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Changes in landscape ecology between nature reserve and palm oil plantation in West Java, Indonesia based on the observations of macrofungal population

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Abstract. *Arko PF, Sudirman LI, Qayim I. 2021. Changes in landscape ecology between nature reserve and palm oil plantation in West Java, Indonesia based on the observations of macrofungal population. Biodiversitas 22: 4526-4537.* As the biggest tropical country in Southeast Asia with the third-largest forest, Indonesia has limited data on macrofungal diversity. The limitation of the data is due to the lack of study on macrofungi in high biodiversity locations such as Dungus Iwul Nature Reserve (CADI). The purpose of this study was to determine and analyze the population of macrofungal species caused by the conversion in landscape structure (fragmentation and land-use change) that occurred in CADI patch and oil palm plantation of PT Perkebunan Nusantara VIII (PTPN) matrix, Cigelung, West Java. The sampling method used was opportunistic sampling assisted by line intercept. The macrofungal identification was based on morphological characters. The analysis of community ecology was performed in R programme. The results showed that macrofungal population and diversity in CADI were the highest, followed by PTPN planted in 2004 and planted in 2003, with a significant difference among the three study locations. The community dominance index shows the opposite, with the highest in PTPN 2003 and the lowest in CADI. These results showed changes in macrofungal population and diversity from the conversion in landscape structure. There were eleven indicator species in CADI, two species in PTPN 2003, and five species in PTPN 2004.

Keywords: Cigelung landscape, Dungus Iwul Nature Reserve, ecology, macrofungi, population

Abbreviations: CADI: Dungus Iwul Nature Reserve, macrofungi: macroscopic fungi, PTPN: oil palm plantation of PT Perkebunan Nusantara VIII

INTRODUCTION

Broad-leaved Tropical Rainforest is home to half the species of living things in the world (Olson et al. 2001). This type of forest is found in large groups in Sub-Saharan Africa, the Americas, and Southeast Asia. Indonesia has the third-largest tropical rainforest (WWF 2005). This forest ecosystem is heterogeneous and continues to be 'green' throughout the year; the canopy covering the forest floor will continue to exist. The conditions under this forest canopy have a low light intensity and high humidity (Nakamura et al. 2017). One example of an organism capable of living in these conditions is a species from the Kingdom of Fungi (Santos-Silva et al. 2011; Smith and Bonito 2012; Chen et al. 2018).

Millions of species from the tropical rainforest are still undescribed (Mora et al. 2011). From the estimated total of 1,500,000, only ± 375,000 species of fungi are known and 0.32% of them are known to be present in Indonesia (Hawksworth 2001; Mycobank 2020). These estimates show that inventory and monitoring processes need to be prioritized, especially in the locations that support fungal growth.

The data on the diversity of Indonesian macroscopic fungi (macrofungi/mushroom) are still limited due to very few studies on Indonesian fungi, especially macrofungi. On the other hand, we face a rapid decline in biodiversity both by natural processes and by human activities (Cardinale et al. 2012; Mendenhall et al. 2012; Dutta et al. 2013).

The ratio of forest destruction in Indonesia is the largest among other countries (replacing Brazil) and continues to grow at an average of 47,600 hectares per year (Margono et al. 2014; Tsujino et al. 2016; Harris et al. 2017; Turubanova et al. 2018). If this condition remains, in the next 20 years, Indonesia will become a country that has lost its largest resource, and as well millions of fungal species shall lose their habitats in Indonesian forests before their potential is explored (Kodra and Syaukani 2004).

Dungus Iwul Nature Reserve (CADI) is a lowland forest area with an altitude ranging from 600 to 800 AMSL. The status of this location was obtained, during the Dutch administration, through the Governor-general Decree of the Dutch East Indies No. 23 *Staatsblad* 99 dated 20 March 1931 with 9.1 ha area (BBKSDA Jabar 2016). Since then, the natural forest has changed its landscape structure and fragmented into rubber trees plantation, and eventually converted again into oil palm plantations in 2003. Studies on the diversity of macrofungi in CADI and the Oil Palm Plantation of PT Perkebunan Nusantara VIII (PTPN) Cigelung have not been carried out since the changes in landscape conditions which necessitates an urgent study in this regard. This study aims to determine

and examine the diversity of macrofungal species caused by changes in landscape structure (fragmentation and land-use change) in CADI and PTPN, Cigelung, West Java.

MATERIALS AND METHODS

Study area

The field exploration was carried out at Dungus Iwul Nature Reserve (CADI) and PT Perkebunan Nusantara VIII (PTPN), West Java, Indonesia, planted in 2003 (PTPN 2003; block 130) and 2004 (PTPN 2004; blocks 131 and 132) Cigelung (Figure 1).

Procedures

In general, the study procedures were divided into four main stages, viz. field exploration, macrofungal fruitbodies documentation and identification, herbarium preparation, and community ecology data analysis.

Field exploration

The inventory process was carried out from October 2018 to March 2019 using opportunistic sampling methods assisted by seven transect lines that cross longitudinally. (Figure 1, dashed line) (Tadiosa and Briones 2013; Barnes et al. 2018; Gaggini et al. 2019; Piętka et al. 2019). These transect lines were evenly distributed within the study area, and stretched from the eastern side to the western side. Each study area was divided into ecotone and interior areas. Ecotone data were collected from the boundary line of each study site (Figure 1, solid line), and interior area data were collected from the seven transect lines within each study site.

