The effect of forest land allocation on understory plant species associations

S H Sidabukke¹,*, T A Barus², B Utomo³, Delvian³ and F R Aulin³

¹ Doctoral Students of Natural Resource and Environmental Management Study Program, Post Graduate School, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155
² Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155
³ Faculty of Forestry, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155

*Email: sidabukke@yahoo.com

Abstract. Species association is a reciprocal relationship among species within a community and can estimate the community composition. This research aimed to obtain information regarding the level of dominance and plant species association in each forest land allocation. Data analysis tested in this study constituted an analysis of the importance value index and association analysis performed on the main constituent species with INP > 10% using a 2x2 Contingency Table. The research revealed that species association in understory plants in plantation forests contained one pair with real associations, five with unreal associations, six with positive associations, and none with negative associations. Meanwhile, there were no real associations in protected forest areas, ten pairs with unreal associations, four pairs with positive associations, and six pairs with negative ones. There were two pairs with real associations in natural forests outside the company's concessions, 13 species with unreal associations, four pairs with positive associations, and 11 pairs with negative associations.

1. Introduction
Forest has a role as a place to live and food for various types of fauna that live in them. Populations of plants and animals in the forest form a closely related community with the surrounding environment [1]. Indonesia is a country that contains extensive rainforests, rich biodiversity, and high sources of germplasm due to fertile soil and abundant natural resources. [2] stated that a forest is an ecological system consisting of various species of plants and animals. A community of plants in a forest ecological ecosystem has a close connection with each other and with the environment. Forests have three main functions, including socio-economic, hydrological and aesthetic benefits [3].

Vegetation is formed by the presence and interaction of several plant species that grow in it. One of the interactions between these species is referred to as association [4]. Association is the interdependence between species with other species. The phenomenon of association or interaction that is also often referred to as symbiosis occurs naturally in nature, as it is part of the process of a balanced ecosystem balance in nature and the interdependence between species with one another [5].

Species association is a reciprocal relationship among species within a community and can be used to estimate the community composition. The presence or the absence of species association in a
community can indicate the level of diversity in that community. A high level of species association, for instance, will indicate a high species diversity. An established community will be affected by the presence or the absence of other species from the community. Groups and related species will establish a dynamic community because the presence or the absence of a species is highly dependent on other species interacting with it [6].

The factors that determine the strength of an association involve: The number of species present. The condition of the place where the plants are located. The number of joint events between the associated species. The measurement used to determine the strength of an association is the association coefficient with a value between −1 to +1. If the coefficient value is equal to +1, there is a maximum association, and vice versa. If the value of the coefficient of association is equal to −1, then there is a minimum association [7]. This study aimed to obtain information about the level of dominance and plant species association in each forest land allocation.

2. Methods

2.1. Time and Location of the study
This research took place from April 2019 to April 2020. It was conducted in the forest work area of Industrial Forest Plantation (IFP), known as IUPHHK-HT of PT. Toba Pulp Lestari, Tbk, in Aek Nauli and Tele Estates. The research was located mainly in the cultivation, the protected and the natural forest areas in Partungko Naginjang as well as in the natural forest area in the Special Purpose Forest Area (KHDTK), Research and Development Centre for Environment and Forestry (BP2LHK) of Aek Nauli in Simalungun Regency of North Sumatra Province.

2.2. Research Tools and Materials
The tools used in data collection in the field included writing instruments, Global Positioning System (GPS), Lux meter, hygrometer, machete, digital compass camera, sewing meter, maps of the industrial forest and the protected areas as well as maps of Partungkonaginjang forest area and BPK in Aek Nauli, raffia rope, tally sheet, and plastic bags. The object of research constituted the understorey plants discovered in the locations of the study.

2.3. Research Procedure

2.3.1. Data Collection Method. The vegetation composition and structure obtained from the Industrial Forest Plantation (IFP) and Natural Forests located outside IFP concessions, vegetation analysis was conducted by first calculating the number of sample plots to be measured using the minimum species area curve (MSAC). The method of placing plots in paths used the line-plot method. Each measuring plot was placed on the left and right of the path by recording all the understorey plants. [8] explained that understorey plants referred to the underlying layer of vegetation other than tree regeneration, including grass, herbs, shrubs and ferns.

