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Assessment of Floristic Composition in a Rehabilitated Forest, Sarawak, Malaysia

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ABSTRACT

Assessment of the floristic composition provides information on forest succession stage which is important but only relatively few information are available on the rehabilitated tropical forest. The information can provide an indication of the recovery status of the forest. The objective of this study was to assess the floristic composition of selected age stands at a rehabilitated forest situated in Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak, Malaysia. A 20 x 20 m plot (0.04 ha) was established each in stands planted in 1991, 1999, 2008 and an adjacent natural regenerating secondary forest (± 23-year-old). All stands were tagged, identified and analyzed for species composition, Importance Value (IV), species diversity and similarity. Floristic analysis showed that in the rehabilitated forest, over 50% of the total family was dominated by the Dipterocarpaceae family but only 14% in natural regenerating secondary forest. Based on the IV Index, stand year 1991 was dominated by *Shorea dasyphylla* (IV=155.8) while stand year 1999, 2008 and natural regenerating secondary forest were *Dryobalanops beccarii* (IV=156.2), *Sandoricum borneense* (IV=144.4) *Teijsmanniodendron holophyllum* (IV=115.3), respectively. The Simpson's diversity index at the rehabilitated forest ranged from 0.82 to 0.87 compared to 0.98 at the natural regenerating secondary forest whereas the Shannon-Wiener diversity index ranged from 2.04 to 2.29 compared to 4.23, respectively. Jaccard's Coefficient of Similarity (C_j) between all combinations of the study plots was generally low (2.2-19.4%). Rehabilitated forest exhibited climax species community despite having lower species diversity. This can promote the conservation of these climax species.

Keywords: Floristic composition, forest rehabilitation, natural regeneration, secondary forest

INTRODUCTION

Forest degradation is one of the most global pressing environmental concerns (Verchot & Petkova 2009). Restoring these degraded forests is important as there has been increasing interest towards these forests as providers of forest products and services for mankind. These require the understanding of the dynamics and ecological processes of the forest. There are some reported studies on the forest dynamics that focused on the structural and floristic aspects of tropical forest such as by Brunig (1970), Whitmore (1984), Kochummen *et al*. (1990), Lee *et al.* (2002), Miyamoto *et al*. (2007) and Gobilik (2008).

It is important to know the floristic composition of these rehabilitated forests compared to the primary forests. In natural succession processes, it is expected that regenerating secondary forest will continue to increase in their similarity to primary forest which was estimated at 50 years (Kochummen 1966), 250-500 years (Kartawinata 1994), 300-500 years (Miyawaki 1999) and even centuries (Whitmore 1991). This information could facilitate in the understanding on the forest dynamics.

The natural succession and recovery takes a long time, but with human intervention by using ecological restoration of degraded forest based on the system of natural forests can build a multi strata quasi-natural forest (Miyawaki 1999). This technique is called accelerating natural regeneration. However, there is a lack of the information on the floristic composition in a rehabilitated forest, in comparison to the adjacent natural regenerating forest. Such information can provide some indication on the recovery status of the rehabilitated forest from the aspect of floristic composition.

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The objective of this study was to assess the floristic composition of selected age stands at the UPM-Mitsubishi Corporation Forest Rehabilitation Project situated in Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak, Malaysia.

MATERIALS & METHODS

Study Sites

The study was conducted at a rehabilitated forest in Universiti Putra Malaysia, Bintulu Sarawak Campus, Sarawak, Malaysia. It is located about 600 kilometers Northeast of Kuching (latitude 03º12’N, longitude 113º02’E) at 50 meters above sea level. A research plot of 20 x 20 m (0.04 ha) was established each at stands planted in 1991 (Plot 1991), 1999 (Plot 1999) and 2008 (Plot 2008). The annual planting size of this project is relatively small and the size of 20 x 20 m was the biggest possible plot size that could be established at each planting year site. As for the purpose of comparison a similar size plot was established at the adjacent natural regenerating secondary forest at Bukit Nyabau (Plot NF). The species planted in the rehabilitated forest are shown in Table 1, while the list of species recorded in the natural regenerating forest is shown in S1.