Macrofungal fruitbodies documentation and identification

During the field study, the various types of macrofungal fruitbodies of agaric fungi, bird's nest fungi, bolete fungi, club and coral fungi, corticioid fungi, cup fungi, cyphelloid fungi, flask fungi, jelly fungi, polypore fungi, puffball and earthstar fungi, sterioid fungi, stinkhorn fungi, and tooth fungi were documented with cameras from different sides in their natural habitat (attached to the substrate, top, side, and bottom). Macromorphological features (form group, stature type, pileus, hymenophores, stipe, and their ornamentation), location coordinates, environmental conditions, and substrate types and conditions were measured and recorded (Andrew et al. 2013; Yilmaz and Zencirci 2016; Dawson et al. 2018).

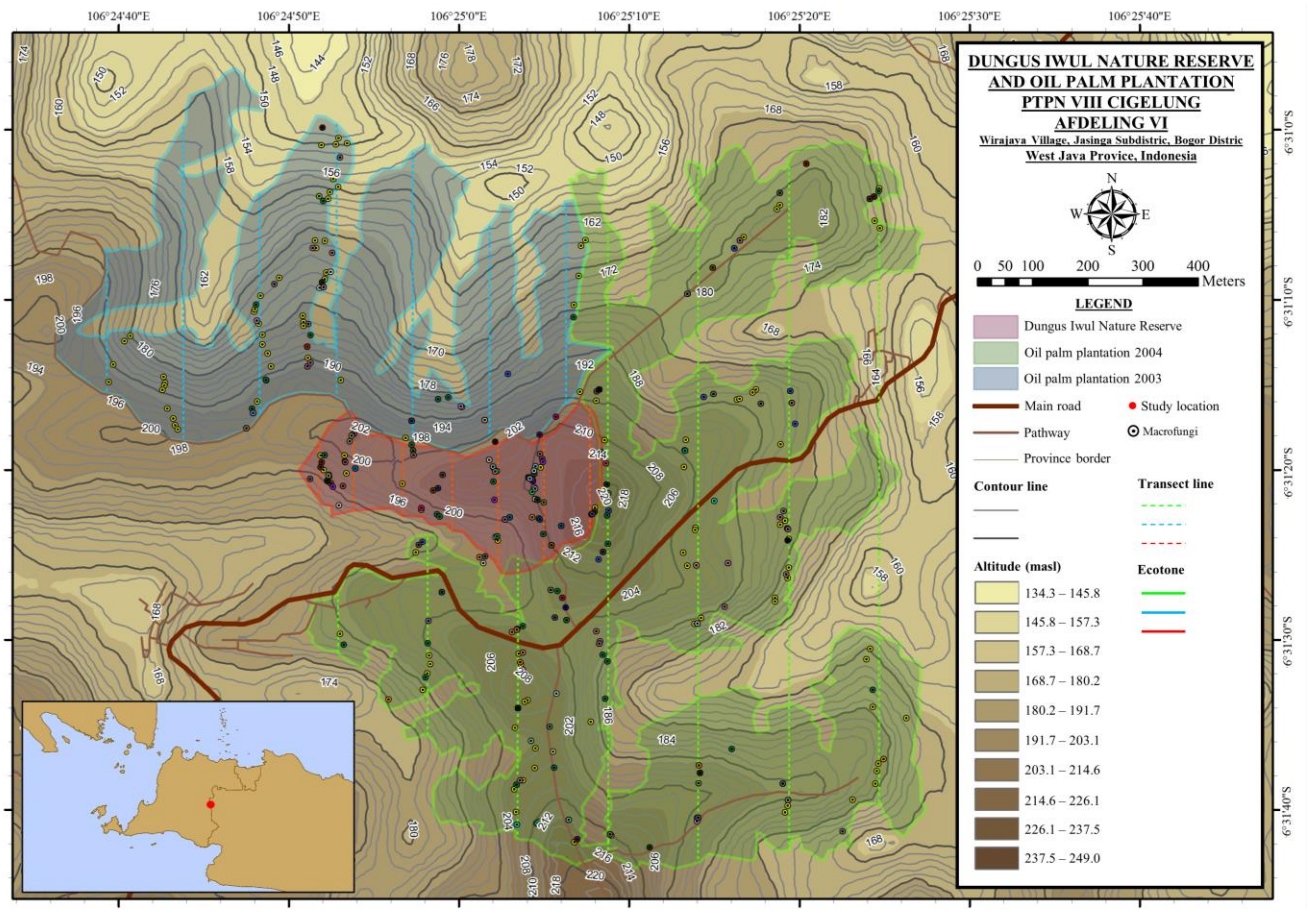

Figure 1. Location of Cigelung Landscape showing three main study locations and macrofungal distribution.