According to [2], in forests with ≥ 1,000 ha or more, the sampling intensity should be 2%, while if the area covers less than 1,000 ha, the sampling intensity should be 5% – 10%. The vegetation analysis activities were conducted in sample plots for each level. The forest was 235 Ha of industrial forest plantation areas, 110 Ha of protected forests, and 48 Ha of natural forests. With a sampling intensity of 5%, the plot area was 2 m x 2 m, the distance between lines was 35 m and the distance between plots was 14 meters. The number of plots in Eucalyptus industrial forest plantation amounted to 480 plots, in the protected areas 224 plots, and in the Natural Forest 96 plots. We determined the understorey plots based on the minimum species-area curve (MSAC).

The variables observed and calculated in this study consisted of seedling. Important Value Index (IVI) of each type of vegetation was calculated in terms of their Density (D), Relative Density (RD), Frequency (F), Relative Frequency (RF), with the following formula: Species Density (D) = Number of Individuals of a species / Area of Observed Plots. Relative Density (RD) = (Density of a Species /
Density of All Species) x 100%. Species Frequency (F) = Number of Plots Where Species Found / Total Number of Observed Plots. Relative Frequency (RF) = (Frequency of a Type /Frequency of All Types) x 100%. Important Value Index (IVI) = RD + RF.

2.3.2. Association Analysis. Association analysis was performed for the primary constituent species with INP > 10% using a 2x2 contingency table [9]. The form of 2x2 Contingency table for 2 species is as follows:

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

Information:
a = Observation of the number of measuring plots containing species A and species B,
b = Observation of the number of measuring plots containing species A only,
c = Observation of the number of measuring plots containing only species B,
d = Observation of the number of measuring plots that did not contain species A and species B
N = Number of observed plots.

To determine the species association tendency, the Chi-square Test was used with the following formulation:

\[ \text{Chi-square Test} = \frac{N(ad - bc)^2}{(a+b)(a+c)(c+d)(d+b)} \]

a = Number of observed plots containing both types A and B
b = Number of observed plots containing only type A
c = Number of observed plots containing only type B
d = Number of observed plots that did not contain types A and B
N = Number of observed plots

The calculated Chi-square value was then compared with the Chi-square table value at degrees of freedom = 1, at the 1% and 5% test levels (value 3.84). If the calculated Chi-square value is > the table Chi-square value, then the association is real. The association is unreal if the calculated Chi-square value is < Chi-square table value [10]. Furthermore, to determine the level or strength of the species association, the following formula was used:

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

The nature of the species association was established by comparing the observed value for F(a) with the expected value for E(a). If F(a) is > E(a), then the association is positive. If F(a) is < E(a), then the association is negative. The association index was tested by calculating the Ochiai, Dice, and Jaccard Indexes [10], with the following formula:

\[ \text{Indeks Ochiai} = \frac{a}{\sqrt{(a+b)}(\sqrt{a+c})} \]
\[ \text{Indeks Dice} = \frac{a}{2a+b+c} \]
Indeks Jacca = \[ \frac{a}{a + b + c} \]

Association occurs at an interval of 0 - 1, the closer to 1, the stronger the relationship between the two species is, and vice versa.

3. Result and discussion

3.1. Understorey Species Association in 3 forest areas (Industrial Forest Plantation, Protection Forest and Natural Forest)

Associations are characterized by similar floristic compositions with uniform physiognomy and unique habitat distribution [11]. Associations are divided into positive and negative associations. A positive association occurs when a tree species is present simultaneously as another tree species and will not be formed without the tree species. A negative association occurs when a tree species is not present at the same time [12].

Every tree species has different needs to grow and live because each species requires environmental conditions that support it to survive. Each plant species will occupy suitable environmental conditions to support it [13]. Shared interests in their relationship for the plants to grow together is known as species association [4]. Associations between species arise when two or more species are present together in a habitat more often than by chance. Association occurs as a consequence of biotic interactions, such as mutualism, competition and predation. The analysis of understorey species associations in industrial forest plantation areas, protected forest areas and natural forest areas showed that each forest area varied in the number of understorey species in associations.

Each species finds an environment that can meet their needs, and in the environment the species become a group that lives naturally in a forest community. The group has a reciprocal relationship (interaction) that is mutually beneficial, and there is also a harmonious life together (association) so that a degree of integration is formed [14].