Table 1. Species planted in the rehabilitated forest.

Plot 2008	Plot 1999	Plot 1991
Artocarpus integer	*Dryobalanops beccarii*	*Calophyllum sclerophyllum*
Artocarpus odoratissimus	*Elaeocarpus* sp.	*Cotylelobium melanoxylon*
Azadirachta excelsa	*Eusideroxylon zwageri*	*Dryobalanops beccarii*
Calophyllum ferrugineum	*Hopea beccariana*	*Durio zibethinus*
Cotylelobium burckii	*Hopea bracteata*	*Hopea bracteata*
Cotylelobium melanoxylon	*Hopea kerangasensis*	*Hopea pentanervia*
Dryobalanops beccarii	*Kokoona littoralis*	*Parashorea smythiesii*
Durio zibethinus	*Koompassia malaccensis*	*Scaphium macropodum*
Elateriospermum tapos	*Litsea elliptica*	*Shorea dasyphylla*
Eurycoma longifolia	*Mangifera foetida*	*Shorea foxworthyi*
Hopea aequalis	*Nephelium mutabile*	*Shorea leprosula*
Hopea dryobalanoides	*Parishia maingayi*	*Shorea macrophylla*
Litsea sp.	*Pentaspadon motleyi*	*Shorea maxwelliana*
Palaquim gutta	*Sandoricum borneense*	*Shorea mecistopteryx*
Sandoricum borneense	*Shorea brunnescens*	*Shorea ovata*
Shorea brunnescens	*Shorea falciferoides*	*Shorea parvifolia*
Shorea leprosula	*Shorea ovata*	*Syzygium* sp.
Shorea macrophylla	*Shorea rugosa*	*Vatica oblongifolia*
Syzygium sp.	*Syzygium oligomyrum*	

Data Collection

All trees in the rehabilitated forest were tagged while in natural regenerating secondary forest, tree seedlings to trees found in the plot were tagged. These trees were identified to genus and species level in 2009. Data collected was analyzed for each study plot.

Data Analysis

The stand data was analyzed for species composition, Importance Value (IV), species diversity and similarity.

Species composition was calculated based on the percentage of the individual species over the total species recorded. Importance Value (IV) (Grieg-Smith 1957; Brower *et al*. 1990) gives good overall estimate of the importance of the species in the community which can be calculated by summation of the relative density, relative frequency and relative dominance. The calculations are as follows (Husch *et al*. 2003):

RD = (number of plots in which species occurs/total number of plots) x 100

RF = (frequency of a species/total frequency of all species) x 100

Rd = (dominance for a species/total dominance for all species) x 100

IV = RD + RF + Rd

Where RD is relative density, RF is relative frequency and Rd is relative dominance. As for the stand species diversity analysis, Shannon-Wiener diversity index and Simpson's diversity index were used. The Shannon-Wiener diversity index assumes that individuals are randomly sampled from an indefinitely large population (Pielou 1975). The index also assumes that all species are represented in the sample (Magurran 1991).

$$H=-\sum pi * \ ln\ pi$$

Where H is Shannon-Wiener diversity index and p_i the proportional abundance of the i^{th} species = (n_i /N).

Simpson's diversity index (Simpson 1949) considered the number of species (s), the total number of individual and also the proportion of the total that occurs in each species. It represents the probability that two randomly selected individuals in the habitat belong to the same species.

$$D = 1-(\frac{\sum n(n-1)}{N(N-1)})$$

Where D is Simpson's diversity index and *n* is the total number of a particular species and N is the total number of all species.

For all the study plots, Jaccard's Coefficient of Similarity (C_J) was used to quantify community similarity (Brower *et al.* 1990) using the following equation (Magurran 1991):

$$C_J=\frac{a}{a+b+c}$$

Where *a* is the number of species in both forest sites, *b* is the number of species in the site *b* only and *c* is the number of species found in site *c* only.

