Diversity and distribution of macrofungi in pine forest and mixed forest in Mount Merbabu National Park

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Abstract. Pine forest and mixed forest in Mount Merbabu National Park (MMNP) have the different potential of macrofungi. However, the information of macrofungi in the pine and mixed forest is still lacking. The research aimed to determine the diversity and distribution of macrofungi in the pine forest and mixed forest MMNP. Retrieval of macrofungi diversity data used a plot method measuring 20 x 20 m which was divided into 16 subplots measuring 5 x 5 m. Subplots measuring 5 x 5 m was used to determine the distribution pattern of macrofungi. The results showed that there were 36 species of macrofungi found in the pine forest and 80 species in the mixed forest. The diversity of macrofungi in the pine forest belonged to moderate value with a diversity index of 2.84, whereas in the mixed forest belonged to high value with a diversity index of 3.64. There were 16 species macrofungi that can be found in the pine forest, 60 species that can be found in the mixed forest, and 20 species in both habitats. The most widespread macrofungi were the agaric type, which included Agaricales order, while the narrowest distributed macrofungi were the coral type, which include the Gomphales order. The distribution pattern of macrofungi species in the pine forest was obtained by 33 grouped species and three uniform species. The distribution pattern of macrofungi species in the mixed forest was obtained by 78 grouped species and two uniform species.

1. Introduction
Fungi have an important role in natural ecosystems through decomposition [1]. Fungi are actively involved in the soil biogeochemical cycles and nutrient cycling [2]. Fungi infect the roots of green plants by forming an association (mutualistic relationship) with green plants called mycorrhiza. Mycorrhizal get nutrients directly from plants, while plants depend upon mycorrhizal for healthy growth [3]. There are several species of fungi that are known as a part of parasitic associations such as Ganoderma applanatum (Pers.) Pat, which causes the decay of the heartwood [4].

Fungi are the second-most diverse group of organisms in the world after arthropods [5]. Fungi biodiversity worldwide has been estimated at 1.5 million [6]. However, only about 100,000 species of fungi have been identified [7]. Fungi in Indonesia has been estimated to be around 80,000 species consisting of 64,000 species of microfungi and 16,000 species of macrofungi. Macrofungi that are known in Indonesia are only around 1,200 species, consisting of 864 species of the Basidiomycota and 336 species of the Ascomycota [8].
The environmental factors such as biotic and abiotic factors influencing the macrofungi growth. The interaction from the host plant is one of the effects of the biotic factors on macrofungi growth. The suitable substrate that has nutrients is used by macrofungi to be a place to grow and develop. Substrates of macrofungi can be soil, litter, weathered wood, and host plant [9]. This makes the habitat type effects the growth of macrofungi in an ecosystem [10]. Abiotic factors such as temperature, humidity, light intensity, and pH which inside the ecosystem cause certain environmental conditions. In particular, macrofungi can grow nicely in humid environmental conditions such as mountain forests.

Mount Merbabu National Park (MMNP) is a mountain forest area with good conditions in Central Java Province. The humidity of MMNP is 90% [11]. Temperature conditions in this region around 15-25°C with 2000-3000 mm of rainfall each year. The intensity of the light entering the region is 10% for the shaded area and 15-25% for the unshaded area [12]. High rainfall and low light intensity cause the MMNP region to become moist and potentially found a variety of macrofungi species.

Pine forests and mixed forests are two types of habitats that can be found in MMNP. Both types of habitat have differences, as seen from the constituent species of vegetation and environmental conditions. Pine and mixed forest MMNP have different potential macrofungi diversity and distribution. However, until now there has been no research on the diversity and distribution of macrofungi in the pine forests and mixed forest MMNP. Research on the diversity of macrofungi was only carried out by Munandar [13] in the southern slope forest of MMNP, which found 23 species of wood-decay fungus. The lack of research on macrofungi has the potential of many macrofungi species that has not been found, especially in the pine forests and mixed forests. Therefore, research needs to be done on the diversity and distribution of macrofungi in the pine forests and mixed forest MMNP.
2.2. Tools and research objects
The tools used in this research include camera, cutter, mirrors, specimen container, hygrometer, multimeter, Global Positioning System (GPS), soil tester, and roll meter. The object of this research is a specimen of macrofungi, aluminum foil, label, flacon jar, alcohol 70%, a string of raffia, and a tally sheet.

