Exploring Macrofungi Abundance and Substrate Specificity Across Diverse Environmental Conditions

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Abstract

Macrofungi, characterized by their visible fruiting structures they play important ecological roles and have a significant economic role. However, comprehensive knowledge regarding their abundance and soil specificity, particularly in tropical regions, remains limited. This study aimed to assess macrofungi abundance and soil specificity across varied environmental settings in the Madre de Dios region of Peru. The project focuses on examining the abundance, distribution, and substrate preferences of macrofungi, with a specific emphasis on comparing the abundance on different growing substrates. The research was conducted during the dry season in diverse land use types surrounding the Sustainable Amazonian Research Station, including primary forests, secondary forests, and a cow pasture. The project aims to contribute to our understanding of macrofungi responses to land use changes and support conservation efforts in the Peruvian Amazon rainforest. The findings aim to have practical implications for conservation and land management strategies.

Keywords Macrofungi Madre De Dios Abundance estimation Substrate tendency

Introduction

Macrofungi are a diverse group of organisms that play crucial roles in ecology and economy (Niego et al. 2023; Zotti et. al. 2013). They are characterized by their visible fruiting structures and can be found growing on various widely varying substrates, such as standing trees, decaying wood, plant debris, insects, dung, soil, and others (Adeniyi et al. 2018; Lee et al. 2014; Tibuhwa 2011; Yerisetouw et al. 2023).

Fungi are believed to comprise a vast number of species, with estimates widely ranging from 1.5 million to 12 million species (Baldrian et al. 2021; Gautam et al. 2022; Wu et al. 2019). In terrestrial ecosystems, macrofungi play crucial roles as decomposers, breaking down organic matter and contributing to the nutrient cycling (Balami et al. 2020; (Karavania et al. 2018; Lee et. al 2014; Osono 2014). Furthermore, they are significant soil organisms that participate in the decomposition of structural and soluble components, increasing the carbon and nutrient release into the soil, acting beneficial for the ecosystem (Balami et al. 2020; Osono 2014). Macrofungi are also known to form mycorrhizal associations with plants, providing them with nutrients and aiding in their survival (Balami et al. 2020; Lee et al. 2014, Soudzilovskaia et al. 2020). Additionally, some species of macrofungi are parasitic, deriving nutrients from living organisms (Aini et al. 2020; Joop & Vilcinskas 2016).

Forestry managers and conservationists have realized that dead decaying wood, forms an important source of biodiversity and an integral part of the recycling of carbon and other nutrients (Tibuhwa 2011). Fungi have significant uses in human life, such as in the medicines and pharmaceuticals, food and beverages, pesticides and fertilizers, myco-based materials and furthermore (Niego et al.

2023; Wu et al. 2019; Yerisetouw et al. 2023).

The Peruvian Amazon rainforest, known for its mega-diversity, is facing significant threats due to land use changes, including agriculture, urban expansion, and mining (Asner & Tupayachi 2016; Bennett et al. 2019; Espejo et al. 2018). These changes have resulted in the loss of forest land and have raised concerns about the impacts on biodiversity (Boulton et al. 2022). However, despite their ecological and economic importance, there is limited information on the abundance, dynamics, and substrate specificity of macrofungi, particularly in the Amazon rainforest (Komura et al. 2017; Tedersoo et al. 2014; Yusran et al. 2022).

Materials

Study Site

The study was conducted within the diverse landscape surrounding the Sustainable Amazonian Research Station, strategically situated in the captivating region of Madre De Dios, Peru. This research station is strategically positioned within the boundaries of the Manu National Park, spanning across the enchanting and ecologically significant landscapes of Madre de Dios. Situated approximately 40km north of Puerto Maldonado, the capital city of the Madre de Dios district in Peru, the research site provides a diverse array of land use types for investigation. These encompass lightly disturbed primary forests, cocoa (Theobroma cacao), papaya (Carica papaya), and banana (Musa) as the predominant crops. Additionally, neighboring properties feature cow pastures, further contributing to the multifaceted land use patterns observed in the area. The selected site spans an elevation range of 240 to 270m above sea level, encompassing the realm of the terra firme forest zone.