Every tree species has different needs to grow and live because each species requires environmental conditions that support it to survive. Each plant species will occupy suitable environmental conditions to support life [13]. The details of the description of the interacting plant species in each forest land allocation are as follows. Based on the plant species with INP > 10%, the pairs of species association in each forest land allocation area are shown in the following table.

| No | Species       | Latin Names                                    | INP Value (%) |
|----|---------------|------------------------------------------------|---------------|
| A. Industrial Forest Plantation |
| 1  | Sintrong      | Crassocephalum crepidioides (B) S. Moore       | 31.587        |
| 2  | Senduduk      | Melastoma malabathricum                        | 24.849        |
| 3  | Kentangan     | Boreria alata                                  | 19.551        |
| 4  | Pegagan       | Centella asiatica Linn                         | 17.671        |
| B. Protected Forest |
| 1  | Senduduk      | Melastoma malabathricum L                      | 21.311        |
| 2  | Lumut daun    | Marchantia polymorpha                          | 19.802        |
| 3  | Jahe liar     | Zingiber officinale Rosc.                     | 12.007        |
| 4  | Paku kawat    | Lycopodium cervuum L                          | 10.787        |
| 5  | Rotan         | Calamus erectus Roxb.                          | 10.264        |
| C. Natural Forest |
| 1  | Paku wangi    | Phymatosorus scolependria                     | 29.951        |
| 2  | Cakar ayam    | Selaginella doederleimii                      | 21.729        |
| 3  | Rasam         | Dicranopteris linearis (Burm.) Underw         | 15.930        |
| 4  | Paku kawat    | Lycopodium cervuum L                          | 13.076        |
| 5  | Suplir daun lebar | Adiantum tenerum                        | 11.111        |
### a. Industrial Forest Plantation

| No | Combination Associations | Associations | E(a)  | a>Ea = + | a<Ea = - |
|----|--------------------------|--------------|-------|----------|----------|
| 1  | (Crassocephalum crepidioides (B) S.Moore) Senduduk (Melastoma malabathricum) | Senduduk | 23.625 | +        |          |
| 2  | (Crassocephalum crepidioides (B) S.Moore) Kentangan/paitan (Boreria alata) | Kentangan/paitan | 21.093 | +        |          |
| 3  | (Crassocephalum crepidioides (B) S.Moore) Pegangan (Centella asiatica Linn) | Pegangan | 11.812 | +        |          |
| 4  | (Melastoma malabathricum) Senduduk | Kentangan/paitan | 21.937 | +        |          |
| 5  | (Melastoma malabathricum) Senduduk | Pegangan | 14     | +        |          |
| 6  | (Melastoma malabathricum) Kentangan/paitan (Boreria alata) | Pegangan | 12.187 | +        |          |

### b. Protected Forests

| No | Combination Associations | Associations | E(a)  | a>Ea = + | a<Ea = - |
|----|--------------------------|--------------|-------|----------|----------|
| 1  | Senduduk (Melastoma malabathricum) | Lumut Daun (Marchantia polymorpha) | 9.38  | -        |          |
| 2  | Senduduk (Melastoma malabathricum) | Jahe Liar (Zingiber officinale) | 11.72 | -        |          |
| 3  | Senduduk (Melastoma malabathricum) | Paku Kawat (Lycopodium cernuum) | 14.44 | +        |          |
| 4  | Senduduk (Melastoma malabathricum) | Rotan (Calamus erectus Roxb) | 15.63 | -        |          |
| 5  | Lumut Daun (Marchantia polymorpha) | Jahe Liar (Zingiber officinale) | 5.63  | -        |          |
| 6  | Lumut Daun (Marchantia polymorpha) | Paku Kawat (Lycopodium cernuum) | 7.5   | -        |          |
| 7  | Lumut Daun (Marchantia polymorpha) | Rotan (Calamus erectus Roxb) | 8.13  | +        |          |
| 8  | Jahe Liar (Zingiber officinale) | Paku Kawat (Lycopodium cernuum) | 9.84  | +        |          |
| 9  | Jahe Liar (Zingiber officinale) | Rotan (Calamus erectus Roxb) | 9.38  | +        |          |
| 10 | Paku Kawat (Lycopodium cernuum) | Rotan (Calamus erectus Roxb) | 13.13 | -        |          |