2.3. Procedures of research
Retrieval of macrofungi diversity data used a plot method measuring 20 x 20 m which was divided into 16 subplots measuring 5 x 5 m. Subplots measuring 5 x 5 m were used to determine the distribution pattern of macrofungi such as random, uniform, and grouped (Figure 2).

Macrofungi that found at each location was collected, observed, and documented. Macroscopic observation conducted through the determination of shape and color of the fruit body, cap, stem, hymenophore, ring, and volva. The habitat of the macrofungi was also recorded. Macrofungi data that have been collected were analyzed by calculating species diversity index and distribution patterns. The formula used to calculate diversity index and Morisita’s index, as follows:
1. Diversity Index (H’)

Analysis of the diversity index (H’) was calculated using the Shannon species diversity formula as follows:

\[
H' = -\sum P_i \ln P_i
\]

\[1\]

where:

- \(H'\): Diversity index Shannon (\(Pi = ni/N\))
- \(n_i\): Density of each species
- \(N\): Total of density

According to Odum [14], the value of diversity index lower than 1 (\(H' < 1\)) means the diversity is low, while the value ranges from 1-3 (\(1 < H' \leq 3\)) in diversity index is moderate, higher than 3 (\(H' > 3\)) means the diversity index is high.

2. Morisita’s Index

Morisita’s index was used to determine the distribution pattern of macrofungi species in the community which is divided into random, uniform, and grouped forms. The formula used to calculate Morisita’s index as follows:

\[
Id = n \frac{\sum x^2 - \sum x}{(\sum x)^2 - \sum x}
\]

\[2\]

where:

- \(Id\): Degree of spread Morisita
- \(n\): Total of plot
- \(\sum x^2\): Total of the squares of the total individuals of a species in a community
- \(\sum x\): Total number of individuals of a species in a community

Analysis of the standardized Morisita’s index (\(Ip\)) was calculated used the formula:

\[
Ip = 0.5 + 0.5 \left( \frac{Id - Mc}{n - Mc} \right)
\]

\[
Ip = 0.5 \left( \frac{Id - 1}{Mc - 1} \right)
\]

\[
Ip = -0.5 \left( \frac{Id - 1}{Mu - 1} \right)
\]

\[
Ip = -0.5 + 0.5 \left( \frac{Id - Mu}{Mu} \right)
\]

\[3\]

where:

- \(Mu\): Uniform Index
- \(Mc\): Clumped Index

According to Morisita [15], the value of standardized Morisita’s index lower than 0 (\(Ip < 0\)) means the distribution pattern is uniform, while the value is 0 (\(Ip = 0\)) means the distribution pattern is random, higher than 0 (\(Ip > 0\)) means the distribution pattern is grouped.
3. Results and Discussion

3.1. Environmental conditions and characterization habitat of macrofungi

There are several differences in environmental conditions in the pine forests and mixed forest in MMNP, especially on vegetation and its abiotic factors. Pine forests are classified as homogeneous forests that can be found only Pinus merkusii Jungh et de Vriese with distantly forest canopy. However, mixed forests are classified as covered and shadier areas because of diverse plant species with tightly forest canopy. The constituent dominant species are Schima wallichii (DC.) Korth., Acacia decurrens Willd., Engelhardia serrata Blume., and Casuarina junghuhniana Miq. The differences in the characteristics of vegetation in both habitats affect the humidity of each research location. The result of calculating abiotic factors is shown that pine forest drier than mixed forest (Table 2).

| Table 2. Abiotic factors in the pine and mixed forest in MMNP |
|---------------------------------------------------------------|
| Air temperature (°C) | Pine forest | Mixed forest |
| G | J | U | A | B | C |
| 24-25 | 23-25 | 21-24 | 19-20 | 18-20 | 17-18 |
| Air humidity (%) | 54-67 | 58-71 | 80-84 | 87-98 | 89-97 | 99 |
| Soil humidity | 1 | 1-2 | 2 | 2 | 2 | 3-4 |
| pH | 7 | 7 | 7 | 7 | 7 | 7 |
| Light intensity (Lux) | 1439-3333 | 1391-3333 | 1028-2720 | 1482-3203 | 2014-2100 | 1634-1803 |
| Altitudes (masl) | 923-938 | 1178-1229 | 1422-1433 | 1853-1878 | 1950-1961 | 2098-2189 |

Environmental conditions in the pine forests drier than mixed forests are also caused by the altitudes. Pine forests are at lower altitudes in the ranges of 923-1433 masl compared to mixed forests with a higher altitude in the ranges of 1853-2189 masl (Table 2).