Macrofungi that were found to have mycophagous larvae or small invertebrates on the inside and surface of its fruitbodies were noted. A total of three to five fruitbodies were gathered at different life stages. The spore prints were collected on black and white paperboard for color observation. The color description used the Munsell color system. Micromorphological features (hyphae, pellis, trama, cystidia, basidia or asci, spores, and their ornamentation) were checked and measured using a BW OPTICS XSZ-N107BN series biological microscopes with the aid of Congo red (CR) 1% and eosin (ES) 1% reagents (Dawson et al. 2018). Macrochemical tests using 5% and 10% potassium hydroxide (KOH) and Melzer's reagent (MR) were carried out on the surface and context of fruitbodies. Microchemical tests were carried out with MR, KOH 5%, lactophenol cotton blue (CB) 1%, and ammonium hydroxide (NH_4OH) 10% for mycelium; and MR, CB 1% and NH_4OH 10% for spores (Dwivedi et al. 2012; Mohanan 2014). Macrofungi were identified from the standard literature and the description of legitimate current name status registered in Mycobank database (Gäumann 1928; Thomas 1928; Corner 1950; Cooke 1961; Denison 1963; Dennis 1978; Dutta et al. 2014; Dwidjoseputro 1978; Dring 1980; Arora 1986; Gilbertson and Ryvarden 1986; Largent 1986; Singer 1986; Hjortstam et al. 1987; Miller and Miller 1988; Largent et al. 1997; Pegler et al. 1997; Spooner 2000; Lodge 2004; Deacon 2005; Halling and Mueller 2005; Cannon and Kirk 2007; Parfitt et al. 2007; Kirk et al. 2008; Læssøe 2013; Petersen 2013; Beug et al. 2014; Shay et al. 2017; Wu et al. 2017; Hussain et al. 2018; Læssøe and Petersen 2019a, b).

Herbarium preparation

Macrofungal herbaria were made by drying the macrofungal fruitbodies in an oven at a temperature of no more than 45°C after being wrapped in clean paper per-specimen type (Drábková 2014). The dried specimens were put in an acid-free paper envelope. The envelopes were put in ziplock plastic which had been given some silica pellets and a herbarium label (Pradhan et al. 2015).

Community ecology data analyses

Mapping and analysis of the distribution of coordinate data were carried out with ArcMap 10.3 software. Community ecology analysis was carried out with R programme 4.0.2 running in RStudio GUI 1.1.463. The package used in R was *BiodiversityR* ver. 2.12-1, *boot* ver. 1.3-25, *ggplot2* ver. 3.3.2, *vegan* ver. 2.5-6, *vegan3d* ver. 1.1-2, and *VennDiagram* ver. 1.6.20.

Data analysis

Community data, the abundance of each species found and species richness, were standardized by the rarefaction method (based on the smallest sample size) (Johnson and Bhattacharyya 2010). The diversity indices used were Shannon-Wiener index (H'), Gini-Simpson index (1-D), the effective number of species from H', community dominance index used Berger-Parker dominance, and Rényi entropy for relative measures of community diversity and evenness (Tóthmérész 1995; Jost 2006; Maurer and McGill 2010; Leinster and Cobbold 2012; Morris et al. 2014; Mbenoun et al. 2017; dos Santos et al. 2020; Nur 'Aqilah et al. 2020). Species accumulation curves were generated by collector and random methods with 1000 permutations (Schön et al. 2018; Atrena et al. 2020; Kärvemo et al. 2021). The analysis of the macrofungal species distribution was done by Venn diagram (López-Quintero et al. 2012; O'Hanlon et al. 2013; Brunner et al. 2014; Ghate et al. 2014; Wei et al. 2019; Ye et al. 2019; Runnel et al. 2021).

Analysis of macrofungal community difference was carried out using the t-test proposed by Hutcheson (1970) by comparing H' and plotted with a bootstrap function using 1000 replication samples (Jost 2006). A further test of macrofungal community difference was done using the Permutational Multivariate Analysis of Variance (PERMANOVA) with Bray-Curtis dissimilarity and 999 permutations, after the equality of variation in each community group was checked with homogeneity of multivariate dispersion (Anderson and Walsh 2013). The scale of difference was described by Non-metric Multidimensional Scaling (NMDS) plot with Bray-Curtis dissimilarity and maximum iteration of 100 times (Asouti et al. 2018; Claudia et al. 2018; Abdo et al. 2019; Leonhardt et al. 2019; Lyons et al. 2021).

Analysis of indicator species was carried out with the chi-square test by observing the Pearson residual and expected value of each species (Gardener 2014). The Pearson residual of species used for this analysis were more than two in one area and no more than minus two for the other two areas. The expected value of fewer than five meant more sampling was needed for the species to be a potential indicator. The probability for finding species at each study location was calculated with the concept of rarefaction (Hurlbert 1971; Heck et al. 1975). The above analyses were done between each study location (CADI - PTPN 2003 - PTPN 2004) and between the ecotone and the interior areas of each study location (CADI ecotone - CADI interior; PTPN 2003 ecotone - PTPN 2003 interior; and PTPN 2004 ecotone - PTPN 2004 interior).

RESULTS AND DISCUSSION

This study recorded 6313 macrofungal samples, belonging to 120 species, 76 genera, and 41 families. All these species were scattered in CADI, PTPN 2003 and PTPN 2004 (Figure 1, colored dot). This indicates that macrofungi can live in various habitats and survive despite the changes in the landscape structure and function in oil palm plantations. The type of morphological group that was not found at the study locations was from the bolete fungi. Most morphological groups found were from agaric fungi (63 species), followed by polypore fungi (22 species).

Macrofungi based on the growth substrate data from all study locations showed diverse results. The difference in the growth substrate indicated different ecological functions of the macrofungi in the landscape communities

in which they grow (Hättenschwiler et al. 2011; Rinkes et al. 2011; Rajala et al. 2012; Dickie et al. 2013; Schilling et al. 2015; Norros and Halme 2017; Runnel and Lõhmus 2017; Frąc at al. 2018; da Costa et al. 2019; Loizides et al. 2019; Lustenhouwer et al. 2020). The fruitbodies of some macrofungi can also function as a growing environment and as a food source for mycophagous larvae and small invertebrates, and other mycoparasitic fungi as well (Henk et al. 2011; Ottosson et al. 2014; Halbwachs and Bässler 2015; Baldrian et al. 2016; Schigel 2012; Epps and Arnold 2018; Kazartsev et al. 2018; Epps and Arnold 2019; Macias et al. 2019). A total of 14.17% of species from the macrofungal fruitbodies observed were a host of mycophagous larvae and small invertebrates.

