Is smallholder farmer maintaining biodiversity in rattan agroforest?

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Abstract. Rattan Agroforestry is usually developed by smallholder farmers in Katingan district, Central Kalimantan. The rattan is planted under woody tree species, mainly rubber. Both rubber and rattan have contributed in the economic development of Central Kalimantan. A vegetation analysis with purposive sampling plot was conducted in two villages in Katingan district to assess flora diversity in the gradient of Agroforestry system (simple to complex Agroforestry) compared with forest. The Agroforestry system consisted of baliang, bahu, complex rubber rattan agroforest, and simple rubber agroforest. Results showed forest has the highest tree diversity ($H’=3.39$), while simple rubber agroforest has the lowest tree diversity ($H’=1.09$). During the survey, 43 rattan species were encountered in the landscape of two villages (Tumbang Malawan and Tumbang Runen). The commonest rattan’s genus was Calamus (consisted of 22 species). Farmers applied an extensive management of rattan-rubber agroforest and they allowed regeneration occurred naturally in the farm. In the rattan agroforests, other trees with economic value, which produce food and fruits were intentionally planted to support food security to their family. Owing to low price, rattan currently is not intensively managed and harvested; nevertheless, the Dayak is still maintaining the rattan agroforest for their domestic and cultural needs.

1. Introduction
Rattan is a climbing palm belongs to Arecaceae family. It usually grows on mineral soil, sandy soil in the riverbanks, and lowland to upland [1]. Rattan is a very well known species in Katingan district, Central Kalimantan. Since many years ago, it has been widely used for indigenous people of Dayak for cash, domestic use and cultural use [2-4]. Rattan is very beneficial, because it has multi-purposes. The shoot of rattan is edible and it can be cooked. The rattan can be used as dye, basketry, joining constructions and tools, handicraft, and medicine [4,5].

The Dayaks Ngaju cultivate some rattan species, such as Calamus caesius (uwei sigi) and Calamus manan (uwei marau) in their farm in agroforestry system [6]. Rattan agroforest is developed in swiddening and shifting cultivation practices. Slash and burning is used for clearing up the forest or secondary forest [2-4,7]. Dry-land paddy is planted for food security in the new farm-land [7]. Rattan management is consisted of collecting seeds, raising seedlings, collecting seedlings, planting and harvested [5]. In practice, Dayaks apply fallow rotation in the rattan management, which allows natural regeneration occurs in the rattan farm. The woody trees that grow along with rattan support rattan to climb. Some trees that are planted as climbing trees, such as meranti (Shorea sp.), halaban (Vitex pubescens), and rubber (Hevea brasiiliensis) [3,8].
Several reports available about rattan agroforests, however, limited information available on the comparison of tree diversity in different type of agroforests and land management. The objective of this study is to investigate diversity in rattan agroforest, and whether farmer is maintaining diversity in rattan agroforest.

2. Methods

2.1. Study site
The study was conducted in the landscape of Katingan district, Central Kalimantan, which covers an area of 17,800 km$^2$. Katingan is known as a rattan district. Katingan also refers to a river’s name. The study sites were located in the upper stream of Katingan river, in Tumbang Malawan (01°04’- 01°05’ S and 112°44’ – 112°45’ E), and in the lower stream of Katingan river in Tumbang Runen (02°16’ – 02°17’ S and 113°26’ E).

Tumbang Malawan positioned at the altitude of 50-500 m above sea level (asl). The geographic condition in Tumbang Malawan is undulating, somewhat steep to very steep. Soil type is dominated by Latisol soil. Tumbang Runen is positioned at 17-50 m asl. The geographic condition in Tumbang Runen is relatively flat, and soil type is consisted of Inceptisol and Latisol soils [9]. The study site is shown in Figure 1.

There were three land use types in Tumbang Malawan, namely forest (himba), secondary forest (baliang), and rattan agroforest (bahu). The land use types were located on Latisols soil. Different land use types were found in Tumbang Runen, e.g. complex rubber-rattan agroforest (KKR) and simple rubber agroforest (KR).

