Macrofungi Species Richness and Diversity in Dagaga and Gambo Plantation and Natural Forests of Arsi Forest Enterprise, Oromia, Ethiopia

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Abstract: The macrofungal diversity of the Dagaga-Gambo plantation and natural forests was studied by plot-based macrofungal survey method for three years (2014-2016) during rainy seasons. Three forest unit habitats (FUH): old plantation forest (OPF), clear cut and replanted plantation forest (CPF) and disturbed natural forest (DNF) were selected for the purpose. Fruitbodies of macrofungi in each plot were recorded. Diversity, abundance and similarity of the macrofungal species were measured. More than 116 macrofungal species were recorded and grouped under 16 orders, 44 families, and 78 genera. Species richness in the two forests and the forest unit habitats (FUH) were varied. Total species richness (\(S\)) was found to be the least in OPF Dagaga (OPF\(_D\)) (19) and the highest in DNF of Gambo (DNF\(_G\)) (49). More macrofungal species number was recorded in Gambo forest (88) than in the Dagaga forest (81). Both Simpson’s diversity indices and Shannon Wiener diversity indices showed different macrofungal species diversity across the FUH and the two forests. The data presented here serve as a baseline for further macrofungal studies in Dagaga and Gambo forests.

Key words: Macrofungi, abundance, diversity, evenness, similarity, Dagaga-Gambo.

1. Introduction

Fungi are the most diverse groups of organisms on earth. The estimated fungal species are about 1.5 million (Hawksworth 2001). Only 80000-120000 species have been described [15]. Fungi are most diverse in forest ecosystems\(^{[16]}\). Peay et al.\(^{[28]}\) reported that fungal species richness increases with increasing forest area. Fungal species richness also increases with the increasing number of tree species present in a forest \(^{[32]}\). Furthermore, forests also support more rare and threatened fungi \(^{[23]}\).

Macrofungi play fundamental roles in forest ecosystems. Measuring the macrofungal species richness and diversity helps to monitor the health of a given natural system \(^{[3]}\). Since macrofungal biodiversity is closely correlated with the total biodiversity of a given site, its quantification also helps for assessing priorities in sites of conservation \(^{[24]}\). According to Humphrey et al.\(^{[14]}\) macrofungal diversity of plantation woodlands are comparable to the macrofungal diversity of semi-natural woodlands.

Many authors have conducted studies on Ethiopian fungi and generated information on different aspects \(^{[7,6,10,11,12,21,31,37,39,40,42]}\). But only few authors conducted studies on macrofungal diversity in Ethiopia \(^{[2,5]}\). Assessment of plot based forest macrofungal diversity study in Ethiopian forests in general and in Dagaga-Gambo plantation and natural forests in particular is not conducted so far. The objective of this study was, therefore, to enumerate and document the macrofungal species diversity, richness and abundance of the Dagaga-Gambo plantation and natural forests the Arsi forest enterprise.

2. Materials and Methods

2.1. Description of the study area

The study was conducted at Dagaga and Gambo plantation and natural forests (Picture 1). The forests are registered under Arsi branch of the Oromia Forest and Wildlife Enterprise (OFWE). OFWE is an autonomous public enterprise which is structured in nine branch offices and 38 forest districts in Oromia regional state, Ethiopia. Arsi branch is one of these branch offices having three forest districts (Dagaga/Munessa, Gambo and Sole) with an estimated area of 23,000 ha \(^{[34]}\). The forest is an important water catchment area for rift valley lakes (Langano, Abjata and Shalla) \(^{[18]}\). The altitudinal gradient of the forest ranges from 1900 to 2700 m asl.
and has a general bimodal rain pattern of a minor rainy season (March-May) and a major rainy season (July-September). Its recorded mean annual precipitation and annual temperature are 1075 mm and 15°C, respectively. There are natural and plantation forests in the district. Its natural forests are highly disturbed and dominated mainly by Podocarpus falcatus, Celtis africana, Croton macrostachys, Syzygium guineense, Maytenus arbutifolia, Primus africana, Schefflera abyssinica and Allophyllus abyssinica [1]. The plantation forest is mainly dominated Cupressus lusitanica which is followed by Pinus patula. Different Eucalyptus species are also planted in small plots at different compartments of the forests. Plots for the present study were established in the Dagaga and Gambo districts (Picture 1).