In general, the growth substrates for macrofungi found were divided into soil and wood. Some macrofungal fruitbodies found growing on the soil act as mycorrhizae in association with roots, while some act as saprophytes in the final stage of wood rot, and pathogens associated with roots. The macrofungal fruitbodies found growing on the wood were found to act as saprophytes and some as a facultative parasites helping in the decay of stems, twigs, leaf sheaths, petioles, empty fruit bunches, and fruit (seeds) of plants (Ostry et al. 2011; Boddy et al. 2017).

Macrofungal fruitbodies in the CADI Fragment were found growing on wood 4.8 times more than the soil. Among these substrates, the weathered tree trunk on the forest floor was the most preferred by macrofungal fruitbodies, and the rotted tree trunk on the forest floor was preferred the least. Several species of macrofungi were associated with *Orania sylvicola*. These associations were possible as mycorrhizae in roots, saprophytes of plant biomass that fell to the forest floor, and facultative parasites (Tuheteru et al. 2019).

In the PTPN matrix, most of the macrofungi grew on the fallen leaf sheaths, petioles, and empty fruit bunches of *Elaeis guineensis*. Some macrofungal fruitbodies that grew on the soil surface were only found around the *E. guineensis* trunk, indicating a possible association with its plant roots (da Silva Maia et al. 2021). One of the substrates with high macrofungal diversity in the PTPN matrix was empty fruit bunches (tankos). This substrate was piled up around the plantation, which would rot and become an additional nutrient source for *E. guineensis* (Abu Bakar et al. 2011; Chiew and Shimada 2013; Santi et al. 2019). This mass of substrate and its surrounding area always had a high diversity of macrofungal fruitbodies. The growing substrate of macrofungi unique to this location compared to CADI was the fruit of *E. guineensis*, which was the substrate of *Calocybe* sp. *Calocybe* species are also reported to be associated with village vegetation at the significance of 0.01 in West Bengal, India (Pradhan et al. 2013). In the present study area, further study is needed to determine the specificity of *Calocybe* sp. for fruits of *E. guineensis.*

Macrofungal abundance varied across the study site and also the abundance was found not directly proportional to the species richness (Table 1). The range of abundance found was from 1-3694/ species. The results of the rarefaction analysis at the three study sites showed that CADI had the highest macrofungal species richness and diversity indices compared to PTPN (Table 1 and Figure 2.A). From the effective number of species, the diversity of macrofungi in CADI appeared to be 3.36 to 6.34 times more than that of PTPN. CADI had the highest evenness of the macrofungal community than the other two locations, and all study locations showed an intermediate evenness curve pattern (Figure 2.B) (Gardener 2014). Higher evenness values indicate a more stable community and more resilient to disturbance (Deng 2012; Pickles et al. 2012; Shade et al. 2012; Griffiths and Philippot 2013; Matsushita et al. 2015; Carrillo-Saucedo et al. 2018; Yang et al. 2021). The highest dominance index value was owned by PTPN 2003, followed by PTPN 2004, and finally CADI. This high dominance index value was shown by *Schizophyllum commune*, which was found to be abundant compared to other species and is a macrofungal species commonly found in the oil palm plantation area (Seephueak et al. 2017; Shuhada et al. 2017). The macrofungal abundance in CADI was 1510 samples and 360 of them consisted of *S. commune* (23.84%), while the proportion in PTPN 2003 and PTPN 2004 was much higher (79.71% and 63.28% respectively). This is also a cosmopolitan species and has a wide variety of hosts (growing substrates) (Fuller et al. 2013; Vulinović et al. 2018). All the results above showed that CADI had the largest macrofungal diversity, followed by PTPN 2004 and finally in PTPN 2003.

Subsequent analyses were carried out between the interior and the ecotone areas of each study location. The rarefaction analysis of the macrofungal species richness in the interior area was higher compared to the ecotone in CADI, as well as PTPN 2004, but in PTPN 2003, the ecotone was higher than the interior area (Table 1). The high macrofungal species richness in the interior area of CADI and ecotone PTPN 2003 was due to differences in the diversity of growing substrates from each study location. CADI is a lowland tropical rainforest with heterogeneous plant species and is rarely disturbed by the outside environment. This condition results in a variety of growth substrates, which results in a higher species richness of macrofungi in the interior area than its ecotone. In contrast, oil palm plantations have homogeneous plant species and the plantation floor is always cleaned. This condition results in a smaller macrofungal species richness in the interior area than its ecotone (Ye et al. 2019). The macrofungal species richness in the PTPN 2004 interior area, which was higher compared to its ecotone, was due to the presence of four piles of tankos located at the exploration area. These piles of tankos had a high macrofungal species richness (7 to 14 species) in a small area (2 to 4 m^2). The rarefaction results of the macrofungal species richness above and the calculation of the diversity indices showed that the highest diversity in CADI was found in the interior area compared to its ecotone, and the highest diversity in PTPN 2003 was obtained in ecotone compared to the interior area (Table 1 and Figures 2.C and 2.E). The diversity of macrofungal species in the interior area of CADI was 2.7 times than its ecotone, and the ecotone of PTPN 2003 was 2.2 times than its interior area

(based on the effective number of species (Table 1). Although the interior area of PTPN 2004 had higher macrofungal species richness, the calculation of the diversity indices showed lower yields than its ecotone (Table 1). This difference was because the evenness of the macrofungal community in PTPN 2004 ecotone was higher than the interior area and it caused the curves of Rényi entropy to cross at each other (Figure 2.G-H). The evenness curve pattern in all macrofungal communities was intermediate (Figures 2.D, 2.F, and 2.H) (Gardener 2014).

