Association of dominated tree species in secondary pamah forest of Ponda-Ponda Nature Reserve, South Sulawesi, Indonesia

Hadijah Azis Karim¹, Asrianny², Witno¹ and Tiara¹

¹ Andi Djemma University, Palopo, Indonesia
² Hasanuddin University, Makassar, Indonesia

Email: asrianny@gmail.com

Abstract. The Ponda-Ponda Nature Reserve is an apamah vegetation type of secondary forest belonging to a forest conservation area. The objective of this research was to gain information about tree species domination and association in the secondary pamah forest. The collecting data was conducted from December 2020 – March 2021. The primary data was obtained from direct measurements, which tree ≥ 10 cm dbh and 5 m tall censused using multiple plots (20 m x 30 m) by systematic sampling in the line transects. The line transect was placed purposively to represent the plant community. The result showed that six tree species are having high dominance with 15 combination types. The highest dominant species is Nauclea orientalis, with an important index value of 18.56%. There were only two couples that had associations, such as N. orientalis & S. celebica. This pair shows a very strong or very significant association at the 5% level with a value of 4.29. While the view of P. anisophylla & S. celebica only had an association at the 10% level with a value of 3.60. Both of the pairs also have the high index association by Jaccard Index. The association presented that six couples had positive association and six couples had a negative association with a level of dependence ranging from low to high classification. But the others three pairs showed unidentified association types.

1. Introduction

Pamah forest vegetation is a lowland forest that receives high rainfall, and biomes in the form of forests that are always wet or humid can be found in areas around the equator, which receive abundant forest rainfall of around 2000 – 4000 mm per year. Pamah forest has a very high plant diversity compared to other types of lowland forest vegetation [1]. According to [2], the characteristics of a pamah forest are the main trees have a height of between 20-40 m with the high tree density and are green throughout the year, get enough sunlight even though the sunlight is not able to penetrate the forest floor, and has a micro-climate around the ground surface or under the canopy cover.

The Ponda-Ponda Nature Reserve is a representative example of a secondary lowland forest ecosystem that is overgrown with various plant species, both endemic, rare, and species that are still common in almost Sulawesi forest areas. Ponda Ponda Nature Reserve, with an area of 77.22 ha, is located in the Mangkutana area, East Luwu Regency. The Ponda Ponda area is designated as a nature reserve area because of the potential for Diospyros celebica, which requires conservation efforts. This species is an endemic species of Sulawesi that has high economic value [3,4], is rare, and its population has not been widely represented in conservation areas. However, the location of this nature
reserve is directly adjacent to Teromu Village, which causes high levels of illegal logging, encroachment activities, and conversion of the area to agricultural land; it is feared that it will reduce the diversity of vegetation types, especially tree-level vegetation in this area [5].

Vegetation is formed by the presence and interaction of several types of plants. One form of interaction between these types is association. Association is a distinctive type of community, found under the same conditions and repeated in several locations. The association is characterized by the presence of similar floristic composition, uniform physiognomy, and distribution with a distinctive habitat [6]. Associations between two types of plants can be positive or negative. If there is a positive association, the associated species have the same response to environmental differences in a community, and if there is a negative association, it means that the associated species has an unequal response to environmental changes in the community. The factors that determine the strength of an association are the number of species present, the condition of the place where the plants are located, and the number of joint events between the associated species, while the measure used to determine the strength of an association is the coefficient of association [7]. Associations between species in Ponda-Ponda nature reserves arise when two or more species are often present together in a vegetation/habitat rather than by chance. Association occurs as a consequence of biotic interactions such as mutualism, competition, and predation [8]. The vegetation in Ponda-ponda is dominated by tree species and shrubs.

Information on plant species associations in ecological implications is very important in the management of the Ponda-ponda Nature Reserve. However, studies on this matter are still rare. Therefore, it is necessary to study the vegetation in this area to know the level of dominance and association of plants in the secondary pama field of Ponda-ponda Nature Reserve.