Land Use Types

To capture the intricate patterns of macrofungi abundance, the data collection efforts were undertaken across 6 distinct

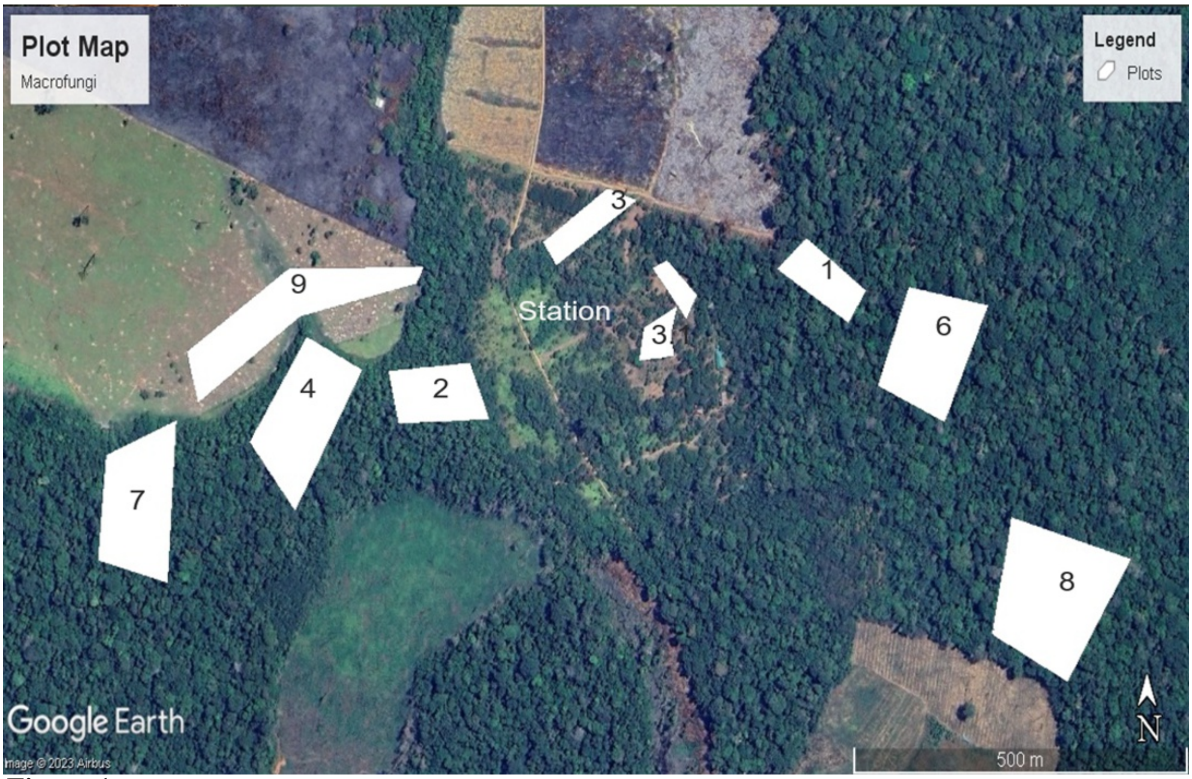


Figure 1

LAND USE TYPES	Plot NUMBER	CHARASTERISTICS
Primary Forest	1, 6, 7	• serves as a significant educational and research resource • sustainable brazil nut harvesting site • prominent presence of of brazil nut trees (Bertholletia excelsa), dominating the canopy layer • soil moisture tends to be low
Primary Forest	2	• serves as a valuable educational and research resource • site for aguaje fruit harvesting • prominent presence of emergent aguaje palms (Mauritia flexuosa), dominating the canopy layer • predominantly characterized as a swamp, ensuring a consistent and abundant water supply throughout
Secondary Forest	3	• has undergone a natural regeneration process for over a decade, with minimal human intervention • has been left to its own ecological processes, enabling the spontaneous regrowth of vegetation • no occurrence of decaying logs • soil moisture tends to be low
Secondary Forest	3.1	• has undergone a regeneration process over a span of six years, utilizing a combination of tree planting and natural dispersal mechanisms • managed forest, predominantly consists of young trees nurtured to facilitate robust growth and development • landscape is occasionally interrupted by the presence of burned decaying logs • soil moisture tends to be low
Primary Forest	4a, 4b	• located in the neighbouring property • 4a: site for aguaje fruit harvesting • 4b: predominantly undisturbed ecosystem • forest floor adjacent to the cow pasture is characterized by swampy conditions, creating a wetland habitat • rest of the area exhibits a tendency towards drier soil conditions
Primary Forest	7	• almost no economic development • minimal human intervention • soil moisture tends to be low
Cow Pasture	9	• located in the neighbouring property • characterized by minimal biodiversity • featuring short grass and a rarity of trees and larger vegetation • landscape is occasionally interrupted by the presence of burned decaying logs

Table 1

land use types, each characterized by varying degrees of human activity. These land use types encompass the realms of primary forests, secondary forests, and the tapestry of a cow pasture. A comprehensive overview of the characteristics of each land use type is presented (Figure 1, Table 1).