The difference in vegetation types and abiotic factors in the pine and mixed forests will certainly affect the macrofungi microhabitat at each location and the availability of substrates for macrofungi growth. An example, the species of Polyporales are a group of cosmopolitan that are less affected by changes in environmental physical factors in their habitat [16]. However, for the species of Agaricales, changes in environmental physical factors will inhibit its growth [16].

3.2. Diversity of macrofungi

The results showed that there were 36 species of macrofungi found in the pine forests from 20 families (Table 3). The twenty families were belonged to eight orders, i.e. Helotiaceae, Xylariaceae, Agaricales, Boletales, Dacrymycetales, Hymenochaetales, Polyporales, and Russulales. Different from the pine forest, the results showed that there were 80 species of macrofungi found in the mixed forest from 30 families (Table 3). The thirty families were belonged to twelve orders, i.e. Helotiaceae, Hypocreales, Xylariaceae, Agaricales, Auriculariales, Boletales, Dacrymycetales, Gomphales, Geastrales, Hymenochaetales, Polyporales, and Russulales.

Whole species were grouped in the division of Ascomycota and Basidiomycota. There are three in the pine forest and seven in the mixed forest of Ascomycota species and 33 species in the pine forest and 73 species of Basidiomycota in the mixed forest. The differences in the number of fungal are caused species of the Basidiomycota macrofungi is greater than Ascomycota [17]. The Ascomycota division has been a low frequency of encounters in nature. Families of Marasmiaceae, Psathyrellaceae, Agaricaceae, Mycenaceae, and Crepidotaceae are classified as Agaricales that dominant in the pine and mixed forest.
Table 3. Macrofungi diversity in the pine and mixed forest in MMNP