2.2. Sampling plots
Five sampling plots of 20 m x 20 m were established at five land use types in Tumbang Runen and Tumbang Melawan. Total area in five land use types is 1 ha. The plots were laid purposively on a transect of 1 km. The distance between the plots was 200 m. Each plot was divided into nested sub-plots of 10 m x 10 m for poles stratum, and sub-plot of 2 m x 2 m for seedling stratum. All trees with minimum diameter at the breast height (dbh) of 10 cm were counted, enumerated and identified. Trunk with buttress was measured 20 cm above buttress. All species recorded were collected as voucher specimen for scientific identification. The herbarium specimens were identified in the Bogoriense Herbarium, Bogor. All rattan species that were encountered in the plot of 20 m x 20 m were counted and identified.

2.3. Data analysis
The land use type and their structure were analysed using the Important Value Index (IVI) [10].

\[ IVI = RD + RF + RBA \]

where relative density (RD) is total individual of a species divided by total number individual of all species; relative frequency (RF) is number of plots in which a species occurs divided by total of number of plots sampled; relative dominance (RBA) is total basal area of a species divided by total basal area of all species. Species with the highest IVI imply the dominant species in each land use type.

For each land use type, species richness ($S$, total number species per land use type) and species diversity was calculated as the Shanon-Wiener index [11]:

\[ H' = \frac{\sum_{i=1}^{p} p_i \ln p_i}{p} \]

(1)

Where $p_i$ is the proportion of the individuals found in the $i$-th species in each concentric plot or in the whole plot. This index considers species richness ($S$) and the evenness of their abundance.

The evenness index was calculated using the equation of [12]:

}\]
\[ E = \frac{H'}{\ln(S')} \]  

(2)

The value of \( H' \) is high if the numbers of species and individuals, and the distribution of individuals of each species are high, and if the distribution of individuals for each species is almost even [13]:

Sorensen index was calculated to measure the similarity of species composition between land use type [14]:

\[ IS_{jk} = \frac{2C}{A + B} \times 100\% \]  

(3)

where \( IS \) is similarity percentage between sample unit of \( j \) and \( k \); \( A \) is species number of \( j \); \( B \) is species number of \( k \); \( C \) is species number presents in both \( j \) and \( k \).

![Figure 1. Study area in Tumbang Malawan and Tumbang Runen, Katingan district, Central Kalimantan (source: [9])](image)

3. Results

3.1. Diversity, species richness, and evenness of vegetation in rattan agroforests

The vegetation characteristics in the four types of rattan agroforests and forest are shown in Table 1. The four types of rattan and rubber agroforests in Katingan have different characters with forest.
Table 1. Species richness, diversity index and evenness index of five land use type in Katingan district

| Stage | Parameter | Forest | Baliang | Bahu | KKR | KR |
|-------|-----------|--------|---------|------|-----|----|
| Tree  | Number of woody species | 49 | 55 | 19 | 34 | 13 |
|       | Number of rattan species | 13 | 15 | 9 | 3 | 4 |
|       | Number of individual | 117 | 108 | 62 | 129 | 108 |
|       | Basal area (m² ha⁻¹) | 149.92 | 38.04 | 49.72 | 77.50 | 659.21 |
|       | Diversity index (H') | 3.39 | 3.35 | 1.52 | 3.31 | 1.09 |
|       | Evenness index (E) | 1.46 | 1.39 | 0.62 | 1.57 | 0.54 |
| Seedling | Number of species | 25 | 22 | 13 | 25 | 22 |
|         | Number of individual | 87 | 52 | 87 | 85 | 83 |
|         | Diversity index (H') | 2.80 | 2.78 | 1.54 | 2.92 | 2.35 |
|         | Evenness index (E) | 1.44 | 1.62 | 0.79 | 1.51 | 1.23 |

Note: KKR=complex rubber-rattan agroforest, KR=simple rubber agroforest

3.2. Species composition of forest and four types of rattan agroforests
The five most important value of woody tree species in forest and four types of rattan agroforest are shown in Table 2. *Shorea parvifolia* is a dominant tree species in forest, while rubber tree is a dominant tree in the simple rubber agroforest. Only few species is a shared species between the land use types. *Diospyros puncticulosa* was found in forest and *baliang*. *Actinodaphne glabra* was a shared species in KKR and KR.