RESULTS

Floristic Composition and Importance Value (IV)

The five most common families, in terms of number of stems found in Plot 1991 were Dipterocarpaceae (80.5%), Sterculiaceae (11.2%), Bombacaeae (6.3%), Clusiaceae (1.5%) and Myrtaceae (0.5%). The dominant species in the plot was *Shorea dasyphylla* Foxworthy (30.7%) from the family Dipterocarpaceae with Importance Value (IV) value of 155.8. There were 5 families, 10 genera and 18 species from 205 trees (Table 2).

In Plot 1999, the five most common families were Dipterocarpaceae (71.4%), Anacardiaceae (22.5%), Fabaceae (2.2%), Lauraceae (1.3%) and Mrytaceae (0.9%). The plot was dominated by *Dryobalanops beccarii* Dyer (31.7%) with IV value of 156.2. There were 9 families, 14 genera and 19 species from 227 trees. On the other hand, in Plot 2008, the five most common families were Dipterocarpaceae (51.4%), Meliaceae (32.7%), Clusiaceae (9.3%), Myrtaceae (1.6%) and Sapotaceae (1.3%). *Sandoricum borneense* Miq. (21.2%) dominated the study plot with IV value of 144.4. There were 10 families, 13 genera and 19 species from 321 trees (Table 2).

Table 2. Floristic features and diversity index of the study plots.

	Plot 1991	Plot 1999	Plot 2008	Plot NF
No. of Trees	205	227	321	546
No. of Species	18	19	19	120
No. of Genera	10	14	13	80
No. of Families	5	9	10	38
5 Most Common Families	Dipterocarpaceae Sterculiaceae Bombacaeae Clusiaceae Myrtaceae	Dipterocarpaceae Anacardiaceae Fabaceae Lauraceae Mrytaceae	Dipterocarpaceae Meliaceae Clusiaceae Myrtaceae Sapotaceae	Dipterocarpaceae Anacardiaceae Euphorbiaceae Sapotaceae Ixonanthaceae
Simpson's Index	0.84	0.82	0.87	0.98
Shannon-Wiener	2.15	2.04	2.29	4.23

In Plot NF, the five most common families were Dipterocarpaceae (14.0%), Anacardiaceae (12.8%), Euphorbiaceae (9.9%), Sapotaceae (6.4%) and Ixonanthaceae (6.2%). *Parishia maingayi* Hook. *f.* (6.8%) dominated the study plot by percentages, however by analyzing using IV, *Teijsmanniodendron holophyllum* (Baker) Kosterm. was considered the most important species with a value of 115.3. There were 38 families, 80 genera and 120 species from 546 trees (Table 2).

Species Diversity and Similarity Index

Generally, the species diversity in the study plots at the rehabilitated forest was relatively lower compared to the natural regenerating secondary forest of 0.98 and 4.23 using the Simpson's diversity index and Shannon-Wiener diversity index, respectively. Among the study plots at the rehabilitation forest, Plot 2008 showed the highest diversity indexes at 0.87 and 2.29, respectively. Jaccard's Coefficient of Similarity (C_j) between all combinations of the study plots was generally low with a range of 2.2-19.4%.

DISCUSSION

The species richness in the rehabilitated forest was restricted to the selected 126 species from the potential natural vegetation. These were based on the field investigations in Kalimantan (Indonesia), Thailand and Malaysia (Miyawaki 1999). Therefore, lower species richness was obtained in the rehabilitated forest compared to the natural regenerating secondary forest. It was also considered low in terms of number of species in comparison to other tropical primary forests. For the purpose of referencing, Swaine *et al*. (1987) reported that tropical forest has species richness from 52 to 141 tree species ha^{-1}. A virgin forest at Danum Valley Conservation Area, Sabah, Malaysia has 114 species ha^{-1} (Jumaat & Kamarudin 1992) while Ayer Hitam secondary forest, Selangor, Malaysia has 146 species ha^{-1} (Kueh 2000). A comparative study by Okimori & Matius (2000), found 35 species in a 15-year-old stand compared to 95 species in a 70-year-old secondary forest. Brearley *et al*. (2004) also found 111 species in a 55-year-old secondary forest in comparison to 174 species in a primary forest in Central Kalimantan (Indonesia) forest. Okuda *et al*. (2003) reported similar findings of having higher species of 822 species in primary plots compared to the regenerating plots of 672 species at Pasoh Forest Reserve, Negeri Sembilan, Malaysia.