| Divisio          | Order       | Family     | Species                              | Type of Habitat |
|------------------|-------------|------------|--------------------------------------|-----------------|
| Ascomycota       | Helotiales  | Helotiaceae| Ascotremella faginea (Peck) Seaver   | √               |
|                  |             |            | Bispora citrina (Batsch) Korf & S.E. Carp. | √               |
| Dermateaceae     |             |            | Mollisia cinerea (Batsch) P. Karst.   | √               |
| Sclerotiniaceae  |             |            | Ciboria batschiana (Zopf) N. F. Buchw. | √               |
| Hypocreales      | Nectriaceae |            | Nectria cinnabarina (Tode) Fr.       | √               |
| Xylariales       | Xylariaceae |            | Xylaria hypoxylon (L.) Grev.         | √               |
|                  |             |            | Xylaria polymorpha (Pers.) Grev.     | √               |
|                  |             |            | Xylaria tentaculata Berk. & Broome.  | √               |
| Basidiomycota    | Agaricales  | Agaricaceae| Agaricus semotus Fr.                 | √               |
|                  |             |            | Lepiota atrodisca Zeller             | √               |
|                  |             |            | Lepiota castanea Quél.               | √               |
|                  |             |            | Lepiota rubrotinctoides Murrill      | √               |
|                  |             |            | Lepiota sequoiarum Murrill           | √               |
|                  |             |            | Leucocoprinus heinemannii Migl.      | √               |
|                  |             |            | Leucocoprinus fragilissimus Murrill  | √               |
| Crepidotaceae    |             |            | Crepidotus applicatus (Pers.) P. Kumm. | √               |
|                  |             |            | Crepidotus epibryus (Fr.) Quél.,     | √               |
|                  |             |            | Crepidotus variabilis (Pers.) P. Kumm. | √               |
| Cortinariaceae   |             |            | Cortinarius anthracinus (Fr.) Sacc.  | √               |
| Entolomataceae   |             |            | Entoloma bloxamii (Berk. & Broome) Sacc. | √               |
|                  |             |            | Entoloma haastii G.Stev.             | √               |
| Hydnangiaceae    |             |            | Laccaria laccata (Scop.) Cooke      | √               |
| Hygrophoraceae   |             |            | Hygrocybe glutinipes (J.E.Lange) R.Haller Aar. | √               |
|                  |             |            | Hygrophorus lucorum Kalchbr.         | √               |
| Inocybaceae      |             |            | Inocybe rimosa (Bull.: Fr.) P. Kumm. | √               |
| Lyophyllaceae    |             |            | Asterophora sp.                      | √               |
| Marasmiaceae     |             |            | Campanella tristis (G. Stev.) Segedin | √               |
|                  |             |            | Connopus acervatus (Fries) R.H.Petersen | √               |
|                  |             |            | Gymnopus sp.                         | √               |
|                  |             |            | Gymnopus dryophilus (Bull.) Murrill  | √               |
|                  |             |            | Gymnopus foetidus (Sowerby) J.L. Mata & R.H. Petersen | √               |
|                  |             |            | Gymnopus fascopurpureus (Pers.) Antonín, Halling & Noordel. | √               |
|                  |             |            | Gymnopus ochlor (Pers.) Antonín &amp; Noordel. | √               |
|                  |             |            | Gymnopus putillus (Fr.) Antonín, Halling & Noordel. | √               |
|                  |             |            | Marasmiellus candidus (Fr.) Singer   | √               |
|                  |             |            | Marasmius androsaceus (L.) Fr.       | √               |
|                  |             |            | Marasmius calhouniae Singer          | √               |
|                  |             |            | Marasmius crinis-equi F.Muell. ex Kalchbr | √               |
|                  |             |            | Marasmius siccus Schwein. ex Fr.     | √               |
|                  |             |            | Rhodocollybia maculate (Alb. & Schwein.) Singer | √               |
| Mycenaceae       |             |            | Mycena sp.                           | √               |
|                  |             |            | Mycena adscendens (Lasch) Maas Geest. | √               |
|                  |             |            | Mycena amicta (Fr.) Quél.            | √               |
|                  |             |            | Mycena flavoalba (Fr.) Quél.         | √               |
|                  |             |            | Mycena galopus (Pers.) P. Kumm.      | √               |
|                  |             |            | Mycena leaiana (Berk.) Sacc.         | √               |
|                  |             |            | Mycena leptocaephalia (Pers.) Gillet | √               |
|                  |             |            | Mycena picta (Fr.) Harmaja           | √               |
|                  |             |            | Mycena ustalis Aronsen & Maas Geest. | √               |
|                  |             |            | Panellus stipicus (Bull.) P.Karst.   | √               |
The diversity of macrofungi in the pine forest belonged to moderate value with a diversity index (H') of 2.84, whereas in the mixed forest belonged to high value with a diversity index (H') of 3.64. The result corresponding to Odum [14] if the value of diversity index ranges from 1-3 (1 < H' ≤ 3) in diversity index is moderate, and if the value of diversity index higher than 3 (H' > 3) means the diversity index is high. The difference of macrofungi diversity index values between pine and mixed forests is influenced by environmental factors, such as the availability of substrates, biotic factors,
and abiotic factors.

The type of substrates in mixed forests is more abundant compared to pine forests as shown in Table 4. Litter substrate is not found in pine forests. It is suspected that *P. merkusii* leaf litter contains allelochemical compounds such as phenols and flavonoids which can inhibit macrofungi growth [18]. Phenols can inhibit the synthesis of chitin which is very important for the formation of macrofungi cell walls [19]. Flavonoid compounds have a mechanism by interfering with mitochondrial homeostasis and disrupting macrofungi cell membrane permeability [20]. Macrofungi are also not found growing on tree trunks because the stem of *P. merkusii* produces a sap that makes macrofungi difficult to grow. *P. merkusii* sap contains terpenoid compounds that can inhibit the growth of macrofungi, both through the cytoplasmic membrane and on the growth and development of spores [21].

**Table 4. Substrate of macrofungi in the pine and mixed forest in MMNP**

| No. | Substrate      | Percentage of Species (%) | Pine forest | Mixed Forest |
|-----|----------------|---------------------------|-------------|--------------|
| 1.  | Soil           | 66.67                     | 42.7        |              |
| 2.  | Weathered wood | 33.33                     | 19.1        |              |
| 3.  | Litter         | -                         | 29.2        |              |
| 4.  | Host plant     | -                         | 8.99        |              |
|     |                |                           | 100         | 100          |

Macrofungi that recorded in mixed forests are thought to have an association with host plant substrate which is a biotic factor for the high diversity of macrofungi (Table 5).