Survey and Timing

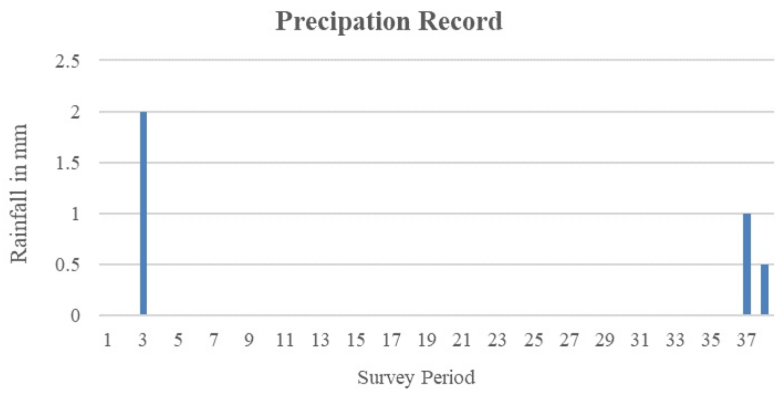
The survey was conducted from 07 July 2023 till the 13 August 2023. During the dry season, a total of 29 surveys days and 43 survey hours were recorded. The data collection of macrofungi within the observation plots was done during daylight hours.

Seasonal Dynamics

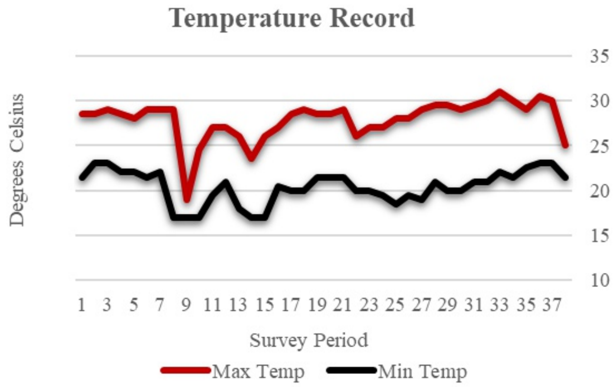
The Amazon rainforest experiences distinct dry and wet seasons, each with unique characteristics and ecological implications. The dry season is characterized by increased sunlight, influencing rainforest phenology and productivity. In contrast, the wet season brings increased rainfall and cloud cover, crucial for maintaining water balance, productivity, and biodiversity (Huete et al. 2006).The precipitation was minimal during the survey period, with only three days of rain totaling less than 3 mm (Graph 1).

Weather Phenomena: Friajes

Friajes, also known as surazos or friagems,



Graph 1



Graph 2

are cold surges in the Amazon region. They involve the incursion of cold, dry air from southern South America, causing significant temperature drops. These events occur throughout the year but are most pronounced during austral winter incursions.

Friajes have severe effects on local communities, livestock, and crops, disrupting normal activities and impacting animal behaviour (Garreaud 2009; Poveda et al. 2020; Villar et al. 2015). In total, 7 friajes were recorded, with the lowest recorded temperature being 17 °C. The average temperature within the friajes was 21.6 degrees Celsius (Graph 2).

Data Collection Methodology

To conduct the estimation of abundance and soil specificity of macrofungi, a meticulous belt transect sampling method was employed, carefully designed to ensure comprehensive coverage of macrofungal abundance. For each land use type, belt transects were established, spanning 2,5 meters to the right and left along the transect line, covering the entire area. After the survey completion, the size of each plot was measured, and the land was accurately marked using a GPS application. Plots within the same land type were strategically spaced at a minimum distance of 50 meters to ensure representative sampling across the diverse land use types.

Data Collection and Analysis

Photographs were taken of all specimens to document macrofungi in their natural habitats and on theirrespective growth substrates. The collected data was meticulously recorded and organized in a comprehensive database. Key elements such as the growing substrate, location, and abundance of macrofungi were carefully noted. The total number of macrofungi findings was documented, by counting lower numbered occurrences and estimating macrofungi in higher numbers by eyesight. The total estimated number of macrofungi was divided by the corresponding area size, allowing for a quantitative assessment of macrofungal density across different land use types. Similarly, the observation spots, each characterized by a distinct growing substrate, were individually analyzed. The average number of macrofungi on each growing substrate was calculated by dividing the abundance estimation by the number of observation spots associated with that specific substrate. Test Plot 1 was excluded from the overall calculations to mitigate potential biases that may have occurred within the test plot.