The species richness as assessed by the number of species and diversity indexes (Shannon-Wiener diversity index and Simpson's diversity index) of the study plots in the rehabilitated forest were considerably lower than that of the natural regenerating secondary forest and the compositional similarity (Jaccard's coefficient) was low. Brearley *et al*. (2004) found similar findings with Shannon-Wiener diversity index of 3.40 for 55-year-old secondary forest and 4.17 for primary forest in Central Kalimantan, Indonesia with Jaccard's coefficient of similarity of only 24%. The rehabilitation forest has low Jaccard's coefficient of similarity despite the choice of species has been predetermined. This was due to the availability of sufficient seedling supplies of the selected species at the particular planting year.

Based on the percentage value and Importance Value (IV) index, species from the Dipterocarpaceae were dominant in the rehabilitated forest except for Plot 2008, where species from Meliaceae was dominant. In the natural regenerating secondary forest, species from Anacardiaceae was dominant by percentages but IV index suggested that the most important species was from the family Labiatae. The dominance of species from the family Dipterocarpaceae in the rehabilitated forest was mainly due to the selection of species based on the potential natural vegetation (Miyawaki 1999). The basic principle is to use climax species which is at the mature stage of succession. As such, in natural succession processes, no species can succeed the climax species. In the natural regenerating secondary forest, several families like Dipterocarpaceae, Anacardiaceae and Euphorbiaceae were dominant while in Plot 2008, Dipterocarpaceae was dominant. These are the several families in the climax communities. Studies conducted in primary forest such as in Sungai Menyala Forest Reserve, Negeri Sembilan, Malaysia found that the best represented families are Dipterocarpaceae, Burseraceae and Euphorbiaceae (Manokaran & Kochummen 1987).

It is worth to note that in some primary forests like Pasoh Forest Reserve, Negeri Sembilan, Malaysia, Dipterocarpaceae only accounted for 9.3% of the total family and 16% for Lambir forest, Sarawak, Malaysia (Lee *et al*. 2002) compared to 51-81% at the rehabilitated forest. In terms of species community among the rehabilitated forest and natural regenerating secondary forest, the variations were obvious. However, by introducing climax species in the tree planting programme to rehabilitate degraded forest could accelerate climax species recovery. With the dominance of the Dipterocarpaceae, it contributed to the forest climax community in the rehabilitated forest. As in the forest dynamics, this indicated the mature phase or the late stage of succession by the dominance of climax species.

The lower species diversity in the study plots at the rehabilitation forest compared to the adjacent natural regenerating secondary forest was anticipated due to the fundamental concept of species selection for the accelerating natural regenerating rehabilitation technique. The species were selected based on the ecological survey conducted in Southeast Asian in the late 70s. The species selected are the natural potential vegetation species that are naturally found in the region and the climax tree species communities are preferred. This also can promote biodiversity conservation of the climax species community especially the Dipterocarpaceae family. The stand of natural regenerating secondary forest is a typical secondary forest species which lack significant of discreet species dominant. Overall, all the study plots showed low similarity and low species diversity which can be an indication of poorer forest in the terms of the species diversity though exhibiting climax community.

CONCLUSION

In conclusion, the climax species dominated the floristic composition in the rehabilitated forest. This indicated the presence of climax species communities. Introducing climax species in the rehabilitated forest is one way to accelerate the formation of climax community which reflects the mature phase of forest dynamics. However, the rehabilitated forest has low species diversity. The assessment on the floristic composition provides an indication of the forest species recovery in the rehabilitated forest. The accelerating natural regeneration technique to rehabilitate degraded forest area has enhanced the dominance of the climax species and can promote conservation of these species. Overall, rehabilitated forest areas have yet to recover in terms of species diversity.

