Tree Species Richness, Diversity and Distribution at Sungai Menyala Forest Reserve, Negeri Sembilan

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Abstract. Tree species richness, diversity and distribution within the Sungai Menyala Forest Reserve, Negeri Sembilan was assessed by establishing 6.91 ha plots. All tree > 5 cm DBH were sampled and identified to species level. Species diversity was defined as a combination of species richness and evenness. For this study, species richness is measured by Margalef’s and Menhinick’s diversity indices. The diversity indices used in this study are Shannon-Weiner diversity index, Simpson’s diversity index, Heip’s index of evenness and Berger-Parker Dominance. Species-accumulation curve was plotted to measure the species and family richness and diversity in Sungai Menyala FR. A total of 1034 individual trees representing 150 species, 87 genera and 34 families were recorded. Compartment 12 (C12) show the highest species richness value of Margalef Index and Menhinick Index which are 12.31 and 5.20 respectively. C12 showed the highest species richness by accumulation curve analysis. The ANOVA analysis for each diversity index to species and family composition showed no significant difference.

Keyword. Tropical rainforest, species diversity, species evenness.

1. Introduction
There were many methods of forest assessment had been developed to provide information and understanding of the forest dynamics in recent years. The idea of an understanding of the forest dynamic is to find the indicator of the quality of the environment of the study areas. These forest dynamics will describe the aspects of tree spatial pattern which are canopy replacement, regeneration, persistent changes after disturbance (regeneration or degradation) and the spatial relationship between tree species in particular forest areas. This assessment then will give information on the forest manager on how to do the rehabilitation works[1].

The reduction of plant diversity in a natural ecosystem is often resulted by changes in land use, habitat fragmentation, nutrient enrichment and environmental stress. The component of diversity that usually has been discussed are species richness and evenness [2]. Species richness is the number of species or taxa in an area. Evenness is the relative abundance of species in a community [3].
In ecological studies, the properties that explain the relationship between communities are the species richness, diversity and distribution. Comparison of each type of community can be made by comparing their diversity indices. These diversity indices are the measurement to describe general properties of communities [4,5].

This study is designed to explain the variation in diversity component in Sungai Menyala Forest Reserve. The forest is divided by compartments number and the diversity component are compared. From the result, this study will suggest which compartment need to undergo conservation effort such as plant enrichment activities.

The objectives of this study are to determine the trees species richness, diversity and distribution in Sungai Menyala Forest Reserve, Negeri Sembilan. This study covers only lowland dipterocarp forest with tree component 5 cm and above.

2. Methodology

2.1. Study Site
This study was conducted in Sungai Menyala Forest Reserve, Port Dickson, Negeri Sembilan. This area is located at 2° 28’ N and 101° 55’ E. Figure 1 is derived by ArcGis 10.4 software and it shows the location of this study area and the detail location of the study compartments and plots by Pleiades image. This forest has been classified as a Lowland dipterocarp-forest formation by Symington in 1943 [6] and Red Meranti-Keruing forest type by Wyatt-Smith in 1966 [7]. This forest is situated 6.5 km from the sea. The soil is flat, well-drained and there are patches of fresh water swamp forest. The type of soil is Alluvial in this area. The irrigation of the soil is inclined to be moderately well drained to poorly drained.
2.2. Compartments and Plots

There were 55 plots established in this area. These plots were established by a method by Walker et al. 2012 [8]. Nine compartments had been gazetted for Sungai Menyala FR. The compartments are C6, C8, C9, C10, C11, C12, C13, C14 and C15 (Figure 2). For this study, the censuses only in compartment C9, C10, C12, C13, C14 and C15. We did not make census in the compartment C6, C8 and C11 as they are inaccessible. The different elevation of study plots was decided to ensure the researcher made the censuses of different plants from each elevation. The 55 plots number are listed in Table 1.
Figure 2. Plot Location in Compartments.

Table 1. Sampling Plots Distribution in Compartments.

| No. | Compartment No. | Plot No.                  | Plots |
|-----|-----------------|--------------------------|-------|
| 1   | C9              | 7B, 7D, 8A, 8B, 8C       | 5     |
| 2   | C10             | 6A, 6B, 6C, 6D, 8D, 9A, 9B, 9C, 9D, 9E | 10    |
| 3   | C12             | 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D | 12    |
| 4   | C13             | 10A, 10B, 10C, 10D, 10E, 11A, 11B, 11C, 11D | 9     |
2.3. Data Analysis
Diversity pattern in the area is described by calculating the species richness and the species evenness [9,10]. Richness (S) is the number of taxa attributes such as species or families that present in the community [5,9]. The pattern of individual distributed over the different species (distinctness or dissimilarity) in a community is expressed by evenness index [9,11].

For this study, species richness is measured by Margalef’s and Menhinick’s diversity indices. The diversity indices that were used in this study are Shannon-Weiner diversity index, Simpson’s diversity index, Heip’s index of evenness, Berger-Parker Dominance. Species-accumulation is to measure the species and family richness and diversity in Sungai Menyala FR.