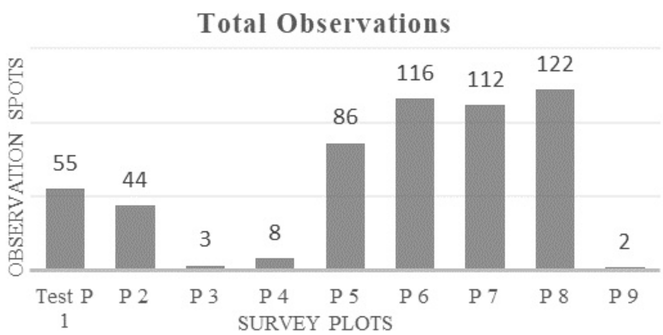
Results

The present study encompassed a comprehensive survey conducted over a duration of 43 hours.

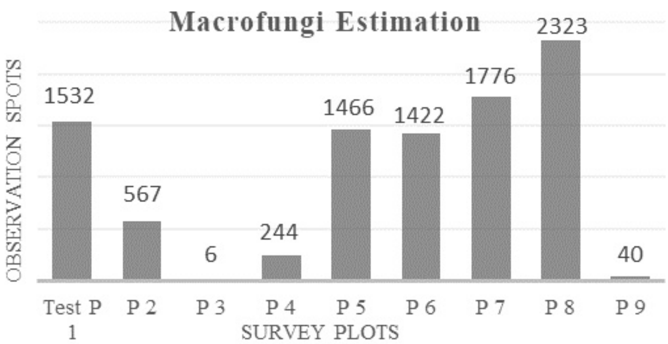
A total of 9376 macrofungi were estimated across 548 observation spots. The surveyed area spanned an extensive 12.46 hectares, ensuring a broad coverage of the study site (Figure 1, Graph 3 & 4).

Density Estimation

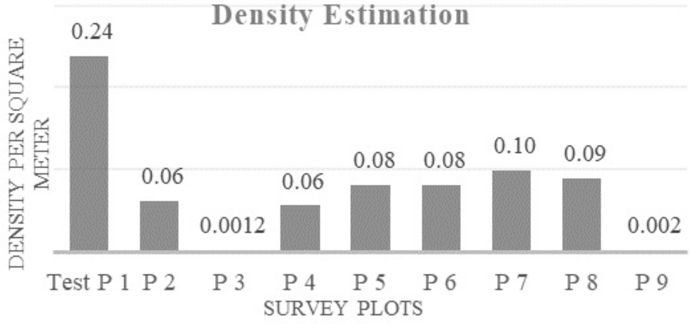
The highest density of macrofungi was observed in Plot 7, located in the Primary Forest, with a count of 0.10 individuals per square meter. Across all plots in the primary forest, on average 0.082 individuals were measured per square meter. In contrast, the



Graph 3



Graph 4



Graph 5

lowest density was recorded in Plot 3, situated in the unmanaged Secondary Forest, where a mere 0.0012 macrofungi per square meter were observed (Graph 5). Test Plot 1 is not included in all calculations.

Density of Observation Spots

In the primary forest, an average of one observation spot was found per 190 square meters. Notably, plot 6 exhibited the highest density of observation spots, indicating a concentrated presence of fungal activity in this area of the primary forest. Conversely, plot 9, situated in the cow pasture, displayed the lowest density, with only two observations recorded across the entire surveyed area

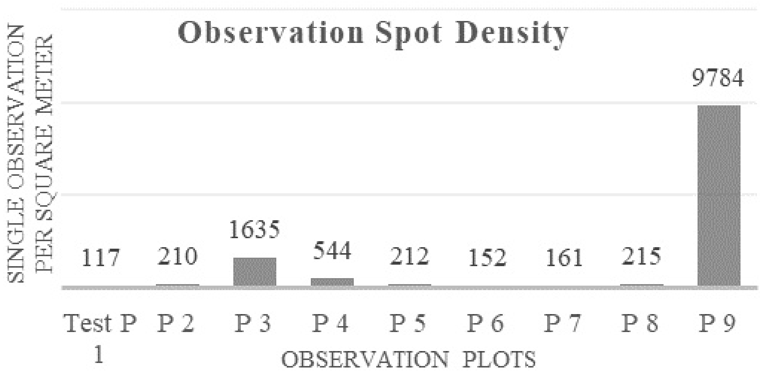
Substrate Specificity

The most prevalent substrate for macrofungi was wood, with a total estimation of 8713 individuals observed across 475 data collection points. These were primarily found growing on decaying logs, which were abundantly present in the primary forest. In Plot 3.1, which is a secondary forest under management, partly burned logs were scattered throughout the area. Interestingly, these logs exhibited a significant abundance of macrofungi growth, despite the overall low abundance of in this area. The abundance of macrofungi growing on palm debris was primarily observed beneath the Aguaje Palms (Mauritia flexuosa).