### c. Natural Forests

| No | Combination Associations | Associations | E(a)  | a>Ea = + | a<Ea = - |
|----|--------------------------|--------------|-------|----------|----------|
| 1  | (Phymatosorus scolependria) Paku Wangi | Cakar Ayam (Selaginella doeder leinii) | 13.656 | -        |          |
| 2  | (Phymatosorus scolependria) Paku Wangi | Rasam (Dicranopteris linearis) | 16.031 | -        |          |
| 3  | (Phymatosorus scolependria) Paku Wangi | Paku Kawat (Lycopodium cernuum) | 15.437 | -        |          |
| 4  | (Phymatosorus scolependria) Paku Wangi | Suplir daun lebar (Adiantum tenerum) | 10.093 | +        |          |
| 5  | (Phymatosorus scolependria) Paku Wangi | Senduduk (Melastoma malabathricum) | 15.031 | +        |          |
| 6  | Cakar Ayam | Rasam | 9.3437 | -        |          |
Of the three forest areas with different allocation management, the relationship between plant species, particularly in the industrial forest plantation areas, tends to be a completely positive association type (100%), if compared to the association between species in the protected forest and natural forest areas. The association composition between species in the industrial forest plantation areas showed that all of the understorey species were interdependent due to biotic interactions such as mutualism, competition and predation. A positive association occurs when both species choose the same habitat or have similar environmental requirements, which implies a beneficial interaction, for example, mutualism. [15] concluded that species pairs with positive associations have the exact needs so that their ecological niches overlap and form a group in which each individual finds an environment that can meet the needs to live together (association).

On the other hand, associations between species in the protected forest areas consisted of 2 types of associations, namely 40% positive associations and 60% negative associations. This situation illustrated that the associations between species made certain species compete and support each other. The occurrence of negative associations is typically caused by different or opposing environmental needs that imply adverse interactions, such as competition between species, predation or unique life conditions so that they will only grow well in certain places that can meet these requirements. The table above shows that industrial forest plantation areas tended to be interacting species (association), and all of the association types were positive. It indicated that the plant species had the same needs for their environment. This was believed to be caused by the same condition of the trees (Eucalyptus) and the relatively uniform physical condition of the environment.

Positively associated plant species interact and depend on each other to sustain life, either for a lifetime or at certain phases, for example during reproduction. These plants grow side by side to form a community by living together showing a connection or shared interest between the plants. According to the research results [16], two species were associated because both species preferred places with almost the same environmental parameters, such as places that tended to be wet with high intensity of sunlight to slightly shaded. It was further explained that species associations could affect species diversity in forest succession.
Table 4. Recapitulation list of description of the strength of relationships (associations) in each forest land allocation area

| No | Forest Land Allocation Area | Association Index | Remarks | Total Combination | Percentage (%) |
|----|-----------------------------|-------------------|---------|-------------------|---------------|
| 1  | Industrial Forest Plantation | 1.00 – 0.75       | Very Strong | 3                  | 50            |
|    |                              | 0.74 – 0.49       | Strong   | 3                  | 50            |
|    |                              | 0.48 – 0.23       | Weak     | -                  | -             |
|    |                              | < 0.22            | Very Weak| -                  | -             |
|    | Total of Protected Forests   | 1.00 – 0.75       | Very Strong| 6                  | 100           |
| 2  |                              | 0.74 – 0.49       | Strong   | 8                  | 80            |
|    |                              | 0.48 – 0.23       | Weak     | 2                  | 20            |
|    |                              | < 0.22            | Very Weak|                   |               |
| 3  | Natural Forests              | 1.00 – 0.75       | Very Strong| 10                 | 100           |
|    |                              | 0.74 – 0.49       | Strong   | 3                  | 20            |
|    |                              | 0.48 – 0.23       | Weak     | 10                 | 66.67         |
|    |                              | < 0.22            | Very Weak| 2                  | 13.33         |
|    | Total                        |                   |          | 15                 | 100           |

From these interactive recapitulation data, it can be seen that the interaction for coexistence between understorey species was found to be closer with a strong association discovered in the industrial forest plantation and protected forest areas as well as the natural forests where the species association was stronger. In industrial forest plantation areas, there was no weak interaction. All of the interactions ranged from strong to very strong. In the protected forest areas, the interactions were between strong and weak. In the natural forests, the interactions ranged from strong, weak and very weak. The descriptions of the plant interactions in these three locations showed that tolerance for cohabitation was higher in the industrial forest plantation areas. This was possibly due to uniform (homogeneous) physical environmental conditions, the exact physical needs, and the same plant species. Meanwhile, the other two forest areas consisted of non-uniform physical and environmental conditions with heterogeneous plants including the primary constituent plants. The associated understorey species and the degree of closeness of their cohabitation relationships in the industrial forest plantation areas Table 5.