2. Research methods
The study site was conducted at Ponda-Ponda Nature Reserve, located in Mangkutana District, East Luwu Regency, South Sulawesi Province. Originally, this area was protected forest, which joined with a much larger area to the Forest Group around the town of Malili, but then was fragmented as the land occupation for plantations and agriculture, as well as the expansion of other settlements occurred. The geographical location of the nature reserve is 120° 48' 47" - 120° 49' 21" east longitude and 02° 24' 58" - 02° 25' 32" south latitude. The Ponda-ponda area was proposed to be a conservation area by the Regional Office of the Ministry of Forestry of South Sulawesi Province through letter number 238/Kwss-6/3/1988 dated March 2, 1988. The Ponda-ponda area was then changed its function into a Nature Reserve area with the Decree of the Minister of Forestry Number 319/Kpts-II/1990 dated June 26, 1990, and Stipulation of SK. Minister of Forestry No. 201/Kpts-II/1999 April 14, 1999, covering an area of 77.22 ha. (Figure 1). The condition of the Ponda-ponda field is sloping to undulating with a slope of 30% - 60%, an altitude of about 350 m - 442 m above sea level; the geological formation consists of Paleogene Sedimentary Rocks, and the type of soil in the Ponda-ponda Nature Reserve area is Podsolik Chocolate. Climate type according to Schmidt and Ferguson: A with an average annual rainfall of about 4,365 mm.

Determination of observation plots using a combination method of plot and line transect method [9]. Line transect was placed purposively to represent the plant community. The plots were set up systematically in the line transect, with the distance between the plots is 200 meters each. A total of 10 plots were designed using a rectangular plot with a size of 20 m x 30 m [10]. The data collection technique was carried out by recording all types of woody plants or trees with a height of > 5 m measured using a haga meter and dbh > 10 cm by diameter tape. Plants of unknown species will be given a symbol and then used as herbarium specimens to be identified. Data on the frequency, density, and dominance of each tree species found were analyzed with the Important Value Index (IVI) and associations between the main constituent species by having IVI ≥ 10% [11].
Association analysis was carried out by using contingency table 2x2 [12,13] as follows:

**Table 1. Contingency table 2x2**

| Species B | Present | Absent | Total |
|-----------|---------|--------|-------|
| Species A | Present | a      | b     | a+b   |
| Absent    | c       | d      | c+d   |
| Total     | a+c     | b+d    | N=a+b+c+d |

Note:
- \( a \) = Observation of the number of measurement points that contains species A and species B,
- \( b \) = Observation number measurement point containing species A only,
- \( c \) = Observation of the number of measurement points containing B species only,
- \( d \) = Observation of the number of measurement points that do not contain species A and species B,
- \( N \) = Number of points observation.

To determine whether there is a tendency to associate or not, the Chi-square Test [14] is used with the following formulation:

\[
\text{Chi-Square (}\chi^2\text{) calculation} = \frac{N(\text{ad}-\text{bc})^2}{(a+b)(a+c)(c+d)(b+d)} \tag{1}
\]

The calculated Chi-Square value is then compared with the Chi-Square table value at degrees of freedom = 1, at the 5% test level (value 3.84). If the calculated Chi-Square > the Chi-Square table value, then an association occurs. If the calculated Chi-Square value is < the Chi-Square table value, then there is no association [7]. Furthermore, to determine the type of association interaction is determined by calculating the value of \( E(a) \) [6,15] with the following formula:

\[
E(a) = \frac{(a+b)(a+c)}{N} \tag{2}
\]

Based on this formula, there are two types of associations: (1) positive association, if \( a > E(a) \), it means that the pairs occur together more than expected. (2) negative association, if the value of \( a < E(a) \) means that the pairs occur together more or less than expected. The size of the association obtained by the Jaccard Index formula in Dewantara (2017) [15,16] is as follows:

\[
\text{Indeks Jaccard (JI)} = \frac{a}{a+b+c} \tag{3}
\]

Note:
- \( a \) = Observation of the number of measurement points that contains species A and species B,
- \( b \) = Observation number measurement point containing species A only,
- \( c \) = Observation of the number of measurement points containing B species only