2.2. Macrofungal assessment

Macrofungi of the Dagaga and Gambo forests were assessed by establishing transact plots [4]. Three forest unit habitats (FUH) were selected from the two forests based on their accessibility: cleared and replanted plantation forest (CPF) (5-8 years old), old plantation forest (OPF) (25-30 years old) and disturbed natural forest (DNF) (Picture 2). Two sites were selected for each FUH and three transact plots were set up at each site (Table 1). Hence, a total of 36 permanent transect plots of 150 X 20 m sizes were established.

All fruitbodies of the macrofungi in each plot were consecutively surveyed during the main rainy season (July-August) for three years (2014-2016). The fruitbodies were photographed and their morphological features were characterized at their natural habitat. Spore prints were obtained whenever possible on daily visit basis. Fresh fruitbodies were collected in separate paper bags and fungal cultures were obtained at the mycology lab of Wondo Genet College of Forestry and Natural Resources (WGCF-NR) of Hawassa University (HU) and herbarium specimens were retained at the mycology lab of the Wood Technology Research Center (WTRC) of the Ethiopian Environment and Forest Research Institute (EEFRI).

2.3. Identification of the macrofungi

The macrofungi were identified at their natural environment wherever possible. But most macrofungi collected from the study plots were brought to the laboratory and characterized. The fungi were identified following the keys and colored morphological features described by standard general texts [20,30,22]. Identification of specimen was based on both macroscopic and microscopic features. The information of the various characters stated was used to identify each specimen by comparison with illustrations in color field guides and also by the use of descriptions and keys. For identification of the remaining fungi, the following mushroom websites were also referred: http://www.pbase.com/tmurray74/mushrooms;http://www.naturephoto-cz.com/mushrooms.html; http://www.first-nature.com/fungi/~id-guide.php;http://www.mushroomexpert.com/taxonomy.html; http://www.mykoweb.com/photography/.

2.4. Statistical analysis

Total species richness (S). \( S \) was computed as the cumulative number of macrofungal species recorded over the entire sampling period of three years [41] with formula
\[
S = \sum X_i \quad ---- Equation 1
\]
where \( X \) is the total species richness of each plot in forest type \( i \).

Simpson’s diversity index (D). \( D \) was calculated using the equation of Simpson [35].
\[
D = \sum P_i^2 \quad ---- Equation 2, \text{ where } P_i = N_i/N, \text{ and } N_i=\sum n_i
\]

Shannon-Wiener diversity index (H’). \( H’ \) was computed using the formula of Shannon and Weaver [33].
\[
H’ = -\sum P_i \ln P_i \quad ---- Equation 3, \text{ where } P_i \text{ is the ratio of individuals found belonging to the } i^{th} \text{ species.}
\]
Evenness ($E$). $E$ was calculated according to Pielou [29].

$$E = \frac{H'}{\ln S} \quad \text{--- Equation 4.}$$

Jaccard’s similarity index (J). $J$ was calculated according to Chao et al. [9].

$$J = \frac{C}{A + B - C} \quad \text{--- Equation 5, Where A and B are the number of species in sample 1 and 2, respectively, and C is the number of species in common between A and B.}$$