The five most important values of seedlings at five land use types in Katingan is shown in Table 3. In the forest, *S. parvifolia* is a dominant species at the seedling stage, although it has a lower value than *Shorea laevis*. Seedlings of *S. parvifolia* are found both in forest and *baliang*. Seedlings of *Calamus caesius* (uwei sigi), which is rattan with high economic value, were encountered in three land use types of bahu, KKR, and KR. Uwei sigi is planted by the farmers for food and economic purposes.

Table 2. The five most important value of woody tree species in the five land use types in Katingan

| Species | Family | Vernacular name | IVI (%) | Forest | Baliang | Bahu | KKR | KR |
|---------|--------|-----------------|---------|--------|---------|------|-----|----|
| *Shorea parvifolia* | Dipt. | Lentang | 54.81 |
| *Dehaasia firma* | Laur. | Bawuan | 16.50 |
| *Diospyros puncticulosa* | Eben. | Mahawai | 6.36 | 10.01 |
| *Xanthophyllum sp.* | Polygal. | Bara tahatung | 5.97 |
| *Parinari oblongifolia* | Ros. | Kayu batu | 5.51 |
| *Hydnocarpus sp.* | Flacourt. | Sabuhe | 10.17 |
| *Milletia sericea* | Fabac. | Nyatu bawui | 10.07 |
| *Sanitria tomentosa* | Anac. | Punggau | 9.79 |
| *Diospyros toaposoides* | Eben. | Kupang | 8.48 |
| *Vitex pinnata* | Verben. | Saluwan | 50.81 |
| *Geunsia pentandra* | Verben. | Nanyut | 31.47 |
| Species                     | Family  | Vernacular name | IVI (%) | Forest | Baliah | Bahu | KKR | KR |
|----------------------------|---------|-----------------|---------|--------|--------|------|-----|----|
| *Macaranga pruinosa*       | Euph.   | Langkuwu        | 13.91   |         |        |      |     |    |
| *Macaranga triloba*        | Euph.   | Gahung          | 12.70   |         |        |      |     |    |
| *Unident sp.14*            | Euph.   |                 | 9.79    |         |        |      |     |    |
| *Unident sp.3*             | -       | Kambang sira    | 24.51   |         |        |      |     |    |
| *Ardisia lanceolata*       | Myrsin. | Tatumbu         | 19.13   |         |        |      |     |    |
| *Actinodaphne glabra*      | Laur.   | Kajunjung        | 18.77   | 11.55  |        |      |     |    |
| *Vatica venulosa*          | Dipt.   | Rasak           | 17.72   |         |        |      |     |    |
| *Elaeocarpus macrophyllus* | Elaeoc. | Mangkinang bangamatan | 14.46 |         |        |      |     |    |
| *Hevea brasiliensis*       | Euph.   | Getah           | 176.60  |         |        |      |     |    |
| *Evodia latifolia*         | Rut.    | Sagagulang      | 22.02   |         |        |      |     |    |
| *Baccaurea javanica*       | Euph.   | Kayu saletik    | 14.85   |         |        |      |     |    |
| *Cananga odorata*          | Annon.  | Kananga         | 12.75   |         |        |      |     |    |

Note: KKR = rubber-rattan complex agroforest; KR = simple rubber agroforest

Table 3. The five most important value of seedlings in the five land use types in Katingan
During the survey, 43 rattan species were found in the landscape of Tumbang Malawan and Tumbang Runen (Central Kalimantan district). The local people recognise rattans very well, and have named the rattan species. Rattan species and their utilization are shown in Table 4.

