secondary forests in the study sites were skewed towards the smaller DBH classes, with more than 90% of all trees with the DBH of $\geq$ 5 cm in the 5.0-10.0 cm class for the 5 and 10 year old secondary forests, while in the 20 year old secondary forest all trees with the DBH of $\geq$ 5 cm in the 5.0-10.0 cm class constituted more than 45% of the total number of tree species. The reverse-J-shaped tree diameter distributions were reported for secondary forests (Álvarez-Yépiz et al. 2008; Feldpausch et al. 2007). The distribution of height classes at different interval classes was slightly positively skewed at each of the three study sites (Figure 3).

Density, basal area, and volume

The highest density was recorded in the 10 year old secondary forest (1,842 stem per hectare) as presented in Table 1. Three species such as *Macaranga gigantea* Mull. Arg., *Vitex pubescens* Vahl., and *Dillenia suffruticosa* Martelli were dominant in terms of density, basal area and volume per hectare in the 5 and 10 year old secondary forests. Several pioneer species, such as *Macaranga hypoleuca* Mull. Arg. and *Macaranga caladifolia* Becc. were also common in the 10 year old secondary forest, and *Macaranga trichocarpa* Mull. Arg. in the 5 year old secondary forest. In the 20 year old secondary forest, *Adinandra dumosa* Jack, *Artocarpus integer* (Thunb.) Merr., *Cratoxylum arborescens* Blume. and *Pellacalyx axillaris* Korth. were the dominant species based on the number of stems, basal area, and volume per hectare.

The total basal area and volume per hectare increased with the increasing period of abandonment. The increase of DBH and height caused increase in total basal area and volume per hectare in the study sites. This indicated that during successional process many seedlings and saplings had grown into larger trees in the older secondary forest. The dynamics and development of secondary forests were showed by the trends in increasing average DBH, height, basal area and volume following the increasing fallow age.

Floristic composition
Importance Value Index (IVi)

The ten most common species consisted mostly of light demanding pioneer and fast growing species in the 5 and 10 year old secondary forests, such as *Macaranga* spp., *D. suffruticosa*, and *V. pubescens* in terms of IVi (Table 2). The dominance of pioneer species appeared in early successional stage, and decreased gradually in the 20 year old secondary forest. The late pioneer species and secondary species were dominant in the 10 and 20 year old secondary forests. The secondary rain forest consists of long-lived intolerant trees, big pioneers, and fast-growing species. This study showed that under similar land use change (due to slash and burn), the species composition of trees with DBH of $\geq$ 5 cm changed gradually during early secondary succession process at abandoned lands after shifting cultivation. The development of vegetation after slash and burn process at different ages of fallow lands can be observed, in terms of density, total basal area, and volume per hectare. It is mainly influenced by secondary succession process and fallow age at abandoned lands. As the average DBH and height as well as basal area and volume increased with increasing fallow ages, the results showed that the secondary forests would continue to develop into mature forest. The results also showed that there were similar species composition in the 5 and 10 year old secondary forests. However, the 20 year old secondary forest showed relatively different species composition among three study sites. This showed that species composition at abandoned lands after burning began to change after 20 years of abandonment. Van Breugel et al. (2006) stated that forest development can show gradual or abrupt changes, depending on the species composition and the degree of dominance by one or few species. Species composition may explain differences in forest structure; particularly stem density and basal area or biomass, across sites (Marin-Spiotta et al. 2007).

Similarity index

The Sørensen similarity index between the 5 and the 20 year secondary forests was the highest (52.17%), followed by the 10 and the 20 year old secondary forests (44.12%), and the 5 and the 10 year old secondary forests (41.70%) (Table 3). The similarities of trees (DBH of $\geq$ 5 cm) were intermediate among all study sites. The results showed that the early stage of secondary succession of fallow lands after shifting cultivation had many common species. This indicated that the compositions of species were dominated by similar species during successional process at different stages of fallow periods.

Table 1. Density, basal area, and volume of ten most common species (DBH of > 5 cm) in 1 hectare of each study site