Table 5. List of interaction strengths of interacting plant species in industrial forest plantation areas

| No | Association Pairs                                      | Ochiai Index | Association Strength |
|----|--------------------------------------------------------|--------------|----------------------|
| 1  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) with Senduduk (*Melastoma malabathricum*) | 0.91         | Very strong          |
| 2  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) with Kentangan (*Borreria alata*)       | 0.85         | Very strong          |
| 3  | Senduduk (*Melastoma malabathricum*) with Kentangan (*Borreria alata*), Sendu | 0.83         | Very strong          |
| 4  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) with Pegagan (*Centella asiatica* Linn) | 0.62         | Strong               |
| 5  | Senduduk (*Melastoma malabathricum*) with Pegagan (*Centella asiatica* Linn)       | 0.71         | Strong               |
| 6  | Kentangan (*Borreria alata*) with Pegagan (*Centella asiatica* Linn)         | 0.71         | Strong               |
Figure 1. Associated Understorey Species 1. *Centella asiatica* Linn, 2. *Crassocephalum crepidioides* (B) S.Moore, 3. *Melastoma malabathricum*, 4. *Boreria alata* in Industrial Forest Plantation Areas

The strength of the interaction relationship between species differs from one species to another. For example, Sintrong (*Crassocephalum crepidioides* (B) S. Moore) had a very strong association only with Sensaat (*Melastoma malabathricum*) and Potato (*Boreria alata*), but the association was not strong with Pegagan (*Centella asiatica* Linn). This strong interaction was presumed due to the fact that these species had the same or similar needs to grow. Alternatively, or these species possibly had relatively the same response to changes in environmental factors. They could also choose the same habitat or have environmental requirements, which implied a beneficial interaction, such as mutualism. To determine the strength of the association, the species association index was tested again based on the calculation of the Ochiai index [10]. The association occurs between values 0-1, and the closer the association is to 1, the stronger the interaction between the two types will be.

Table 6. List of interaction strength of interacting plant species in protected forests

| No | Association Pairs | Ochiai Index | Association Strength |
|----|------------------|--------------|----------------------|
| 1  | Senduduk (*Melastoma malabathricum*) with Paku Kawat (*Lycopodium cernuum*) | 0.52 | Strong |
| 2  | Lumut Daun (*Marchantia polymorpha*) with Rotan (*Calamus erectus* Roxb) | 0.57 | Strong |
| 3  | Jahe Liar (*Zingiber officinale*) with Paku Kawat (*Lycopodium cernuum*) | 0.70 | Strong |
| 4  | Jahe Liar (*Zingiber officinale*) with Rotan (*Calamus erectus* Roxb) | 0.63 | Strong |
| 5  | Senduduk (*Melastoma malabathricum*) with Lumut Daun (*Marchantia polymorpha*) | 0.37 | Weak |
| 6  | Senduduk (*Melastoma malabathricum*) with Jahe Liar (*Zingiber officinale*) | 0.45 | Weak |
Senduduk (*Melastoma malabathricum*) with Rotan (*Calamus erectus* Roxb) 0.56 Strong
Lumat Daun (*Marchantia polymorpha*) with Jahe Liar (*Zingiber officinale*) 0.56 Strong
Lumat Daun (*Marchantia polymorpha*) with Paku Kawat (*Lycopodium cernuum*), 0.58 Strong
Paku Kawat (*Lycopodium cernuum*) with Rotan (*Calamus erectus* Roxb) 0.59 Strong

The strength of the association between plant species differed significantly. This table illustrates that Senduduk (*Melastoma malabathricum*) had a high/strong relationship with Paku Kawat (*Lycopodium cernuum*) plant species. However, it had a weak or low relationship with other plant species, such as Lumut Daun (*Marchantia polymorpha*) and Jahe Liar or wild ginger (*Zingiber officinale*). This condition supported Clement’s view [13] stating that each plant species required suitable environmental conditions to grow. Thus, the life requirements for each species are different, where they only occupy a certain part that is suitable for them to grow. In conclusion, every plant is the result of the conditions in the place where they grow. In this way, plants can be used as environmental indicators.