### Table 4. Rattan species encountered in the landscape of Tumbang Runen (TR) and Tumbang Malawan (TM), Katingan district

| No | Species name | Vernacular name | Utilization* | Presence in |
|----|--------------|-----------------|--------------|-------------|
| 1. | *Calamus blumei* | Uwei kipas kalaweh | Cash, construction, tools, medicine, ritual | TM |
| 2. | *Calamus caesius* | Uwei sigi kabon/uei jelar sigi/uei jelar irit | Construction, tools | TM, TR |
| 3. | *Calamus cf. zonatus* | Uwei paria | Construction, tools | TM (forest) |
| 4. | *Calamus corrugatus* | Uwei anak | Construction, tools | TM (forest) |
| 5. | *Calamus diepenhorstii* | Uwei tunggal | Food, basketry | TM (bahu) |
| 6. | *Calamus hispidulus* | Uwei bulu | Construction, tools | TM (baliang), TR |
| 7. | *Calamus javensis* | | | TM (baliang) |
| 8. | *Calamus cf. gibbsianus* | Uei irit | | TR |
| 9. | *Calamus laevigatus var. mucronatus* | Uwei banang | Food, basketry | TM (forest) |
| 10. | *Calamus manan* | Uwei marau | Cash, food, basketry, construction, tools | TM (baliang) |
| 11. | *Calamus nematospadix* | Uwei sarihit | Food, construction | TM (baliang) |
| 12. | *Calamus nigricans* | Uwei ikuh angkes | Dye, construction, tools | TM |
| 13. | *Calamus paspalanthus* | Uei bujuk | | TR |
| 14. | *Calamus rugosus* | Uei naning | | TR (peatland) |
| 15. | *Calamus sp. A* | Uei anak janan | | TM |
| 16. | *Calamus sp. B* | Uwei pendung asu | Food | TM |
| 17. | *Calamus sp. C* | Uwei satuwu | Food, construction, tool | TM |
| 18. | *Calamus sp. D* | Uwei tantuwu | | TR, TM |
| 19. | *Calamus sp. E* | Uwei tahesa | | TR |
| 20. | *Calamus sp. F* | Uei katip | | TR |
| 21. | *Calamus sp. G* | Uwei munduk | Food, construction, tools | TM |
| 22. | *Calamus sp. H* | Uwei rami | | TM (bahu) |
| 23. | *Ceratolobus subanguilatus* | Uwei gumin harimaung | Basketry, construction, tools | TM (forest) |
| 24. | *Daemonorops didymophylla* | Jarenang | Cash, food, dye | TM (forest) |
| 25. | *Daemonorops fissa* | Uwei sarihit babilem | | TM (baliang) |
| 26. | *Daemonorops formicarius* | Uei bulu | | TR |
| No | Species name                  | Vernacular name | Utilization* | Presence in  |
|----|--------------------------------|-----------------|--------------|-------------|
| 27. | *Daemonorops sabut*           | Uwei rongkong   | Food, basketry, tool, construction, medicine | TM (forest) |
| 28. | *Daemonorops sp. A*           | Uwei gitan harijiliwan/ Uei bajungan | Food | TM (forest), TR |
| 29. | *Daemonorops sp. C*           | Uwei manta      | Construction  | TM (forest) |
| 30. | *Daemonorops cf. didymophylla*| Uei tapah       |              | TR          |
| 31. | *Daemonorops sp. F*           | Jarenang        | Dye          | TM (baliang) |
| 32. | *Korthalsia cheb*             | Uei ahas        |              | TR          |
| 33. | *Korthalsia concolor*         | Uwei edan       | Food, basketry, tools, construction, medicine | TM (himba) |
| 34. | *Korthalsia ferox*            | Uwei kalasi     | Food, basketry, tools, construction | TM (baliang) |
| 35. | *Korthalsia flagellaris*      | Uei dahanen     |              | TR          |
| 36. | *Korthalsia hispida*          | Uwei ahas       | Food, construction, tools, medicine | TM (baliang) |
| 37. | *Korthalsia rigida*           | Uei paka        | Food, basketry, tools, construction, medicine | TR (peatland) |
| 38. | *Korthalsia cf. rigida*       | Uwei edan       | Food, basketry, tools, construction | TM (himba) |
| 39. | *Korthalsia echinometra*      | Uwei sahar      | Food, basketry, tools, construction | TM (himba) |
| 40. | *Korthalsia rostrata*         | Uwei potik      | Basketry     | TM (himba) |
| 41. | *Korthalsia sp.1*             | Uwei lemi       |              | TM (baliang) |
| 42. | *Plectocomiopsis mira*        | Uwei jela       |              | TM (bahu)   |
| 43. | *Plectocomiopsis sp.*         | Uwe samare      | Basketry, tools, construction | TM (bahu)   |