The range of Jaccard Index values is 0-1. The value of 0 is the minimum value, which indicates the absence of association, while the value of 1 indicates the maximum value, which indicates a high level of association [17]. Determination of the association index level based on the association index class interval as follows:

**Table 2. The interval of association index class**

| The interval of association index class | Classification |
|----------------------------------------|----------------|
| 0-0.25                                 | Low            |
| 0.26-0.50                              | Moderate       |
| 0.51-0.75                              | High           |
| 0.76-1.00                              | Very High      |
3. Results and Discussions

3.1. Dominated tree species in Ponda-Ponda Nature Reserve

Based on the results of the composition of plant species in the study area, it shows that in total, there were 53 species from 34 families with a total of 277 individual trees. The Cluciaceae family is the family that has the greatest variety of species, followed by the Rubiaceae, Moraceae, and Sapotaceae families. From a total of 53 species, six species have an IVI above 10%. These species include *Nauclea orientalis*, *Porterandia anisophylla*, *Sarcotheca cf. celebica*, *Calophyllum soulatrii*, *Glochidion sp.*, and *Salacia korthalsiana*. The results of the calculation of the Important Value Index (IVI) showed that the species *Nauclea orientalis* (Rubiaceae) was the most dominating species, with a value of 18.56%. The IVI value indicates a plant species and its role in the community. The greater the IVI value, the greater the role of a species in a community [18]. Meanwhile, according to [19], the IVI value is a quantitative parameter that can be used to express the level of dominance of a species. *N. orientalis* is a pioneer species that is relatively fast-growing and able to adapt to both wet and dry lands. This tree grows at an altitude of 0-500 mdp4, with rainfall of 800-3800 mm/year [20,21].

*Porterandia anisophylla* is the second dominant plant species after *N. orientalis*, with an IVI of 15.32%. [22] states that *Porterandia anisophylla* usually grows in undisturbed to moderately disturbed (open) mixed dipterocarp forests and sub-mountain forests up to 1700 m altitude. Usually on hillsides and ridges with clay to sandy soil. In the secondary forest, it is usually present as a pre-disturbance
residue. [23] found the dominant presence of *Porterandia anisophylla* in the educational forest area of Mulawarman University with a density of 360 individuals per hectare. This species is very suitable to grow in forest areas that have experienced disturbances such as fire, and soil types are podzolic kandik, podzolic chronic, and district cambisol. This species is often found at a relatively low altitude from sea level, namely 6-71 m above sea level, with moderate rain intensity and relatively high humidity. *Porterandia anisophylla* is used by the Jambi community as a herbal medicinal plant because it contains alkaloids and saponins [24].

As an endemic species, *S. celebica*, or in the local language called makeli, kongilu, and sengilu, is known as a plant that can grow in ultrabasic soils with high nickel content [25]. *S. celebica* grows in open areas in South Sulawesi (Malili, Soroako, around Lake Toweuti and Lake Matano), Central Sulawesi (Morowali Nature Reserve; Solodik and in Padamuka, Ampama) and Southeast Sulawesi (Pomalaa – Bombana, Tinoleri, Lamedai Kolaka and Kabeana Island). The type of *S. celebica* is also found in the ponda-ponda nature reserve after the research; this species has an IVI of 12.83% with a relative dominance value of 6.17%. *S. celebica* has used the fruit to be a flavoring ingredient cooked with fish. Besides, this species is being investigated as a nickel-absorbing agent in phytomining [26].