**Table 7. List of interaction strength of interacting plant species in natural forest areas**

| No | Association Pairs | Ochiai Index | Association Strength |
|----|-------------------|--------------|----------------------|
| 1  | Paku Wangi (*Phymatosorus scolependria*) with Suplir daun lebar (*Adiantum tenerum*) | 0.34 | Weak |
| 2  | Paku Wangi (*Phymatosorus scolependria*) with Senduduk (*Melastoma malabathricum*) | 0.44 | Weak |
| 3  | Cakar Ayam (*Selaginella doederleini*) with Paku Kawat (*Lycopodium cernuum*) | 0.48 | Weak |
| 4  | Cakar Ayam (*Selaginella doederleini*) with Senduduk (*Melastoma malabathricum*) | 0.44 | Weak |
| 5  | Paku Wangi (*Phymatosorus scolependria*) with Cakar Ayam (*Selaginella doederleini*) | 0.74 | Strong |
| 6  | Paku Wangi (*Phymatosorus scolependria*) with Rasam (*Dicranopteris linearis*) | 0.37 | Weak |
| 7  | Paku Wangi (*Phymatosorus scolependria*) with Paku Kawat (*Lycopodium cernuum*) | 0.64 | Strong |
| 8  | Cakar Ayam (*Selaginella doederleini*) with Rasam (*Dicranopteris linearis*) | 0.05 | Very Weak |
| 9  | Cakar Ayam (*Selaginella doederleini*) with Rasam (*Dicranopteris linearis*) | 0.44 | Weak |
| 10 | Rasam (*Dicranopteris linearis*) with Paku Kawat (*Lycopodium cernuum*) | 0.36 | Weak |
| 11 | Rasam (*Dicranopteris linearis*) with Senduduk (*Melastoma malabathricum*) | 0.29 | Weak |
| 12 | Rasam (*Dicranopteris linearis*) with Senduduk (*Melastoma malabathricum*) | 0.32 | Weak |
| 13 | Paku Kawat (*Lycopodium cernuum*) with Suplir daun lebar (*Adiantum tenerum*) | 0.22 | Very Weak |
| 14 | Paku Kawat (*Lycopodium cernuum*) with Senduduk (*Melastoma malabathricum*) | 0.60 | Strong |
| 15 | Suplir daun lebar (*Adiantum tenerum*) with Senduduk (*Melastoma malabathricum*) | 0.32 | Weak |
The strength of the relationship between plant species in the natural forest areas varied, ranging from strong to weak and very weak relationships. Based on the calculation results, there were differences in interactions among the plant species. For example, a strong species interaction occurred between Paku Wangi (*Phymatosorus scolependria*) and Cakar Ayam (*Selaginella doederleinii*), but the relationship between Paku Wangi (*Phymatosorus scolependria*) and Rasam (*Dicranopteris linearis*) was found to have a weak association. Likewise, the strength of the association between Paku Kawat (*Lycopodium cernuum*) and Suplir Daun Lebar (*Adiantum tenerum*) was weak. However, the strength of the association between Paku Kawat (*Lycopodium cernuum*) and Senduduk (*Melastoma malabathricum*) turned out to be strong. These plants were found to grow together side by side to form a community as if there was a connection or shared interest among these plants.

It was also suspected that the plant species with strong associations were due to the fact that each plant had the same secondary metabolite chemical compounds discovered under Eucalyptus stands. These species included the Gotu Kola plants that contain triterpene saponins, with primary active constituents saponins causing a foaming effect in water. The triterpene saponins content in Gotu Kola constitutes asiaticoside, asiacid, thanakuside, isothankuside, madecassoside, brahmaside, brahmic acid, madasiatic acid, meso-inosetol, centellose, caroteinoid, salt K, Na, Ca, Fe, vellarine, tannin, mucilage, resin, pectin, sugar, protein, phosphorus, B vitamins, vitamin C and a little essential oil [17]. Sintrong (*Crassocephalum crepidioides*) contains many important nutrients, such as polyphenols.

The Saponins as well as flavonoids contents in Gotu Kola (*Centella asiatica* Linn) contain asiaticoside, thankeuside, isothankuside, madecassoside, brahmaside, brahmic acid, brahminoside, madasiatic acid, centelloside, carotenoids, hydrocotylin, vellarine, tannins, and magnesium salts. The composition of a community is determined by the maximum selection of plants that are able to grow in that place. The activities of community members depend on the adjustment of each individual to the existing physical and biotic factors in the place. Thus, the results from the calculation of association index certainly strengthened the conclusion based on the contingency table calculation results. In general, the understorey species that composed the industrial forest plantation areas showed to tolerate to live together in the same area, or there was a mutually beneficial relationship, especially in life spatial division. Apart from the effect of interaction on a community, every plant provided each other a place to live in the same area and habitat. The integrity of a community is a well-established phenomenon [11].