*: source [4]

**Table 5. Similarity species at tree stage based on Sorensen’s index**

| IS (Sorensen) | Forest | Baliang | Bahu  | KKR   | KR   |
|---------------|--------|---------|-------|-------|------|
| Forest        | -      | 34.85   | 16.33 | 9.68  | 17.02|
| Baliang       | -      | 24.49   | 11.54 | 9.64  | 17.02|
| Bahu          | -      | 3.23    | 0.00  |       |      |
| KKR           | -      | 29.79   |       |       |      |
| KR            | -      |         |       |       |      |

Note: KKR= complex rubber-rattan agroforest, KR= simple rubber agroforest

**Table 6. Similarity species at seedling stage based on Sorensen’s index**

| IS (Sorensen) | FO   | BAL  | BAU  | KKR  | KR   |
|---------------|------|------|------|------|------|
| Forest        | -    | 25.53| 2.30 | 1.16 | 2.96 |
| Baliang       | -    | 22.86| 4.26 | 4.55 |      |
| Bahu          | -    | 21.05| 11.43|      |      |
| KKR           | -    | 55.32|      |      |      |
| KR            | -    |      |      |      |      |

Note: KKR= complex rubber-rattan agroforest, KR= simple rubber agroforest

3.3. Similarity index of species at five different land use types

Similarity index between two habitats is determined at the threshold of 25% [14]. At the tree stage, most land use types has low similarity index to another. The vegetations in productive simple rubber...
agroforest (KR) are totally different with tree vegetation in rattan agroforest (bahu), which is IS=0%. Baliah has low similarity index with forest, which is IS=34.85% (Table 5).

At the seedling stage on the other hand, vegetations in KR is almost similar to KKR (IS=55.32%). Other land use types has low similarity index to another (Table 6).

4. Discussion

4.1. The cultivation system of rattan agroforests in Katingan

The indigenous people of Katingan are Dayak Ngaju. Ngaju is a large group of Dayak from Katingan and Kapuas [15]. Dayak Ngaju in the upper stream of Katingan river has different culture and land holding system with the Dayak in the lower stream. It creates different land management and perception on farming systems of both villages [3]. The types of rattan agroforest found in Tumbang Malawan are baliang and bahu. Baliah is an old secondary forest which is a late succession from abandoned bahu after more than 10 years. Bahu is formerly used as a farm (ladang), which is planted with rattan and woody trees, such as rubber and fruit trees [16]. About 13 plant species produce food and fruits that were identified in the rattan agroforests of Tumbang Malawan [17]. Tree species also grew in the rubber-rattan agroforest, owing to limited resources, the land is managed extensively. The low management intensity allows natural regenerations in the Agroforestry system.

The rattan agroforest is developed as a swidden shifting cultivation, and applied slash and burnt as prescribed burning [2,4]. Rattan management in the upper stream of Katingan includes swiddening, collecting seeds, raising seedlings, collecting seedlings or wilding, planting and harvesting. C. caesius (uwei sigi) is the most preferable rattan species planted by farmer, because it has market and higher price compare to other species. This rattan species was dominated the three types rattan agroforests (bahu, KKR, and KR). This shows that C. caesius is widely planted in Katingan.