The other three species are *Calophyllum soulatrii*, *Salacia korthalsiana*, and *Glochidion sp.*, have relatively the same IVI in the range of 10. *C. soulatrii* is found in every observation plot but has a low relative dominance value with a value of 2.13%, this tree grows at an altitude of 0-300 m above sea level with rainfall of 1,000-3,000 mm/year, and the average temperature is 18 - 33°C with a pH 4 - 7.4 [27,28] According to [29], *Calophyllum soulatrii* is used by the people of Mangkutana District as house and window poles because the wood is durable, so it is not easily eaten by termites. It's just that these plant species are slowly starting to decrease because there is no cultivation on community land. At the same time, the type of *Salacia korthalsiana* is a species whose distribution is found in Southeast Asia, including Thailand, Malaysia, and Indonesia (Java, Sulawesi, and Papua). It grows wild in forests and shrubs, sometimes on limestone rocks, in eastern Java in teak plantations, up to an altitude of 1,400 m. This species has edible fruit, and a decoction of its roots is used as a medicinal plant to treat chapped lips [30,31].

A unique thing happened to the *Glochidion sp.* species, which were found to be clustered in several research plots. According to [32], this species belongs to the Euphorbiaceae family, which is often found in tropical rain forest climates, especially pamah forests with loose soil habitat and open land. Its distribution is found from Aceh to Biak Papua in lowland areas. [33] stated that this type of plant is one of the plants that has been traditionally used by the community around Katembe, North Aceh. This type is used as a cold medicine in children, medicine for the digestive tract, and skin medicine. While in the Biak area of Papua, this species is called by the local name of Samurai. This type is a traditional medicinal plant that has long been used for generations from their ancestors. By the local people of Biak, this plant is used for antimalarial herbal medicine or as a cure for malaria. Local people take advantage of medicinal plants for sampare by drinking boiled water from the leaves [32].

### Table 3. Dominated tree species in Ponda-Ponda Nature Reserve

| Species Name                  | Family     | RD (%) | RF (%) | RDM (%) | IVI (%) |
|------------------------------|------------|--------|--------|---------|---------|
| *Nauclea orientalis* (L.)     | Rubiaceae  | 5.07   | 4.24   | 9.24    | 18.56   |
| *Porterandia anisophylla* (Jack ex Roxb.) Ridl. | Rubiaceae  | 5.79   | 3.03   | 6.49    | 15.32   |
| *Sarcotheca cf. celebica* Veldk. | Oxalidaceae | 3.62   | 3.03   | 6.17    | 12.83   |
| *Calophyllum soulatrii* Burm.f. | Clusiaceae | 5.07   | 3.63   | 2.14    | 10.85   |
| *Glochidion sp.*               | Euphorbiaceae | 2.53   | 3.63   | 4.21    | 10.39   |
| *Salacia korthalsiana* Miq.    | Celasteraceae | 3.62   | 2.42   | 4.14    | 10.19   |

Note: RD = Relative Density, RF = Relative Frequency, RDM = Relative Dominance, IVI = Important Value Index.
3.2. Associations between the main species composition

**Table 4.** Association between the main species composition in Ponda-Ponda Nature Reserve

| Species                      | X²t(5%) | X²t(10%) | X²t cal | Association |
|------------------------------|---------|----------|---------|-------------|
| N. orientalis & P. anisophylla | 3.84    | 2.70     | 0.48 ns | na          |
| N. orientalis & S. celebica  | 3.84    | 2.70     | 4.29**  | a           |
| N. orientalis & C. soulatri  | 3.84    | 2.70     | 0.08 ns | na          |
| N. orientalis & Glochidion sp. | 3.84    | 2.70     | 0.08 ns | na          |
| N. orientalis & S. korthalsiana | 3.84    | 2.70     | 1.27 ns | na          |
| P. anisophylla & S. celebica | 3.84    | 2.70     | 3.60*   | a           |
| P. anisophylla & C. soulatri | 3.84    | 2.70     | 1.67 ns | na          |
| P. anisophylla & Glochidion sp. | 3.84    | 2.70     | 0 ns    | na          |
| P. anisophylla & S. korthalsiana | 3.84    | 2.70     | 1.67 ns | na          |
| S. celebica & C. soulatri    | 3.84    | 2.70     | 0 ns    | na          |
| S. celebica & Glochidion sp. | 3.84    | 2.70     | 0 ns    | na          |
| C. soulatri & S. korthalsiana | 3.84    | 2.70     | 0.28 ns | na          |
| S. celebica & S. korthalsiana | 3.84    | 2.70     | 1.67 ns | na          |