### Table 8. The calculated chi-square value presenting real or unreal association in each forest land allocation area

| No | Association Combination | Calculated Chi-square | Chi-table (5%) | Conclusion |
|----|--------------------------|-----------------------|----------------|------------|
| 1  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) Senduduk (*Melastoma malabathricum*) | 4.097 | 3.84 | Real |
| 2  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) Kentangan/paitan (*Boreria alata*) | 0.097 | 3.84 | Unreal |
| 3  | Sintrong (*Crassocephalum crepidioides* (B) S.Moore) Pegagan (*Centella asiatica* Linn) | 0.045 | 3.84 | Unreal |
| 4  | Senduduk (*Melastoma malabathricum*) Kentangan/paitan (*Boreria alata*) | 0.006 | 3.84 | Unreal |
| 5  | Senduduk (*Melastoma malabathricum*) Pegagan (*Centella asiatica* Linn) | 1.143 | 3.84 | Unreal |
| 6  | Kentangan/paitan (*Boreria alata*) Pegagan (*Centella asiatica* Linn) | 2.706 | 3.84 | Unreal |
|   | Natural Forest Areas          | Protected Forest Areas          |
|---|-------------------------------|----------------------------------|
|   |                               | B. Protected Forest Areas        |
|   |                               | 1 Senduduk (Melastoma malabathricum) | 0.110 3.84 Unreal |
|   |                               | 2 Senduduk (Melastoma malabathricum) | 0.379 3.84 Unreal |
|   |                               | 3 Senduduk (Melastoma malabathricum) | 0.204 3.84 Unreal |
|   |                               | 4 Senduduk (Melastoma malabathricum) | 2.060 3.84 Unreal |
|   |                               | 5 Senduduk (Marchantia polymorpha) | 0.209 3.84 Unreal |
|   |                               | 6 Senduduk (Marchantia polymorpha) | 0.142 3.84 Unreal |
|   |                               | 7 Senduduk (Marchantia polymorpha) | 0.423 3.84 Unreal |
|   |                               | 8 Senduduk (Marchantia polymorpha) | 0.014 3.84 Unreal |
|   |                               | 9 Senduduk (Marchantia polymorpha) | 0.209 3.84 Unreal |
|   |                               | 10 Senduduk (Marchantia polymorpha) | 0.748 3.84 Unreal |
|   |                               | C. Natural Forest Areas          |
|   |                               | 1 Paku Wangi (Phymatosorus scolependria) | 3.761 3.84 Unreal |
|   |                               | 2 Paku Wangi (Phymatosorus scolependria) | 1.096 3.84 Unreal |
|   |                               | 3 Paku Wangi (Phymatosorus scolependria) | 0.051 3.84 Unreal |
|   |                               | 4 Paku Wangi (Phymatosorus scolependria) | 0.273 3.84 Unreal |
|   |                               | 5 Paku Wangi (Phymatosorus scolependria) | 2.341 3.84 Unreal |
|   |                               | 6 Paku Wangi (Melastoma malabathricum) | 0.033 3.84 Unreal |
|   |                               | 7 Paku Wangi (Selaginella doeder leinii) | 9.722 3.84 Real  |
|   |                               | 8 Paku Wangi (Selaginella doeder leinii) | 7.481 3.84 Real  |
|   |                               | 9 Paku Wangi (Selaginella doeder leinii) | 1.035 3.84 Unreal |
|   |                               | 10 Paku Wangi (Selaginella doeder leinii) | 0.829 3.84 Unreal |
|   |                               | 11 Paku Wangi (Selaginella doeder leinii) | 0.273 3.84 Unreal |
|   |                               | 12 Paku Wangi (Melastoma malabathricum) | 0.644 3.84 Unreal |
|   |                               | 13 Paku Wangi (Melastoma malabathricum) | 2.835 3.84 Unreal |
|   |                               | 14 Paku Wangi (Melastoma malabathricum) | 0.004 3.84 Unreal |
|   |                               | 15 Paku Wangi (Melastoma malabathricum) | 0.062 3.84 Unreal |
Of the three forest areas with different allocation management, there were 2 types of associations between species, particularly in the industrial forest plantation and natural forest areas, namely real associations and unreal associations. On the other hand, associations between species in the protected forest areas only consisted of 1 type of association which was unreal. The species association was unreal because these species directly or indirectly tended to grow independently and did not affect each other. However, associations between species that are unreal can also occur due to competition or mutually negating one another [18].

Sofiah et al [19] explained that species pairs do not always result in a positive relationship. Plant species with a high frequency of presence do not always lead to a high positive association value with other species. Likewise, species with a low frequency of presence do not always result in negative associations with other species. Pratama et al [20] explained that negative associations indicated a lack of tolerance for growing together in the same area or the absence of mutually beneficial relationships. The existence of various species in a plant community created an opportunity for competition, as explained by Melanda et al [21]. Furthermore, various plant species in the community resulted in competition between individual plants with the same species or between species, which ultimately formed a community. In general, living organisms in nature do not stand alone or do not live alone, but become a collection of individuals that occupies a certain place leading to associations between organisms. The associations can be interactions between individuals of the same species or between individuals of different species [22]. Interactions between species of the same population members will affect the condition of the population, considering the activity of the individual species can affect the speed of growth or life in the population.