Species	SF-5 years old			SF-10 years old			SF-20 years old		
	N	BA	V	N	BA	V	N	BA	V
Adinandra dumosa Jack							169	3.62	32.50 (1)
Alphitonia excelsa Reissek ex Endl.	53	0.20	0.82 (7)						
Alstonia spatulata Blume				15	0.15	1.57 (7)			
Artocarpus integer (Thunb.) Merr.							35	0.94	11.13 (2)
Cratoxylum arborescens Blume.	19	0.08	0.37 (10)				11	0.79	9.63 (3)
Cratoxylum formosum Benth. & Hook. f. ex Dyer							6	0.22	3.33 (7)
Cratoxylum glaucum Korth.	72	0.30	1.40 (5)						
Dillenia suffruticosa Martelli	115	0.33	1.23 (6)	224	0.68	2.34 (5)			
Endospermum diadenum (Miq.) Airy Shaw				39	0.23	1.47 (9)	20	0.39	3.23 (9)
Euodia glabra (Bl.) Bl.	85	0.36	1.56 (3)				14	0.35	4.25 (5)
Glochidion arborescens Blume.	25	0.12	0.55 (8)						
Macaranga caladifolia Becc.				66	0.33	1.79 (6)			
Macaranga gigantea Mull. Arg.	112	0.60	2.83 (1)	81	0.90	6.50 (1)			
Macaranga hypoleuca Mull. Arg.				42	0.32	2.51 (4)			
Macaranga pruinosa Mull. Arg.				32	0.20	1.27 (10)			
Macaranga trichocarpa Mull. Arg.	88	0.35	1.48 (4)						
Macaranga triloba Mull. Arg.				83	0.52	3.41 (2)			
Nephelium cuspidatum Blume				60	0.26	1.48 (8)			
Palaquium decurrens H.J. Lam							14	0.27	3.32 (8)
Pellacalyx axillaris Korth.							53	0.91	8.09 (4)
Saurauia glabra (Ruiz & Pav.) Soejarto							22	0.35	3.12 (10)
Timonius flavescens Baker							32	0.43	3.64 (6)
Vernonia arborea Buch. Ham.	19	0.10	0.47 (9)						
Vitex pubescens Vahl.	120	0.43	1.83 (2)	135	0.67	3.35 (3)			
Total	708	2.87	12.55	777	4.25	25.72	376	8.26	82.24
Total per hectare	997	3.87	16.73	1,842	9.11	53.12	834	14.06	133.73

Note: SF=secondary forest, N=density (stem ha^{-1}), BA=basal area (m^2 ha^{-1}), and V=volume (m^3 ha^{-1}). The figures in parentheses are the ranking in terms of volume, (1) being the species with the highest volume

Table 2. Importance value index (IVi) of ten most common species of trees (DBH of > 5 cm) in 1 hectare of each study site

Species	Family	SF-5 years old	SF-10 years old	SF-20 years old
Adinandra dumosa Jack	Theaceae		7.81 (8)	50.34 (1)
Alphitonia excelsa Reissek ex Endl.	Rhamnaceae	15.61 (7)		
Artocarpus integer (Thunb.) Merr.	Moraceae			14.70 (3)
Cratoxylum arborescens Blume.	Clusiaceae			9.26 (5)
Cratoxylum glaucum Korth.	Clusiaceae	17.72 (6)		
Dillenia suffruticosa Martelli	Dilleniaceae	26.43 (3)	21.74 (1)	
Endospermum diadenum (Miq.) Airy Shaw	Euphorbiaceae		7.26 (9)	7.97 (7)
Euodia glabra (Bl.) Bl.	Rutaceae	24.19 (5)		5.94 (10)
Ficus aurata Miq.	Moraceae	8.99 (9)		
Glochidion arborescens Blume.	Euphorbiaceae	9.58 (8)		
Macaranga caladifolia Becc.	Euphorbiaceae		9.32 (5)	
Macaranga gigantea Mull. Arg.	Euphorbiaceae	31.16 (1)	17.41 (2)	
Macaranga hypoleuca Mull. Arg.	Euphorbiaceae		8.56 (6)	
Macaranga trichocarpa Mull. Arg.	Euphorbiaceae	24.26 (4)		
Macaranga triloba Mull. Arg.	Euphorbiaceae		13.39 (4)	
Nephelium cuspidatum Blume	Sapindaceae		8.43 (7)	7.26 (8)
Pellacalyx axillaris Korth.	Rhizophoraceae			16.19 (2)
Saurauia glabra (Ruiz & Pav.) Soejarto	Actinidiaceae			8.19 (6)
Timonius flavescens Baker	Rubiaceae			9.97 (4)
Vernonia arborea Buch. Ham.	Asteraceae	7.45 (10)		
Vitex pubescens Vahl.	Verbenaceae	30.34 (2)	16.48 (3)	6.57 (9)
Whiteodendron moultonianum (W.W.Sm.) Steenis	Myrtaceae		6.93 (10)	
Number of families		28	45	43
Number of genera		43	107	75
Number of species		62	173	99