**Table 5. Host plant of macrofungi in the mixed forest MMNP**

| No. | Species of host plant       | Species of macrofungi                      |
|-----|------------------------------|--------------------------------------------|
| 1.  | *Schima wallichii* (DC.) Korth | *Psathyrella candolleana* (Fr.) Maire<br>Mycena sp.<br>*Crepidotus applanatus* (Pers.) P. Kumm. |
| 2.  | *Casuarina junghuhniana* Miq. | *Trametes pubescens* (Schumach.) Pilát<br>*Sarcodontia pachyodon* (Pers.) Spirin<br>*Mycena ustalis* Arnsen & Maas Geest<br>*Marasmiellus candidus* (Fr.) Singer. |
| 3.  | *Engelhardia serrata* Blume  | *Mycena picta* (Fr.) Harmaja                |

The availability of substrate resources can determine the strength of the effects of the emergence of macrofungi species on the functioning of the ecological community. This can be seen from the number of macrofungi species grouped by ecological functions in each habitat (Figure 3). The number of macrofungi species as decomposers in pine and mixed forests has the highest order compared to symbionts and parasites. It is because of decomposers macrofungi have been abundant such as soil, litter, and weathered wood. The more substrate resources the higher the number of macrofungi species found.
Figure 3. The number of macrofungi species based on ecological functions in the pine and mixed forest MMNP

Based on each plot, macrofungi have quite interesting diversity. The high and low diversity of macrofungi is directly proportional to the height of the plot in both pine forests and mixed forests. At an altitude of 1400 masl, pine forests have the highest diversity of macrofungi with a diversity index value of 2.65. The lowest macrofungi diversity was calculated at an altitude of 900 masl with a diversity index value of 1.76. The same results were found in mixed forests, the highest diversity of macrofungi was found at an altitude of 2100 masl with an index value of 3.17 including the high category. The lowest macrofungi diversity was calculated at an altitude of 1800 masl with an index value of 2.53, including the moderate category. It is because of abiotic factor that the higher the location, the more humid environmental conditions.

3.3. Distribution of macrofungi

There were 16 species macrofungi that can be found in the pine forest, 60 species can be found in mixed forest, and 20 species in both habitats (Table 3). Macrofungi that can be found only in pine forests have an ectomycorrhizal role in P. merkusii such as Russula emetica (Schaeff.) Pers., Suillus granulatus (L.) Roussel and Lactarius torminosus (Schaeff.) Gray. [22]. Macrofungi that can be found only in mixed forests have a humid habitat characteristic such as Armillaria mellea (Vahl) P.Kumm. [23]. Macrofungi that can be found in pine and mixed forests include cosmopolitan fungi such as the Xylariaceae [24].

The distribution of macrofungi can also be seen by morphological type and order is shown in Table 6. The result relates to the spread spore of each macrofungi [25]. Environmental conditions cause the production of macrofungi fruit bodies to differ from one species to another [5]. The most widespread macrofungi were the agaric type, which included Agaricales order, while the narrowest distributed macrofungi were the coral type, include the Gomphales order.
Table 6. Distribution of macrofungi based on type of morphological and order

| No. | Type of morphological | Order                        | Frequency of species | Total plot of Frequency species |
|-----|-----------------------|------------------------------|----------------------|---------------------------------|
|     |                       |                              | Pine forest          |                                  |
|     |                       |                              | G | J | U | A | B | C |                  |
| 1.  | Agaric                | Agaricales                   | 10 | 13 | 16 | 23 | 25 | 28 | 6                  |
| 2.  | Boletes               | Boletales                    | 0  | 1  | 1  | 1  | 0  | 1  | 4                  |
| 3.  | Leather dan Polypores | Polyporales                  | 2  | 1  | 2  | 0  | 4  | 3  | 5                  |
| 4.  | Puffballs             | Boletales, Geastrales        | 1  | 0  | 1  | 1  | 1  | 2  | 5                  |
| 5.  | Jelly dan flask       | Helotiales, Dacrymycetales,  | 1  | 0  | 2  | 1  | 2  | 4  | 5                  |
|     |                       | Auriculariales, Hypocreales, |                              |                                  |
|     |                       | Xylariales                   |                              |                                  |
| 6.  | Stinkhorn             | -                            | 0  | 0  | 0  | 0  | 0  | 0  | 0                  |
| 7.  | Coral                 | Gomphales                    | 0  | 0  | 0  | 0  | 1  | 2  | 2                  |
| 8.  | Cup                   | Helotiales                   | 1  | 0  | 1  | 1  | 1  | 3  | 5                  |
| 9.  | Tooth                 | Polyporaceae                 | 0  | 0  | 1  | 1  | 3  | 1  | 4                  |
| 10. | Truffle               | -                            | 0  | 0  | 0  | 0  | 0  | 0  | 0                  |