According to Odum [23], each member of a population can consume other population members, compete for food, excrete other harmful impurities, or kill each other, making the interaction be unidirectional or bidirectional (reciprocal). Therefore, in terms of population growth or life, interactions between species members of a population can be positive, negative or zero. Associations are characterized by the presence of similar floristic compositions, uniform physiognomy and unique habitat distribution [24].

Early control is needed to prevent ecosystem damage due to the presence of invasive plant species at the research site.

4. Conclusion

Based on the results from this study, it can be concluded that the association of understorey species in the industrial forest plantation areas involves 1 pair with real associations, 5 pairs with unreal associations, 6 pairs with positive associations and 0 pairs with negative associations. Meanwhile, in the protected forest areas, there were 0 pairs with real associations, 10 pairs with unreal associations, 4 pairs with positive and 6 pairs with negative associations. In the natural forest areas outside the company's concession, there were 2 pairs with real associations, 13 pairs with of unreal associations, 4 pairs with positive and 11 pairs with negative associations.

References

[1] Su S J, Liu J F, He Z S, Zheng S Q, Hong W and and Xu D W 2015 National Nature Reserve J Mt Sci 12 637
[2] Soerianegara I and Indrawan 2005 Ekologi Hutan Indonesia (Bogor : Fakultas IPB)
[3] Richards P 1988 Experimenting farmer and agricultural research Paper prepared for ILEIA Workshop on Operational Approaches for Particative Technology Development in Sustainable Agriculture, 11-12 April 1988 (Leusden : Netherlands).
[4] Kurniawan A, Undaharta N K E and Pendit I M R 2008 Biodiversitas 9 199
[5] Malindu F D, Labiro E and Ramlah S 2016 Jurnal Warta Rimba 4 112.
[6] Hitalessy R B, Leksono A S and Herawati E Y 2015 Indonesian Journal of Environment and Sustainable Development 6 64.
[7] Martono D S 2012 Jurnal Agri-Tek 13 18.
[8] Ewusie J Y 1990 Ekologi Tropika (Bandung: Penerbit ITB).
[9] Greig Smith P 1983 Quantitative Plant Ecology. Blackwell Scientific Publications (Oxford).
[10] Ludwig J A and Reynolds J F 1988 Statistical Ecology: A Primer on Methods and Computing (Singapore (SG): John Wiley and Sons).
[11] Dombois M and Ellenberg H 1974 Aims and Methods of Vegetations (Jhon Wiley and Sons Inc)
[12] McNaughton S J dan Wolf Larry L 1992 Ekologi Umum. Edisi -2 (Yogyakarta: Gadjah Mada
[13] Barbour M G, Burk J H, and Pitts W D 1987 Terrestrial plant ecology (Benjamin: Cummings)
[14] Resosodarmo S, Kartawinata K and Soegiarto A S 1986 Pengantar Ekologi (Bandung)
[15] Call L J and Nilsen E T 2003 Robinia pseudoacacia Am Midl Nat 150 1
[16] Windusari Y, Susanto, R H, Dahlan Z and Susetyo W 2011 Biota: Jurnal Ilmiah Ilmu Hayati 16 242
[17] Winarto I W and Surbakti I M 2003 Khasiat dan Manfaat Pegagan: Tanaman Penambah Daya Ingat (AgroMedia)
[18] Purnomo S, Matius P, Simarangkir B, Bratawinata A A and Rahmawati R 2014 Jurnal Forest Sains 11 92
[19] Sofiah S, Setiadi D and Widyatmoko D 2013 Berita Biologi 12 239.
[20] Pratama B A, Alhamd L and Rahajoe J S 2012 J Tek Ling Edisi Khusus Hari lingkungan Hidup 69
[21] Metanda A A., Zuhud A M dan Hikmat A 2015 Media Konservasi 20
[22] Indriyanto 2008 Ekologi Hutan (Jakarta: PT Bumi Aksara)
[23] Odum EP 1993 Dasar-dasar Ekologi (Terjemahan) Edisi III (Yogyakarta: Gadjah Mada University Press)
[24] Clements F E 1978 Palnat Succession An Analysis Of Development Vegetations (Carnigie Inst: Washington Publ 512).