Note: SF=secondary forest. The figures in parentheses are the ranking in terms of IVi, (1) being the species with the highest IVi
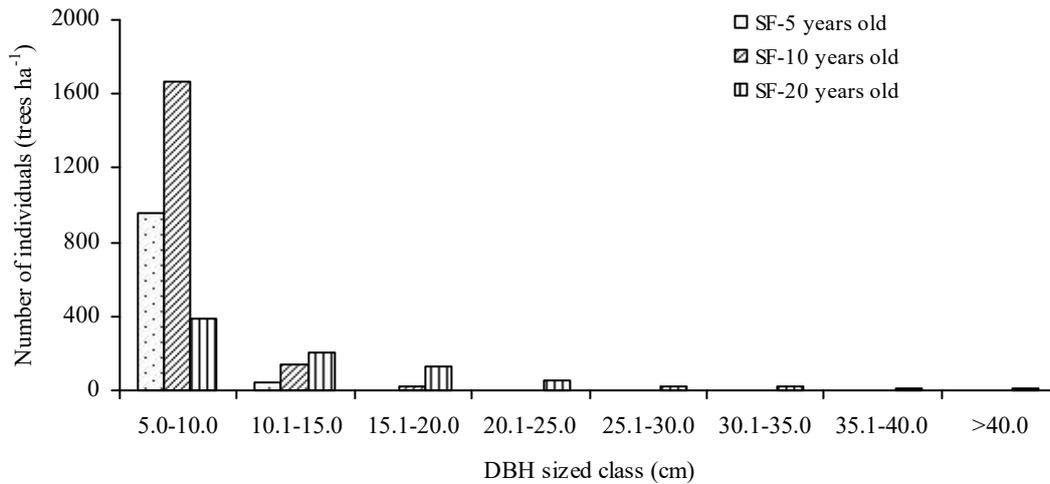
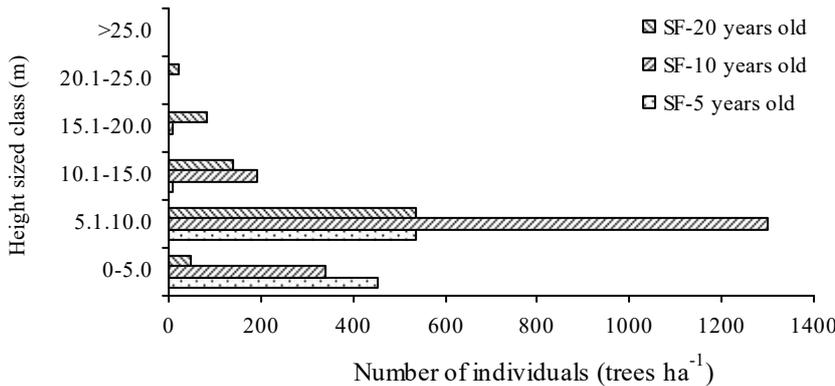**Figure 2.** Distribution of tree DBH in secondary forest of different ages

Figure 3. Distributions of tree height in secondary forests of different ages

Table 3. SØrensen similarity index (ISS) of trees with DBH of $\geq$ 5 cm in the study sites

Type	SF-5 years old	SF-10 years old	SF-20 years old
SF-5 years old	-		
SF-10 years old	41.70	-	
SF-20 years old	52.17	44.12	-

Note: SF=secondary forest. Sørensen similarity index was computed for the entire study plots (1 ha)

Species diversity

The species diversity (H' values) was categorized as 'intermediate' at all sites based on Odum (2005) classification of species diversity as presented in Table 4. There were significant differences in H' values between the 5 and the 10 year old of secondary forests, but there was no significant differences of those compared to the 20 year old of secondary forest. The ecological dominance (D_s value) of trees species in our studied secondary forests was categorized as 'low dominance'. There were a few species to almost no species dominant in every community. In all study sites, D_s values showed no significant difference among them. This is typical for most tropical lowland forests. All of the trees species in the secondary forests had high value of J'. Every species was distributed evenly in community. The J' values also showed no significant differences in three study sites. There were significant differences among R values in all study sites. The high J' and R values were due to high number of trees per hectare and number of species recorded in the study sites. The results showed that as the diversity (H'), evenness (J'), and richness (R) increased, the dominance (D_s) decreased. Sapkota et al. (2010) proved that tree diversity declines while dominance increases linearly along a disturbance gradient. The change in tree density is also related to relative basal area of the dominant tree species.

The values of Shannon-Wiener diversity index (H') of trees (DBH of $\geq$ 5 cm) varied from 2.09 to 2.70, the Simpson dominance values (D_s) 0.12-0.17, Pielou evenness

index (*J'*) 0.86-0.88, and the Margalef richness values (*R*) 3.02 to 5.57 in all study sites. The values of *H'* and *R* increased from the 5 year old to the 10 year old of secondary forests, then decreased in the 20 year old of secondary forest. The results showed that diversity indices were not related to stand age. This finding may be influenced by number of families, genera, species, and individuals in each study site. The highest number of families, genera, species, and individuals were recorded in the 10 year old of secondary forest (Table 2). Similarly, the number of species increased from tree to sapling and seedling strata in fallow stand since recruitment into the sapling of tree strata always requires the seedlings to go through the seedling stage (Van Do et al. 2011).