The distribution pattern of macrofungi species in pine forest was obtained by 33 grouped species and three uniform species. The distribution pattern of macrofungi species in the mixed forest was obtained by 78 grouped species and two uniform species. The diagram of the distribution pattern of macrofungi species in pine and mixed forest in MMNP is shown in Figure 4.

![Figure 4. Distribution pattern of macrofungi in pine and mixed forest in MMNP](image)

Macrofungi that can be found in pine and mixed forests that have group living behavior are *Bisporella citrines* (Batsch) Korf & S.E. Carp., *Crepidotus applanatus* (Pers.) P. Kumm., *Crepidotus epiphyrus* (Fr.) Quél., *Crepidotus variabilis* (Pers.) P. Kumm., *Scleroderma cepa* Pers., *Schizophyllum commune* Fries, and *Ramaria stricta* (Pers.) Quél. These species have grouped distribution patterns with Ip > 0. Three macrofungi species that have a uniform distribution pattern in pine forests are *Leucoprinus heinemannii* Migl., *Leucoprinus fragilissimus* (Berk. & M.A.Curtis) Pat., and *Inocybe rimos* (Bull.) P. Kumm. While the two macrofungi species that have a uniform distribution pattern in mixed forests are *Mycena amicta* (Fr.) Quél. and *Gymnopus fuscopuspurae* (Pers.) Antonin, Halling & Noordel. Distribution analysis through the Morisita approach that these species have Ip < 0 which means uniform. The presence of these fungi is suspected because it has a solitary growing behavior.
4. Conclusion

There were 36 species of macrofungi found in the pine forest and 80 species in the mixed forest. The diversity of macrofungi in the pine forest belonged to moderate value with a diversity index of 2.84, whereas in mixed forest belonged to high value with a diversity index of 3.64. There were 16 species macrofungi can be found in the pine forest, 60 species can be found in the mixed forest, and 20 species in both habitats. The most widespread macrofungi were the agaric type, which included Agaricales order, while the narrowest distributed macrofungi were the coral type, which include the Gomphales order. The distribution pattern of macrofungi species in the pine and mixed forest tends to be grouped.