3. Results and Discussion

3.1. Total species richness and abundance

A total of above 116 macrofungal species were identified from the Dagaga and Gambo plantation and natural forests (species list not shown). These species were distributed among 16 orders, 44 families and 78 genera. Most of the macrofungal species identified belonged to the Agaricales (50%) which was followed by the Polyporales (21%). Most species were collected from decaying woods in the forests, i.e., saprophytic macrofungi. This could be explained in terms of the biodegrading ability of many recalcitrant substrates found in the forests. Wood-based substrates have been shown to be a major determinant of macrofungal diversity in woodland vegetation [38]. When the number species in families compared, Polyporaceae, Agaricaceae and Tricholomataceae had 15, 8 and 7 species, respectively. Macrofungal species diversity was found to differ between the Dagaga and Gambo forests in general, between the plantation and natural forests and among the FUH (CPF, OPF and DNF). The overall observation of the macrofungal distribution of the forests showed that the Gambo forest was richer in macrofungal species composition (88 species distributed in 15 orders, 42 families and 59 genera) than the Dagaga forest (81 species distributed in 13 orders, 37 families and 58 genera). When the FUH compared, DNF had the highest species (49) and followed by CPF (38) and DNF (37). OPF had the least species accumulation (19). Agaricales had the highest species composition which was followed by Polyporales and Russulales (Fig. 1.). Polyporaceae had the highest number of species composition which was followed by Agaricales and Tricholomataceae (Fig. 2.). Photographs of some of the isolated fungi are presented in Picture 3.

Many macrofungal species encountered during the studies were not identified though some of them were assigned to a family and/or a genus (data not shown). Three years survey could not give a guarantee of exhaustive assessment of the
macrogungi in the forests. A complete knowledge of the fungi for any locality requires continuous observation and collection over many years. Bolhassan et al. [8] and Lopez-Quintero et al. [17] showed that species diversity and occurrence increased with the increasing number of visits over a longer period. Straatsma and Krisai-Greilhuber [36] made 551 visits on 1500 m² for 21 years on a Swiss forest and recorded 71,222 fruitbodies representing 408 species. Therefore, long term studies should be carried out to obtain sufficient information on type of fungi present and diversity of the macrofungal biota of the Dagaga and Gambo plantation and natural forests.

3.2. Species diversity

The macrofungal species diversity of the Dagaga and Gambo plantation and natural forests varied (table 1). The number of species in the corresponding family (Fig. 3) and order (Fig. 4) were different. The highest Simpson's diversity index (D) was obtained in OPF₉ (0.088) and followed by CPF₉ and OPF₉. D value in DNF₉ was the least (0.027). D values of the two forests showed lower D values showing that the macrofungal species distribution of the two forests are highly diversified and not dominated by few species. Similarly, higher 1-D values ranging 0.912–0.973 were obtained indicating the presence diversified macrofungal species. D values of the plantation forests were relatively lower than the D values of the natural forests. Hence, higher species number existed in natural forests and plantation forests were dominated with lower number of macrofungal species.

Shannon Wiener diversity indices (H) varied across the three FUH and the two forests (table 3). High Shannon diversity indices 3.778, 3.355, 3.255 were obtained in DNF₉, CPF₉, DNF respectively (table 3). This indicates the higher the diversity of the macrofungal species distribution in the indicated FUH. The least Shannon diversity index was found in OPF₉ (2.698). The FUH of the plantation forests in both forests showed lower Shannon diversity indices except CPF₉. This exception could be explained in terms of the presence of more decaying woods as substrate for the macrofungal species. When the two forests compared, Dagaga forest with Shannon diversity index 0.917 was more diversified in species composition than Gambo forest with Shannon diversity index of 0.844. This result agrees with the findings of Tibuhwa [38]. Wood based substrates have been shown to be a major determinant of macrofungal diversity in forest in both temperate and tropical regions [36]. The species composition of Polyporaceae, Tricholomataceae, and Agaricaceae, respectively, were higher than the remaining families (Fig. 2). This could be explained in terms of the physiological capabilities of these fungi in degrading the recalcitrant wood remains in the forests [19,25,38].

Table 1 Species richness and diversity indexes of macrofungi of Dagaga and Gambo plantation and natural forests.