The tree species diversity in the 10 year old secondary forest was the highest among all study sites. In fact, this site had an intermediate disturbance compared with the others. Diversity will be greatest at an intermediate intensity, because it contains a great variety of species of both pioneer and climax species. The early stages of secondary successional process were responsible for the change and development of community structure, composition, and diversity in secondary forests of different ages. The highest diversity in 10 year old secondary forest may reflect a successional change in the intermediate age of secondary forest, mainly through reorganization in structure, composition, and diversity. The 10 year old secondary forest was the intermediate stage among all study sites. In this site, community structure, floristic composition, and species diversity looked quite different from those of the others. This may indicates that the change and dynamic of succession process began after 10 years fallow period. In Marin-Spiotta's et al. (2007) study, the successional change was shown in 30 year old sites among all studied sites. In their study, the younger secondary forests were 10 and 20 year old secondary forests, while the older secondary forests were 60 and 80 year old secondary forests. In addition, due to the poor soil fertility status in the area, 50 years of fallow period would be insufficient for the land to recover its vegetation condition, equivalent to that of natural forests (Wasli et al. 2011). The tree growth of secondary forest reflects the development during secondary succession process as well as their community structure, composition, and diversity (Karyati et al. 2017). Tanaka et al. (2007) stated that with increasing length of fallow periods, tree species replace the pioneering small plants, such as grasses, ferns, and shrubs, through vegetation succession. Some species appear during a specific period of stand development, and then disappear in older stands (Van Do et al. 2010). Wasli et al. (2009) reported no substantial differences of the species composition and the sizes of tree species between suitable and unsuitable sites of fallow lands under intensive shifting cultivation systems in the Engkari river area in Sarawak, Malaysia.

The rate of changes of plant succession attributes increased gradually at early secondary succession up to 10 years since abandonment and decreased slowly until 20 years of fallow period. This dynamic successional process was probably due to relatively high rate of recruitment and growth of seedlings and saplings at early fallow ages. At the older stages, the trees with DBH of ≥ 5 cm played an important role in the dynamics of secondary forests. The community structure, composition, and diversity varied among all studied sites. These differences were probably due to various factors, such as fallow age, community development, disturbance intensity, seed bank, and seed rain from surrounding environment, edaphic and climatic factors in each study site. In addition to being affected by the degree and frequency of disturbance during the cultivation period, early successional secondary process after shifting cultivation may also be affected by other factors, such as fire intensity and the number of cultivations, seed sources in soils or from the surrounding forests, soil fertility, and light condition (Kendawang et al. 2007), tree composition of surrounding old-growth forest and climate conditions (Van Do et al. 2010).

The study revealed that the existence of 5, 10, and 20 year old secondary forests related to their importance in community structure, floristic composition, and species diversity. The ten most common species of secondary forests were dominated by fast growing species. Their basal area and volume composed more than 60% of the total basal area and volume as well as their importance value index. The tree species of study sites were categorized as 'intermediate diversity' (*H'*), 'low dominance' (*Ds*), and 'high evenness' (*J'*). The highest species richness (*R*) was recorded in the 10 year old secondary forest. The findings of this study were important to provide ecological data of secondary forests of different ages after abandonment. Studies on future management of secondary forests and the related issues like global climate change, biodiversity, carbon marketing and sustainability of ecosystem service of secondary forests are needed.

Table 4. Diversity indices of trees with DBH of ≥ 5 cm in the study sites

Diversity indices	SF-5 years old (n=25)	SF-10 years old (n=25)	SF-20 years old (n=25)
Shannon-Wiener diversity index (*H'*)	2.09 ($\pm$0.07)[a]	2.70 ($\pm$0.14)[b]	2.39 ($\pm$0.07)[ab]
Simpson dominance index (*Ds*)	0.17 ($\pm$0.01)[a]	0.12 ($\pm$0.02)[a]	0.14 ($\pm$0.01)[a]
Pielou evenness index (*J'*)	0.86 ($\pm$0.01)[a]	0.86 ($\pm$0.02)[a]	0.88 ($\pm$0.02)[a]
Margalef species richness (*R*)	3.02 ($\pm$0.20)[a]	5.57 ($\pm$0.52)[c]	4.22 ($\pm$0.20)[b]

Note: SF=secondary forest. Calculation was done according to the 20 m × 20 m subplots. Values are average and standard error in parentheses. Different letters in each line indicate a significant difference at 5% level by Tukey's test among secondary forests of different ages

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