The species accumulation curve formed using the collector method shows the species richness profile of macrofungi during the inventory process (Figure 3.A). In CADI, the first asymptote (eighth to tenth sampling) happened when the weather on the day before was dry and hot. The next sampling was done again on the day after rainfall (eleventh sampling), and the number of species new to the study site increased. This also happened at the PTPN 2003 curve, which reached the asymptote phase in the fourth sampling and increased in the seventh sampling. It showed that weather conditions and sampling time affected the species richness of macrofungi (Gates et al. 2011; Dutta et al. 2013; Karim et al. 2013; Zotti et al. 2013; Hofmeister et al. 2014; Piepenbring et al. 2015; Marzana et al. 2018; Chakraborty 2019; Filippova and Lapshina 2019; Kouki and Salo 2020; Fink et al. 2021; Kujawska et al. 2021). The result of the species accumulation curve with the random method showed all study sites hadn't reached the asymptote (Figure 3.B). The boundary of confidence interval (95%) distance from each curve still looked wide and didn't converge with the midline, indicating that there were species that were still not recorded during sampling.

The distribution composition analysis of macrofungal species using the Venn diagram shows the similarity of species at the three study sites (Figure 4.A). Seven species were tolerant of microclimate in Cigelung Landscape, and the other species preferred specific environmental conditions. Of the 120 species found, 52 were species-specific to CADI (remnant patches of lowland tropical rainforest) and may have disappeared from the PTPN matrix. The loss of macrofungal species richness from the PTPN matrix was accompanied by the discovery of 50 (8+5+37) species that grew specifically only in that matrix. The remaining three species were found to be tolerant to the microclimate CADI and PTPN 2003 and eight species between the microclimates of CADI and PTPN 2004. The composition of the macrofungal species distribution between the interior area and its ecotone showed some differences in the macrofungal species richness (Figure 4.B). From these results, it can be concluded that several species of macrofungi are sensitive to environmental conditions and are suitable as indicator species for lowland tropical rainforest ecosystems that are not disturbed by human activity (O'Hanlon and Harrington 2012; Abrego et al. 2017; Dvořák et al. 2017).

Based on the Hutcheson t-test and bootstrap function of the H', there was a significant difference between CADI with PTPN 2003 (t=11.83399; p=0.0016), CADI with PTPN 2004 (t=7.3027; p=0.0035), and PTPN 2003 with PTPN 2004 (t=3.49978; p=0.01850) after the p-value was adjusted by the Holm (1979) method (Figure 5.A). The PERMANOVA test results further supported the differences of the macrofungal community in the three study locations (F=0.036) with equal variation sample data (F=0.3286) in α value of 0.05. The differences in these communities were illustrated by the NMDS analysis plotted in a three-dimensional area. The three separate centroids represent a different macrofungal community with a stress value of 0.1281 (Figure 5.B). The significant difference between the diversity index and the macrofungal community proved that there the alteration in landscape structure and function led to a change in macrofungal diversity.

Table 1. Abundance, species richness, diversity indices, and community dominance index of macrofungi in CADI fragments and PTPN matrix

Location	Macrofungal abundance	Macrofungal species richness	Standardized macrofungal species richness [a]	1-D [b]	H' [c]	Effective number of species [d]	Community dominance index [e]
CADI [f]	1,510	70	70	0.90	2.84	17.18	0.26 ± 0.10
PTPN 2003 [f]	1,794	23	22	0.38	1.00	2.71	0.78 ± 0.28
PTPN 2004 [f]	3,009	57	49	0.60	1.63	5.11	0.61 ± 0.21
Total	6,313	120	115	0.68	2.18	8.85	0.55 ± 0.28
CADI							
Interior	1,398	61	37.99	0.93	3.14	23.04	0.19
Ecotone	112	15	15.00	0.84	2.15	8.56	0.30
PTPN 2003							
Interior	1,400	13	9.55	0.29	0.71	2.04	0.84
Ecotone	394	14	14.00	0.61	1.49	4.44	0.61
PTPN 2004							
Interior	2,452	42	29.12	0.53	1.48	4.37	0.67
Ecotone	557	24	24.00	0.77	2.02	7.53	0.42

Note: [a]based on the smallest sample size, [b]Gini-Simpson index, [c]Shannon-Wiener index, [d]based on H' formula, [e]Berger-Parker dominance index, [f]ecotone and interior area