Note: ns = not significant, ** = very significant at 5%, * = significant at 10%, a = association
na = not association

IVI calculation results obtained 6 dominant tree species or those with IVI 10% (Table 3). The results of the calculation of the association between the 6 species indicate that the chance of being associated is very small compared to that of being unassociated. This is because the calculated X² value (Chi-square) is lower than the X² table value tested at the 5% (3.84) and 10% (2.70) levels. So that the results obtained are 13 pairs of species that are not associated, thus these results indicate that pairs of dominant species in the study area tend to associate less. The absence of association is because the two species have different life cycles and different ecological roles. This is because other than the absence of associations, it is also caused by environmental factors, such as the soil pH, nutrients, and the maximum-minimum temperature in the environment, which select the species for growing properly. The absence of association can also be caused by a supportive environment for the growth and reproduction of both species so that both species can grow and develop together without competition.

Of the 15 types of pairs, there were only two pairs that had associations, namely N. orientalis & S. celebica. This pair shows a very strong or very significant association at the 5% level because it has a chi-square value of 4.29. While the view of P. anisophylla & S. celebica only had an association at the 10% level with a chi-square value of 3.60. Thus, these results indicate that the dominant sex pairs in the study area who tend to live together are less than those of the sex partners who do not tend to live together. It can be said that the determination of species associated with the 2x2 Contingency table approach has not yet indicated the degree of association (Table 4).
Table 5. Association type between the main species composition in Ponda-Ponda Nature Reserve

| Species                          | a  | E(a) | Type of Association |
|----------------------------------|----|------|---------------------|
| N. orientalis & P. anisophylla  | 4  | 3.50 | +                   |
| N. orientalis & S. celebica     | 5  | 3.50 | +                   |
| N. orientalis & C. soulatri      | 4  | 4.20 | −                   |
| N. orientalis & Glochidion sp.   | 4  | 4.20 | −                   |
| N. orientalis & S. korthalsiana  | 2  | 2.80 | −                   |
| P. anisophylla & S. celebica    | 4  | 2.50 | +                   |
| P. anisophylla & C. soulatri     | 2  | 3.00 | −                   |
| P. anisophylla & Glochidion sp.  | 3  | 3.00 | ni                  |
| P. anisophylla & S. korthalsiana| 1  | 2.00 | −                   |
| S. celebica & C. soulatri       | 3  | 3.00 | ni                  |
| S. celebica & Glochidion sp.     | 3  | 3.00 | ni                  |
| S. celebica & S. korthalsiana   | 1  | 2.00 | −                   |
| C. soulatri & Glochidion sp.     | 4  | 3.60 | +                   |
| C. soulatri & S. korthalsiana   | 4  | 3.60 | +                   |
| Glochidion sp. & S. korthalsiana| 3  | 2.40 | +                   |

Note: a = Observation of the number of measurement points that contains species A and species B, E(a) = the strength of association level, + = Positive association, - = negative association, ni = not identify.

Furthermore, to determine the level or strength of the association is determined by calculating the value of E (a). The results provided determine two types of interactions, namely positive and negative. Positive association, if a > E(a) means that the pair of sex occurs together more than expected. (2) Negative association, if the value of a < E(a) means that the pairs of sexes occur together more or less than expected [34].

From the calculation results in table 5, it can be seen that the types of positive and negative associations are the same, namely 6 pairs each. This shows that the association relationships between pairs of species are mutually beneficial and detrimental to each other or have different adaptation responses to the environment, which means that there is competition in terms of getting sunlight, for example, N. orientalis with C. soulatrii and S. korthalsiana. It can be seen that N. orientalis is the type that gets the most sunlight compared to C. soulatrii and S. korthalsiana, and there is also competition in terms of getting nutrients, growing space, and other needs between the two species. According to [34] negative associations indicate that the species in question tend to be found together or do not want to live together. However, three pairs showed unidentified association types such as P. anisophylla & Glochidion sp., S. celebica & C. soulatri, and S. celebica & Glochidion sp. This due to the value of E (a) is similar to a value. It means that even though they live together in the same plot, but there is no interaction. The absence of associations can also be caused by a supportive environment for the growth and reproduction of both species so that both species can grow and develop together without competition.