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Supplementary Materials

S1. The list of species recorded in the natural regenerating secondary forest.

Aglaia rubiginosa	*Garcinia* sp.	*Pternandra coerulescens*
Aglaia sp.	*Gironniera nervosa*	*Santiria megaphylla*
Allantospermum borneense	*Gluta aptera*	*Santiria oblongifolia*
Alseodaphne insignis	*Gomphia serrata*	*Santiria rubiginosa*
Anisophyllea beccariana	*Goniothalamus nitidus*	*Sarcotheca diversifolia*
Anisophyllea disticha	*Goniothalamus* sp.	*Scaphium macropodum*
Ardisia elliptica	*Gonocaryum minus*	*Schoutenia glomerata*
Artocarpus elasticus	*Gymnacranthera contracta*	*Shorea curtisii*
Artocarpus integer	*Hopea kerangasensis*	*Shorea isopteran*
Austrobuxus nitidus	*Horsfieldia grandis*	*Shorea macroptera*
Baccaurea hookeri	*Horsfieldia* sp.	*Shorea mecistopteryx*
Baccaurea minor	*Hydnocarpus borneensis*	*Shorea monticola*
Beilschmiedia sp.	*Hydnocarpus kunstleri*	*Shorea pubistyla*
Brownlowia ovalis	*Ixora* sp.	*Sindora beccariana*
Calophyllum ferrugineum	*Knema elmeri*	*Stemonurus grandifolius*
Calophyllum sclerophyllum	*Knema intermedia*	*Stemonurus scorpioides*
Calophyllum soulattri	*Knema stenophylla*	*Streblosa glabra*
Chionanthus cuspidata	*Kokoona littoralis*	*Strombosia lucida*
Cinnamomum sp.	*Lithocarpus cyclophorus*	*Swintonia acuta*
Cleistanthus decurrens	*Litsea artocarpifolia*	*Swintonia schwenkii*
Crudia reticulata	*Litsea oppositifolia*	*Syzygium beccarii*
Cyathocalyx biovulatus	*Lophopetalum* sp.	*Syzygium fastigiatum*
Dacryodes rostrata	*Macaranga denticulata*	*Syzygium lineatum*
Dacryodes rugosa	*Madhuca kunstleri*	*Syzygium palembanicum*
Derris dalbergioides	*Mallotus penangensis*	*Tabernaemontana marcocarpa*
Dialium indum	*Mallotus wrayi*	*Teijsmanniodendron coriaceum*
Dimorphocalyx denticulatus	*Mangifera griffithii*	*Teijsmanniodendron holophyllum*
Diospyros evena	*Meliosma sumatrana*	*Terminalia foetidissima*
Diospyros venosa	*Memecylon* sp.	*Terminalia* sp.
Dipterocarpus rigidus	*Mesua calophyllodies*	*Timonius wallichianus*
Dryobalanops beccarii	*Mesua macrantha*	*Upuna borneensis*
Drypetes sp.	*Monocarpia marginalis*	*Urophyllum glabrum*
Elaeocarpus glabrescens	*Neoscortechinia kingii*	*Urophyllum hirsutum*
Elaeocarpus sp.	*Nephelium maingayi*	*Vatica compressa*
Fagraea acuminatissima	*Parishia maingayi*	*Vatica nitens*
Fagraea sp.	*Pentace adenophora*	*Xanthophyllum amoenum*
Fagraea spicata	*Pentace hirtula*	*Xanthophyllum ellipticum*
Fahrenheitia pendula	*Polyalthia glauca*	*Xanthophyllum glaucum*
Fordia coriacea	*Porterandia anisophylla*	*Xanthophyllum griffithii*
Garcinia parvifolia	*Pouteria malaccensis*	*Xylopia ferruginea*