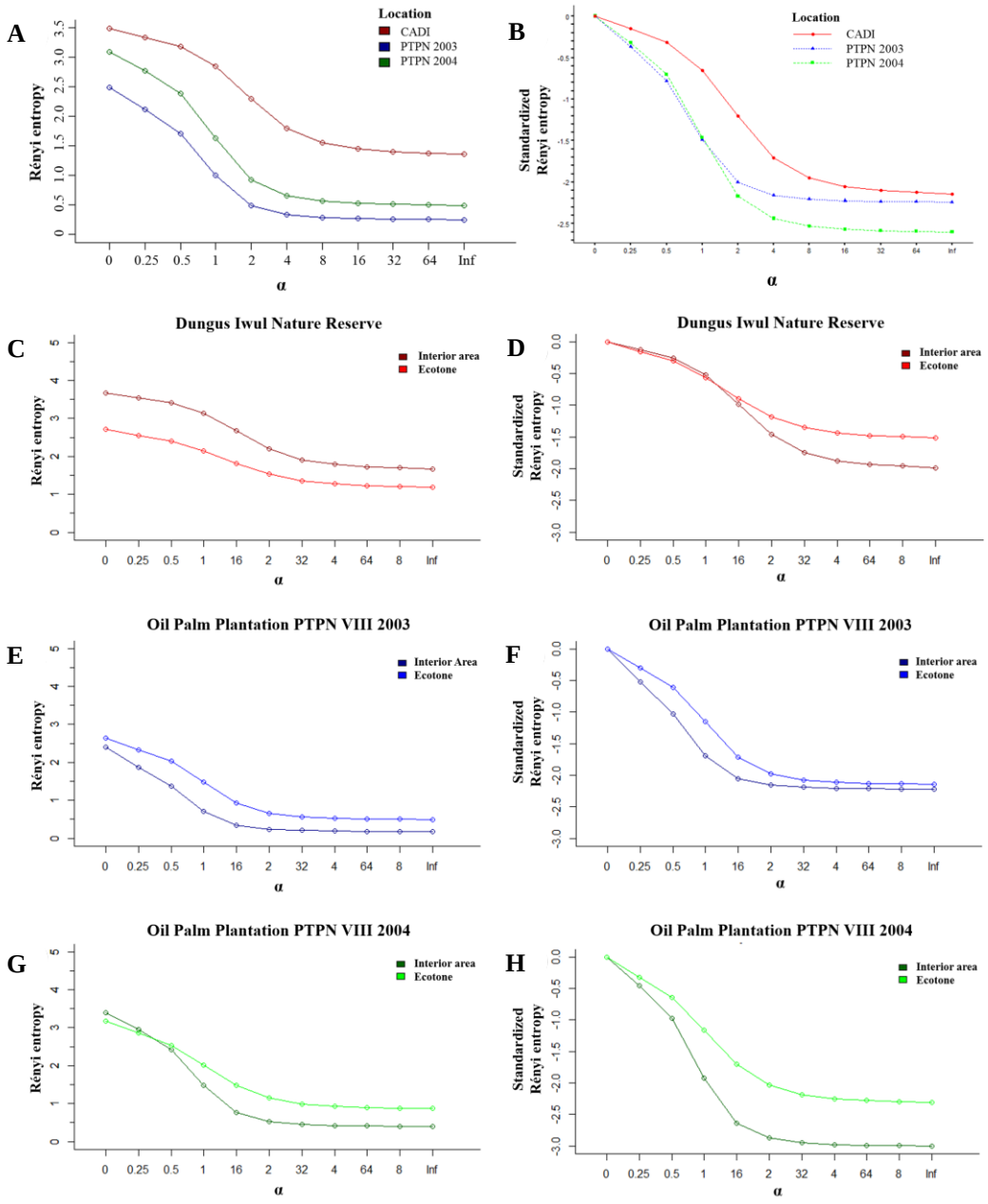

Figure 2. Rényi entropy (*left*) shows relative measures of community diversity and its standardization (*right*) shows relative measures of community evenness from each study site (A and B); CADI ecotone and interior area (C and D); PTPN 2003 ecotone and interior area (E and F); and PTPN 2004 ecotone and interior area (G and H)

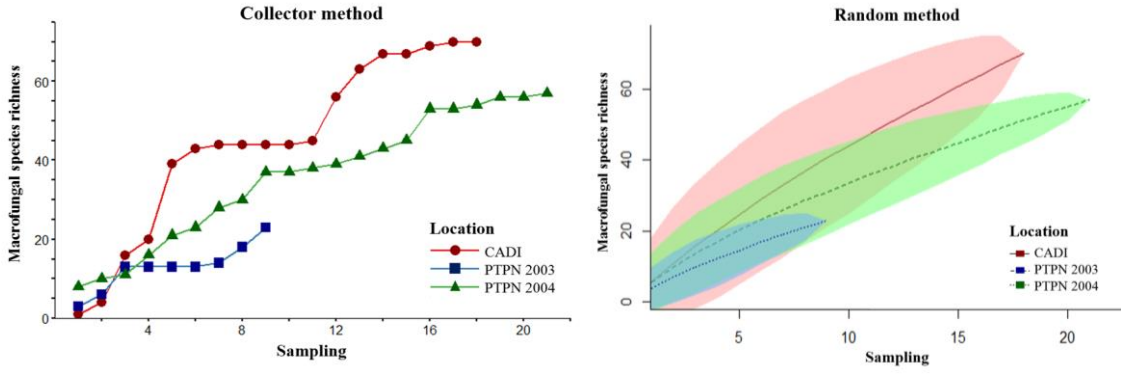

Figure 3. Species accumulation curves from the three study locations generated with collector (A) and random (B) methods with 95% confidence interval