From the calculation results in table 5, there are 6 pairs of species that are positively associated. This shows that these species can live together and are dependent on each other. [19] states that if the type is positively associated, it will produce a positive spatial relationship with its partner. Positive association occurs when the two species require the same conditions or the presence of predators.
Based on the degree of association/value of the magnitude of the association using the Jaccard index, the pair N. orientalis & S. celebica had a high association value compared to other pairs, namely 0.71 with a relatively high classification of association level, P. anisophylla & S. celebica, had a value the second-highest association with a value of 0.67 with a relatively high level of association. Nine pairs have a moderate association value with an association index class of 0.26 – 0.50. While the pairs of P. anisophylla & S. korthalsiana, and S. celebica & S. korthalsiana had the lowest association value compared to the other species, namely 0.13, although there were still two pairs that also had a low classification, namely N. orientalis & S. korthalsiana, and P. anisophylla & C. soulatii. By the opinion of [17,35,36] that the Jaccard index value ranges from 0-1. The closer the relationship between the two types of organisms, the higher the value of the index. On the other hand, the further the relationship between the two types of the index value is closer to 0 (zero). This shows that although between species, according to table 6 there are no associations, the closeness is low, medium, and high. However, this did not apply to the pair N. orientalis & S. celebica and P. anisophylla & S.
celebica. From the beginning, these two pairs showed an association with a positive type of association. After further testing with the Jaccard association index, these two pairs even showed the highest index classification among other types of pairs. This means that this type of couple shows a high dependency relationship to live together. This shows that these species can live together and have a high dependency/association index, so this type of pair has a very real relationship and can live side by side. The togetherness of the two types is due to having the same or almost the same response to environmental factors [13].

In contrast, some types of partners did not initially show any association tendencies but had moderately dependent relationships. [36] explains that organisms in a community are interdependent so that they are not bound by chance alone, and disturbance of one organism will have consequences for the whole organism. However, in plants N. orientalis & S. korthalsiana, P. anisophylla & C. soulatri, P. anisophylla & S. korthalsiana, and S. celebica & S. korthalsiana, although there is a tendency to have negative associations, they have a low association index that allows pairing these cancel each other out. In addition, the tendency to cancel each other out between the two types is due to the competition between the two types. Following [36] that the emergence of this competition is due to these species having the same necessities of life while the sources that support the necessities of life themselves are in limited circumstances. The type of negative association is that the pairs of species occur together less than expected [37] but have a low association index, meaning that the species does not have a partial dependence or reciprocal relationship that shows no tolerance for living together in areas that are the same, especially in the division of living space [34,37].

The results of the calculation of the association index (Table 6.) strengthen the results of the calculation of the association type (Table 5.) that most of the dominant trees of lowland forest vegetation in Ponda-Ponda Nature Reserve show no tolerance for living together in the same area and there is no mutual relationship interaction, especially in the division of living space.

4. Conclusions
There were 53 tree species from 34 families, with a total of 277 individual trees in Ponda-Ponda Nature Reserve. Nauclea orientalis (Rubiaceae) was the most dominating species with an important value index of 18.56%. The other three species are Calophyllum soulatri, Salacia korthalsiana, and Glochidion sp., have relatively the same IVI in the range of 10%. The association between the six species indicates that the chance of being associated is very small compared to that of being unassociated. The types of positive and negative associations are the same, namely 6 pairs each, but the other 3 pairs showed unidentified association types. There were only two pairs that had associations, namely N. orientalis & S. celebica. This pair shows a very strong or very significant association at the 5% level with a value of 4.29. While the view of P. anisophylla & S. celebica only had an association at the 10% level with a value of 3.60. Both of the pairs also have the high index association by Jaccard Index.

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