References

[1] Solle H, Klau F, and Nuhamara ST 2017 Keanekaragaman jamur di Cagar Alam Gunung Mutis Kabupaten Timor Tengah Utara, Nusa Tenggara Timur Biota 2(3) 105-10
[2] Dighton J and White JF 2017 The fungal community: its organization and role in the ecosystem. Fourth Edition (Florida: CRC Press)
[3] Lindsay A, Robinson R, May T, and McMullan-Fisher SJM 2013 Guide to Surveying Fungi in Australia (Australia: Fungimap)
[4] Garrett LG, Kimberley MO, Oliver GR, Parks M, Pearce SH, Beets PN, and Paul TSH 2019 Decay rates of above and below ground coarse woody debris of common tree species in New Zealand’s natural forest Forest Ecology and Management 438 96-102
[5] Moore S and O’Sullivan P 2014 A guide to common fungi of the Hunter-Central Rivers region (NSW: Hunter Local Land Services)
[6] Hawksworth DL 1991 The fungal dimension of biodiversity: Magnitude, significance, and conservation Mycological Research 95(6) 641-55
[7] Campbell NA, Reece JB, Urry LA, Cain ML, Wasserman SA, Minorsky PV, and Jackson RB 2012 Biologi Jilid 2 edisi ke delapan Terjemahan Wulandari DT (Jakarta: Erlangga)
[8] Widjaja EA, Rahayuningisih Y, Rahajoe JS, Ubaidillah R, Maryanto I, Walujo EB, and Semiadi G 2014 Kekinian Keanekaragaman Hayati Indonesia 2014 (Jakarta: LIPI Press)
[9] Priskila, Ekamawanti HA, and Herawatiningsih R 2018 Keanekaragaman jenis jamur makroskopis di kawasan hutan sekunder areal IUPHHK-HTI PT. Bhatara Alam Lestari Kabupaten Mempawah Jurnal Hutan Lestari 6(3) 569-82
[10] Rohmaya, Mardji D, and Sukartiningsih 2011 Keanekaragaman jenis jamur ektomikoriza pada kondisi hutan dengan kelerengan yang berbeda di Hutan Wisata Bukit Bangkirai PT INHUTANI I Balikpapan Jurnal Kehutanan Tropika Humida 4(2) 150-61
[11] Astuti FK, Murningsih, and Jumari 2017 Keanekaragaman jenis tumbuhan paku (Pteridophyta) di jalur pendakian Selo kawasan Taman Nasional Gunung Merbabu, Jawa Tengah Jurnal Biologi 6(2) 1-6
[12] Mulyanto H, Cahyuningdari D, and Setyawan AD 2000 Kantung semar (Nepenthes sp.) di Lereng Gunung Merbabu Biodiversitas 1(2) 54-8
[13] Munandar AA 2017 Inventarisasi Jamur Pelapuk Kayu dari Hutan Lereng Selatan Gunung Merbabu Jawa Tengah [Skripsi] Program Studi Pendidikan Biologi, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Surakarta
[14] Odum EP 1993 Dasar-dasar Ekologi edisi Ketiga Terjemahan Samingan T (Yogyakarta: Gadjah Mada University Press)
[15] Morisita M 1959 Measuring of the dispersion of individuals and analysis of the distributional patterns Memoirs Faculty of Science, Kyushu University, Seri E (Biology) 40 3-5
[16] Prasetyaningsih A and Rahardjo D 2015 Keanekaragaman dan potensi makrofungi Taman Nasional Gunung Merapi The 2nd University Research Colloquium
[17] Dwidjoseputro D 1978 Pengantar Mikologi 2nd Edition (Bandung: Penerbit Alumni)
[18] Christoper W, Natalia D, and Rahmayanti S 2017 Uji aktivitas antijamur ekstrak etanol umbi bawang Dayak (Eleutherine americana (Aubl.) Merr. Ex K. Heyne.) terhadap Trichophyton mentagrophytes secara in vitro Jurnal Kesehatan Andalas 6(3) 685-9

[19] Wu X, Cheng A, Sun L, and Lou H 2008 Effect of Plagiochin E, an antifungal macrocyclic bis (Bibenzyl), on cell wall chitin synthesis in Candida albicans Acta Pharmacol Sin. 29(12) 1478-85

[20] Kang K, Fonng W, and Tsang PW 2010 Antifungal activity of baikalein against Candida krusei does not involve apoptosis Mycopathologia 170 391-6

[21] Lutfiyanti R, Ma’ruf WF, and Dewi EN 2012 Aktivitas antijamur senyawa bioaktif ekstrak Gelidium latifolium terhadap Candidus albicans Jurnal Pengolahan dan Bioteknologi Hasil Perikanan 1(1) 1-8

[22] Darwo and Sugiarti 2008 Beberapa jenis cendawan ektomikoriza di kawasan hutan Sipirok, Tongkoh dan Aek Nauli, Sumatera Utara Jurnal Penelitian Hutan dan Konservasi Alam 5(2) 157-73

[23] Islam MR and Aminuzzaman FM 2016 Macro fungi biodiversity at the central and northern biosphere reserved areas of Tropical Moist Deciduous Forest Region of Bangladesh Journal of Agriculture and Ecology Research 5(4) 1-11

[24] Sir EB, Hladki AI, Parrado MF, and Romero AI 2012 Biodiversity of Xylariaceae (Ascomycota) and their hosts in protected areas from Tucuman (Argentina) Tomo 37(2) 35-48

[25] Andrew EE, Kinge TR, Tabi EM, Thiobal N, and Mih AM 2013 Diversity and distribution of macrofungi (Mushrooms) in the Mount Cameroon Region Journal of Ecology and the Natural Environment 5(10) 318-34