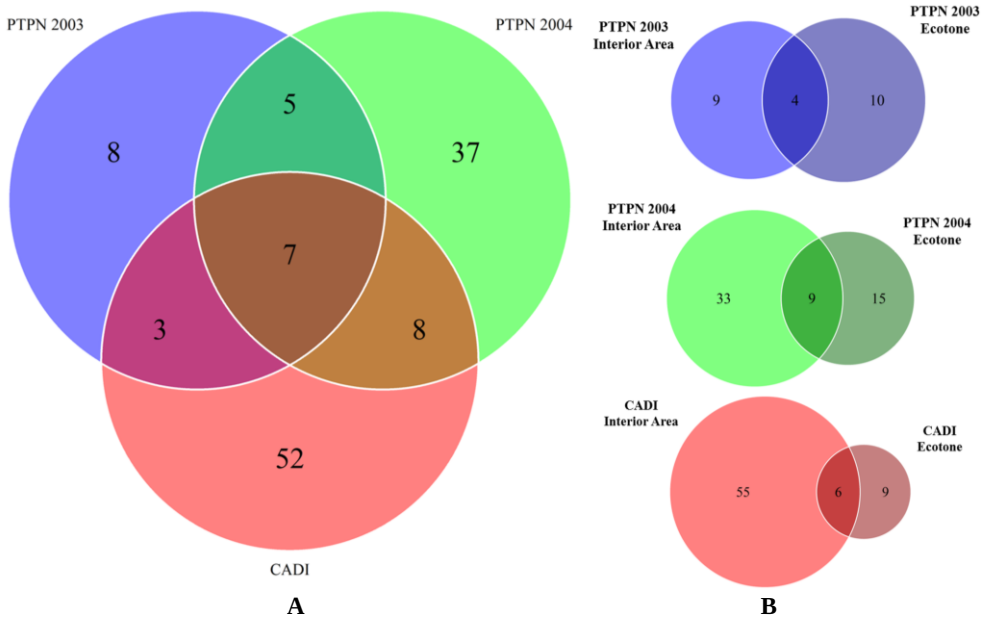

Figure 4. A. Venn diagram from the composition of macrofungal species richness between three study locations; and B. between interior and ecotone area in CADI (*right bottom*), PTPN 2003 (*right top*), and PTPN 2004 (*right middle*)

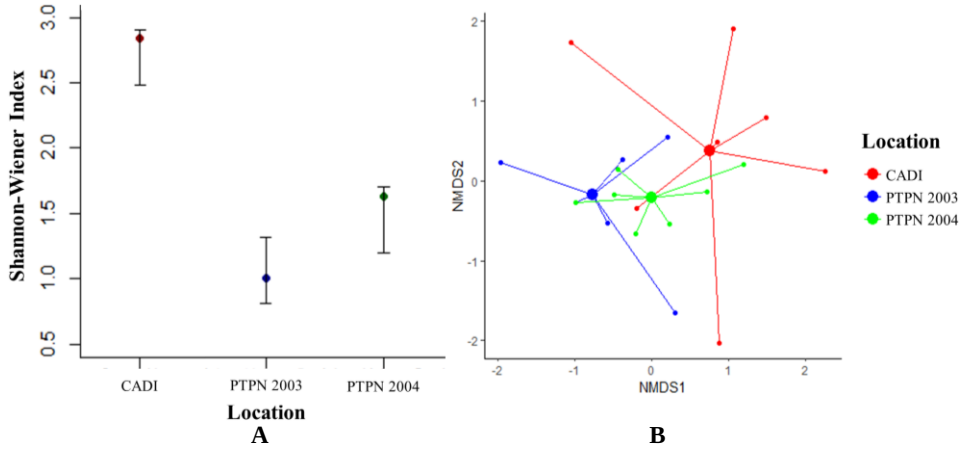

Figure 5. A. Bootstrap of H' with 95% confidence interval using 1000 replicated samples between three study locations. B. NMDS analysis of the macrofungal community with Bray-Curtis dissimilarity

The Hutcheson t-test and bootstrap function of the H' shows that there was a significant difference between the diversity in the ecotone and interior areas of CADI (t=8.45; p=0.01133), PTPN 2003 (t=8.33167; p=0.002095), and PTPN 2004 (t=5.9488; p=0.002466) with α value of 0.05 (Figure 6). This significant difference between the ecotone and interior areas indicates that the macrofungal community is sensitive to the difference in the environmental conditions of the ecotone microclimate.

Macrofungal species that have potential as an indicator was analyzed with chi-square test. Species with the potential as indicator species for natural lowland tropical rainforest in Cigelung Landscape with its probability to find the species in the study location were *Calocera cornea* (13.32%), *Calocybe* sp. (9.10%), *Cyclomyces setiporus* (22.41%), *Earliella scabrosa* (16.06%), *Favolus manipularis* (12.50%), *Macrotyphula* sp.$_1$ (7.22%), *Marasmius* sp.$_3$ (9.10%), *Microporus affinis* (27.75%), *Pholiota* sp.$_2$ (13.77%), *Rigidoporus* sp., (12.36%), and *Xylaria hypoxylon* (12.04%) (Figure 7). For *Ganoderma tropicum* (5.91%), *Lentinus strigosus* (6.46%), and *Marasmius* sp.$_2$ (11.59%), it was necessary to collect more samples to determine its potential as an indicator species candidate. *Crepidotus applanatus* (9.10%) and *Daldinia concentrica* (21.83%), were both candidates for indicator species but could also be found in other study locations (9.95% in PTPN 2003 and 4.49% in PTPN 2004), meaning that these species had a preference for CADI. The species that were uniquely found in PTPN 2003 were *Hemimycena cucullata* (14.28%) and *Hygrocybe cantharellus* (7.87%), while the ones in PTPN 2004 were *Coprinopsis* sp.$_1$ (9.02%), *Gymnopilus dilepis* (8.93%), *Lycoperdon perlatum* (8.57%), *Mycena inclinata* (8.57%), and *Pleurotus* sp. (19.51%). The species *Lactarius* sp.$_2$, apart from being found in PTPN 2004 (10.80%), was also found in the CADI area (0.91%), meaning that this species had a preference for PTPN 2004.