2.3.1. Species Richness Indices (S)

Margalef’s diversity index

\[ D_{Mg} = \frac{(S-1)}{\ln N} \]  

Menhinick’s diversity index

\[ D_{Mn} = \frac{S}{\sqrt{N}} \]  

Where;

S = the number of species recorded
N = the total number of individuals in the sample
\( \ln \) = log base \( e \)

2.3.2. Diversity Indices

Shannon-Weiner diversity index (\( H' \))

\[ H' = -\sum_{i=1}^{n} p_i \ln p_i \]  

Where;

n = the number of species
\( p_i \) = the proportion of individuals or the abundance of the \( i \)th species expressed as a proportion of total abundance
\( \ln \) = log base \( e \)

Simpson’s diversity index (1-D)
\[ D = \frac{\sum n(n-1)}{N(N-1)} \]  

(4)

Where;

\( n \) = the total number of individuals of a particular species

\( N \) = the total number of individuals of all species

Heip’s index of evenness (\( E_{\text{Heip}} \))

\[ E_{\text{Heip}} = \frac{e^{H'_{-1}}}{S-1} \]  

(5)

Where;

\( H' \) = the number derived from the Shannon diversity index; and

\( S \) = the total number of species

Berger-Parker Dominance (\( d \))

\[ d = \frac{n_{\text{max}}}{N} \]  

(6)

where;

\( n_{\text{max}} \) = the dominance individual within a community

\( N \) = total number all individual within a community

To calculate the diversity index, the inverse or reciprocal of Berger-Parker dominance is required as follow:

\[ I_{BP} = \frac{1}{d} \]  

(7)

2.3.3. Species Accumulation Curve

Species accumulation curve is an analysis to describe the relationship between the number of species observed in a field study as a function of observed abundance [9]. This curve shows the species richness each of the sites (plots or compartment) respectively. This analysis is to show the distribution trend in a site which not always shared the similar species. Although if the value of species richness of compared sites is nearly similar, the curve itself can tell whether the plot consists of similarity or diverse individual in its community.

For this study, the comparison was made between the compartment of the Sungai Menyala FR.

2.3.4. Cluster Analysis

A cluster analysis analyses the pattern of the similarity or dissimilarity in species composition between the site. For this study, cluster analysis by using Morista index was applied to each compartment. The paired group was used based on Morista index data calculation for each compartment [12]. This calculation is assisted by using the ecological software PAST.
3. Result

3.1. Species Richness

This study uses the Margalef Index and Menhinick Index to evaluate the species richness for each of the compartment.

C12 shows the highest species richness value of Margalef Index and Menhinick Index which are 12.31 and 5.20 respectively. For C9, it shows the lowest species richness for both Margalef Index and Menhinick Index which are 6.87 and 3.92 respectively (Table 2). However, there is no significant difference for each of the species richness of compartment for Margalef Index and Menhinick Index (p > 0.05).

C12 shows the highest family richness value of Margalef Index and Menhinick Index which are 5.04 and 2.17 respectively. C13 shows the lowest family richness value for both Margalef and Menhinick Index which are 3.23 and 1.43 respectively (Table 2). However, there is no significant difference for each of the family richness of compartment for Margalef Index and Menhinick Index (p > 0.05).

Table 2. Species and Family Richness in Sungai Menyala Forest Reserve, Negeri Sembilan

| Level   | Compartment | Margalef Index | Menhinick Index |
|---------|-------------|----------------|-----------------|
| Species | C9          | 6.87           | 3.92            |
|         | C10         | 9.11           | 4.43            |
|         | C12         | 12.31          | 5.20            |
|         | C13         | 11.72          | 4.97            |
|         | C14         | 10.88          | 5.13            |
|         | C15         | 9.44           | 4.37            |
| Family  | C9          | 3.32           | 1.98            |
|         | C10         | 3.56           | 1.79            |
|         | C12         | 5.04           | 2.17            |
|         | C13         | 3.23           | 1.43            |
|         | C14         | 3.70           | 1.81            |
|         | C15         | 4.93           | 2.33            |

3.2. Species Accumulation Curve

The species accumulation curves analysis is needed to analyse the species richness of numbers of plots or compartments. For this study, we are comparing between the compartments level. Because of the differences in sampling efforts or sample size for each compartment, the number of species accumulation curve can stop in the middle of the plot area. However, by looking at the curves, we can distinguish the richness level of the compartments.

For the species accumulation curve in Figure 3, C12 show the highest peak of the curve line compared to other compartments. Even though the C14 curve increases dramatically at the start, but the curve tends to stabilize and flattened and stops in the middle of the graph due to lack of sample size. The C12
curve shows a steady increment of accumulation curve and stops at the highest species richness value. Thus, the highest species richness is shown by C12.

For family accumulation curve in Figure 4, C12 show dramatically increments of curve line from the beginning and become gradually stabilize and flatten in the end. The C12 accumulation curve stop at the highest value of family richness. However, C15 accumulation curve also shows the increment and overlap with C12 accumulation curve and keep increasing and did not show it going to the stabilize or flattened trend. If the researcher adds the sample size or sampling effort, C15 might show the highest family richness compared to the compartments.