<table>
<thead>
<tr>
<th>Test</th>
<th>CPF₁₉</th>
<th>CPF₉</th>
<th>DNF₁₉</th>
<th>DNF₉</th>
<th>CPF₁₀</th>
<th>CPF₁₉</th>
<th>DNF₁₀</th>
<th>DNF₉</th>
<th>Dagaga</th>
<th>Gambo</th>
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<tr>
<td>5</td>
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<td>0.97</td>
<td>0.98</td>
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<td>0.97</td>
<td>0.98</td>
<td>0.97</td>
<td>0.99</td>
<td>0.97</td>
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<td>0.97</td>
<td>0.98</td>
<td>0.97</td>
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<td>0.97</td>
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<td>0.97</td>
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<td>0.98</td>
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</table>

3.3. Species evenness (E)

The calculated E values ranged from 0.902 to 0.971 (table 1, Fig. 5.). These values are near 1 indicating even distribution of the macrofungal species in the FUH and in the two forests studied. The species distribution in DNF₉ was relatively more even than the other FUH. When the two forests are compared, E value of Gambo forest was less than E value of Dagaga forest indicating that distribution of macrofungal species in Gambo is more diversified than the Dagaga forest.
3.4. Jacard’s similarity index (J)

The distribution of the macrofungal species of the FUH of the Dagaga and Gambo natural and plantation forests are relatively less similar ($J \leq 0.243$) (table 2). The J value when DNF$_D$ and CPF$_D$ compared, was the least of all (0.017). Since Jacard’s similarity index near zero is an indication of dissimilarity, the macrofungal species distribution of these two FUH was the most dissimilar macrofungal species distribution. The J index of the Dagaga and Gambo natural and plantation forests was found to be 0.457. This is somewhat larger than the remaining J values indicating that there is similar macrofungal species distribution in the two forests.

**Table 2 Jacard’s similarity index values of the forest unit habitats and the two forests**

<table>
<thead>
<tr>
<th>FUH</th>
<th>CPF$_D$</th>
<th>CPF$_G$</th>
<th>DNF$_D$</th>
<th>DNF$_G$</th>
<th>CPF$_D$</th>
<th>DNF$_D$</th>
<th>DNF$_G$</th>
<th>Dagaga Forest</th>
<th>Gambo Forest</th>
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<td>1.000</td>
<td>0.071</td>
<td>0.154</td>
<td>0.105</td>
<td>0.143</td>
<td>0.109</td>
<td></td>
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<tr>
<td>CPF$_G$</td>
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<td>0.075</td>
<td>0.241</td>
<td>0.143</td>
<td>0.145</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>DNF$_D$</td>
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<td>0.077</td>
<td>0.146</td>
<td>0.194</td>
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<tr>
<td>DNF$_G$</td>
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<td>0.100</td>
<td>0.025</td>
<td>0.197</td>
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<tr>
<td>DNF$_D$</td>
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<td>0.100</td>
<td>0.100</td>
<td>0.100</td>
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<tr>
<td>DNF$_G$</td>
<td>1.000</td>
<td>0.100</td>
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</table>

**Conclusion**

Like other living organism, distribution of fungal flora of any ecosystem has to be recorded. But unlike plants the identification of macrofungi mainly depends on the collection of fruiting bodies, which is of course depends upon the availability of moisture in most cases. The list of macrofungi in this study provides the baseline information for further detail assessment of macrofungal diversity of the forests.

**Acknowledgment**

The authors are greatly thankful to the Ethiopian Environment and Forest Research Institute (EEFRI), Wondo Genet College of Forestry and Natural Resources (WGCNR) for the financial and logistic support. We appreciate the chemical and lab facility obtained from Wood Technology Research Center, Wondo Genet College of Forestry and Natural Resources and National Agricultural Biotechnology Research Center. We are also grateful to the Dagaga and Gambo forests district management and staff for letting us to conduct this study in their plantation and natural forests.

**References**