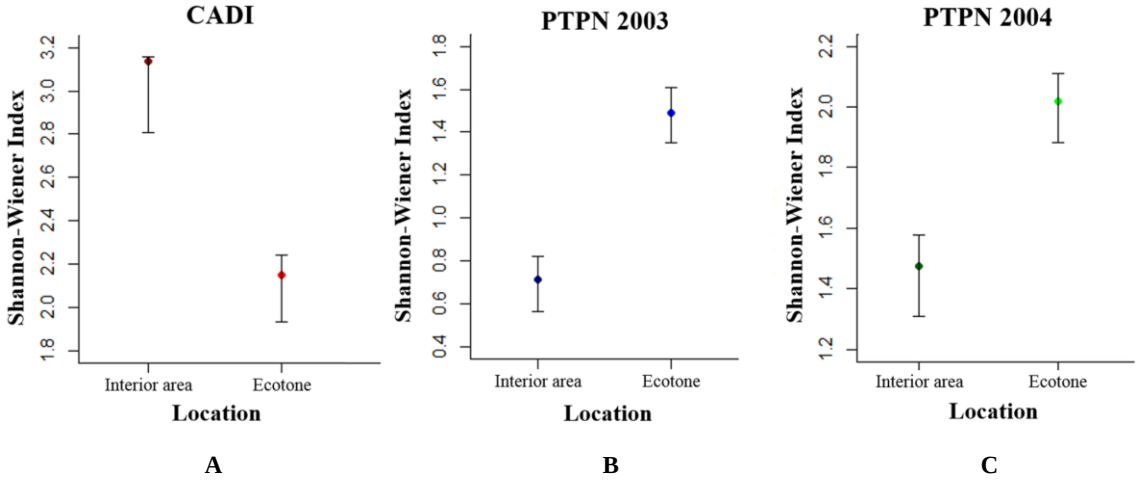

Figure 6. Bootstrap of H' with a 95% confidence interval using 1000 replicated samples between ecotone and interior area of CADI (A), PTPN 2003 (B), and PTPN 2004 (C)

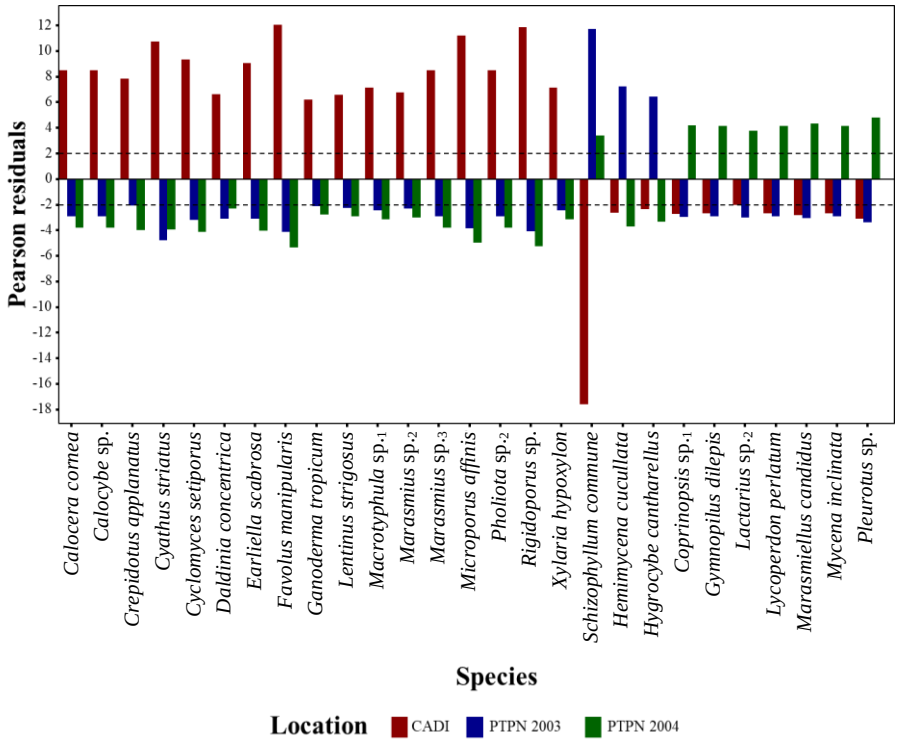

Figure 7. Pearson residuals from species with a score of no less than 2 in one study site and no more than -2 in the other study sites

In conclusion, the highest morphological group found belonged to agaric fungi, with *S. commune* being the most dominant in all study locations. Changes in landscape structure (fragmentation and land-use change) occurred in Cigelung Landscape, West Java, which resulted in changes in macrofungal diversity. Macrofungi had a different response and sensitivity to environmental conditions (microclimate) between the ecotone and interior area. Lastly, we suggest regularly carrying out further inventory and monitoring processes to obtain a complete diversity of macrofungal species and further exploring their potential.

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