**Figure 3.** Species-Accumulation Curves
3.3. Species Diversity

Diversity indices are used by ecology study to make a quantitative comparison between the ecosystem biological components [9]. For highest Shannon-Weiner index (H’) for species level is shown by C14 followed by C12, C13, C9, C15 and C10. This shown C14 has the diverse species in its compartment compared to others. For the Simpson index, C14 has the highest value followed by C10, C12, C13 and C15 with the same value of 0.96 and the lowest index value is C9. C14 has the highest Heip evenness index value followed by C10, C9, C15, C10, C12 and C13. Berger-Parker index for species in C9 is the highest value followed by C15, C13, C10, C12 and C14. From this result, C14 has the highest diversity and evenness of species. Form the Berger-Parker index, C9 has the highest dominant composition of species. From ANOVA analysis for each species index to the compartment, there is no significant difference was found (p > 0.05).

The comparison in family level for Shannon index was shown the highest value for C12 followed by C14, C10, C15, C9 and C13. For the Simpson index, both C10 and C14 show the highest value of 0.85 and followed by C12, C15, C9 and C13. For Heip evenness index, C10 show the highest value followed by C9, C14, C13, C12 and C15. Berger-Parker index shows C9 is the highest value followed by C13, C15, C12, C10 and C14. From the result, C12 has the highest value of family diversity, C10 show the highest family evenness value and C9 has the highest dominant family composition. From ANOVA analysis for each family index to the compartment, there is no significant difference was found (p > 0.05).

Table 3. Descriptive Statistic for Species and Family Diversity Indices in Hutan Simpan Sungai Menyala, Negeri Sembilan

| Level | Variable/ Index | C9   | C10  | C12  | C13  | C14  | C15  |
|-------|-----------------|------|------|------|------|------|------|
| Species | Shannon_H      | 3.00 | 3.45 | 3.70 | 3.60 | 3.71 | 3.47 |
|        | Simpson_1-D     | 0.92 | 0.96 | 0.96 | 0.96 | 0.97 | 0.96 |
Evenness \( e^{H/S} \) 0.71 0.75 0.65 0.62 0.80 0.71
Berger-Parker 0.22 0.09 0.08 0.10 0.07 0.11
Family Shannon_H 2.12 2.34 2.48 2.11 2.37 2.28
Simpson_1-D 0.79 0.85 0.84 0.79 0.85 0.81
Evenness \( e^{H/S} \) 0.60 0.61 0.46 0.48 0.60 0.41
Berger-Parker 0.42 0.32 0.35 0.40 0.32 0.38

3.4. Cluster Analysis

The result from cluster analysis, dendrogram as in Figure 5 was developed based on Morista index where this analysis divided the six (6) species composition and distribution data between the compartments. From the dendrogram, we can see three (3) groups of assemblages. The first assemblages are C10, C13 and C12 show the highest similarity with 0.72 similarity coefficient. C14 and C15 are the second assemblages with 0.60 similarities. C9 has the lowest similarity to the each of the compartment with the 0.49 similarity.

![Dendrogram Based on Morista Index for Each of Compartment in Sungai Menyala FR.](image)

**Figure 5.** Dendrogram Based on Morista Index for Each of Compartment in Sungai Menyala FR.

4. Discussion

Sungai Menyala FR had experienced human disturbances activity as it has been selectively logged in the 1950th. This activity has separate this forest into three (3) patches of primary forest consist of 19 ha forest area [13]. This forest is still undergoing a regeneration process and with the management state forestry department, this forest is classified as the Forest Reserve area and this activity in this area just limited only for study purpose.

Even though the forest area is protected, the forest location near coastal area gives the area exposure to natural disturbance such as a windstorm. It has been reported of windstorm events from 2003 to 2012 in Sungai Menyala FR and affects the forest structure and large trees [1].

From the species and family accumulation curve, there are several compartment show asymptotic lines. This result indicate that more sampling effort would be necessary of the compartments. However, this data can be continue with estimator analysis to estimates the species richness of each of the compartments [11].
5. Conclusion
Compartment 12 showed the highest value for both Magalef’s Index and Menhinick’s Index for the species and family richness for each of the plots. However, there was no significant difference in the statistical comparison of the richness value for the compartments. C12 also shown the highest value in the accumulation curve analysis. For species diversity index analysis, there also no significant difference of the index to the species and family composition. The C14 show the highest species diversity, however, C12 show the highest family diversity. The cluster analysis shows the clearer pattern of species composition in the Sungai Menyala FR with three (3) assemblages of similarities.

This study found that the diversity of the Sungai Menyala FR for each of the plot is similar. The total Shannon Weiner Index for the Sungai Menyala FR is 4.12 which mean this forest has a high value of diversity in general[14].

Compartment 9 has the lowest diversity index and show the lowest similarity to the compartment. A conservation effort should be taken place in this compartment to increase its species and family diversity composition.

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