The people of Dayak Ngaju usually do cultivation on mineral soils and avoid wetland areas (swamp – luwau, and peatswamp – napu) as cultivation land, because it is frequently flooded [16,18]. Rubber, rattan and fruit trees are not cultivated on peatland area. Farmers in Tumbang Runen planted rubber trees in a simple Agroforestry system on mineral soils. The more complex rubber-rattan agroforest was developed unintentionally from abandoned simple rubber agroforest.

4.2. Composition, species richness, diversity and similarity of vegetation

Plant diversity in the five land use types in Katingan was assessed by calculated the index of Shanon-Wiener (H’). It is showed that forest has the highest diversity index (H’≈ 3.39) than the other four land use types. The lowest index diversity was in KR (H’≈1.09). Total species found in baliang, however, higher (55 species) than that found in forest (49 species). It showed that forest as a climax ecosystem has highest tree diversity. Other report about tree diversity in secondary forest in three villages (viz. Tumbang Hiran, Tumbang Kalemei, and Tumbang Liting) in Katingan was ranging from 3.40-2.87 [6].

Baliah as a secondary forest has a slightly lower H’ index (3.35) than that of forest. Baliah has the highest species richness, but it has lower tree density and lower basal area than in forest. Rattan species found in Baliah was 15 species, which was higher than that of in forest (13 species). Baliah plays role as a refugee area for tree species from natural regeneration and dispersal agent.

The complex rattan agroforest (bahu) in Katingan has low tree diversity. Many fast growing tree species, such as G. pentandra, M. triloba, M. pruinosa, were found in bahu. The farmers in Tumbang Malawan planted C. caesius (uwei sigi kabon) in bahu, while farmers in Tumbang Runen planted C. caesius in a complex rubber-rattan agroforest (KKR). Sigi rattan is usually planted in the planting distance of 4-4.5 m x 5 m. In Tumbang Runen, fruits and rubber tree is planted as the climbed tree, while in Tubang Malawan, the climbed trees are not intentionally planted, but it comes from natural regenerations. It is reported there were several trees as climbing trees for rattan, such as benuas (Hopea celebica), jelutung (Dyera costulata), halaban (Vitex pubescens) and others [6].
Simple rubber agroforest (KR) in Tumbang Runen has the highest basal area, but it has the lowest species richness and tree diversity. The most dominant tree in simple rubber agroforest is rubber (*H. brasiliensis*). The rubber agroforest (KR) is currently being less managed but still productive. It is interesting to see diversity in complex rubber-rattan agroforest (KKR), that it has high diversity index ($H' = 3.31$), the highest Evenness index ($E' = 1.57$), and the highest tree density (645 tree/ha). The rattan is planted in the abandoned rubber, since very limited rubber grow on the sites. Number of tree species presence in the KKR was 34 species. At the seedling stage, the similarity index between KKR and KR is high (IS=55.32), which implies many shared species between the two land use types. At tree stage, on the other hand, very few shared species between KKR and KR in Tumbang Runen with three other land use types in Malawan (forest, *baliang* and *bahu*). The distance between the two villages is about 460 km. The distance and different land management by farmers may influence the composition of vegetation in the villages.

The rattan agroforest currently is not being maintained, owing to limited market to sell raw material of rattan; if it can be sell, the rattan price at farmer level is very low. Farmers were not willing to take much effort on rattan harvesting when the price is not competitive [3]. This condition is affected by ban regulation of raw rattan material export without sufficient support for the local communities in improving their capacity to improve added value of rattan. Other stakeholders, such as private and government together need to improve infrastructure of rattan industry, control on illegal rattan trading, and providing financial trading[19,20].

5. Conclusion
Rattan agroforests conserve tree diversity of the landscape. Tree diversity in rattan agroforest was influenced by farm management. The abandoned rattan agroforest (*baliang*) has the highest tree and rattan diversity; whilst the productive rubber agroforest has the lowest tree diversity. Baliang (a secondary forest that was formed by succession from bahu) tends to be a refugee area for some tree species, as it has the highest species richness (both for woody trees and rattan species). Currently, the potency of rattan in Katingan is high, which can be developed for further use and it needs strong support from government as a policy makers.

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