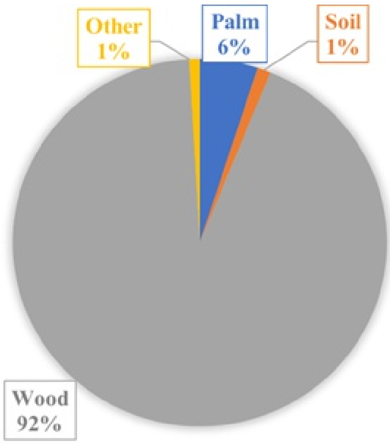
A total of 471 macrofungi were estimated to be present in 18 specific locations, with an additional specimen observed growing on the guaje fruit. Macrofungi growing on soil were found to be widely scattered, with a relatively low abundance ranging from 1 to 9 individuals per observation spot. In total, 108 were identified across 38 observation spots. Occasionally, they were also observed growing on other substrates. For instance, 53 been found growing on brazil nut seed capsules (Bertholletia excelsa) across 7 individual capsules. Additionally, 14 were discovered on living plants in 5 observation spots, while 6 were found in 3 spots growing on decaying broad leaves. Lastly, 10 were observed growing on cow dung in a single location, and a single parasitic macrofungi was found growing on an insect in the genus Lepidoptera.

Abundance tendencies on Substrates

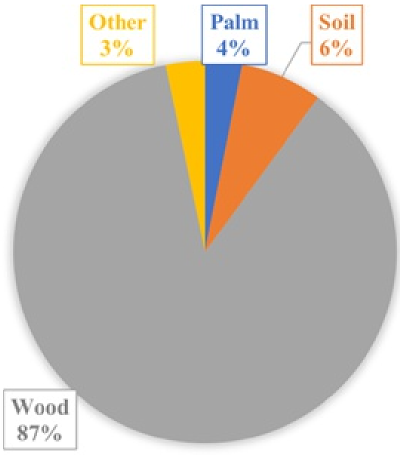
The highest recorded abundance of macrofungi was observed on a single decaying log, with an estimated count of 500 individual fruiting bodies. These macrofungi exhibited a size range of 4mm to 1cm. Notably, the most concentrated occurrence of macrofungi on palm debris within a single location was discovered



Graph 6

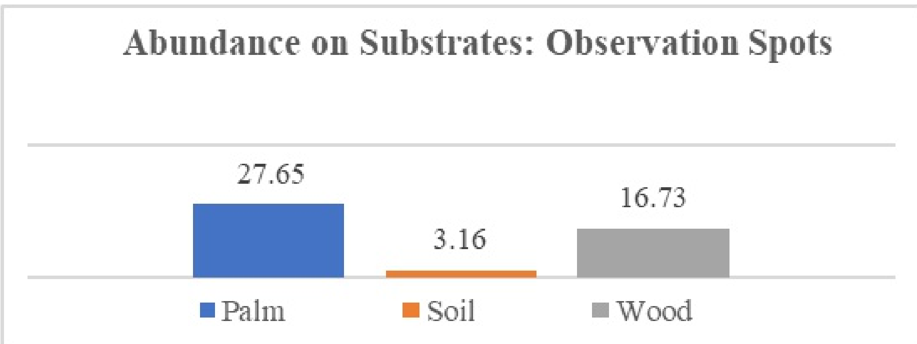


Graph 7: Substrates: Estimated Macrofungi Number



Graph 8: Substrates: Observation Spots

beneath an aguaje palm (Maurita flexuosa), where an estimated count of 170 macrofungi was observed, ranging in size from 5cm to 8cm. Furthermore, the highest average abundance across all observation spots was observed on palm debris, with an average of 27.65 individuals per spot. Notably, the most concentrated occurrence of macrofungi on palm debris within a single location was discovered beneath an aguaje palm (Maurita flexuosa), where an estimated count of 170 macrofungi was observed, ranging in size from 5cm to 8cm. Furthermore, the highest average abundance across all observation spots was observed on palm debris, with an average of 27.65 individuals per spot.



Graph 9

Discussion

The study provides insights of a positive correlation between macrofungi abundance and overall diversity. The primary forest was found to have the highest macrofungi density, highlighting the importance of diverse environments for their proliferation (Kewessa et al. 2022; Komura et al. 2017; Li et al. 2018). The findings suggest that decaying logs serve as a primary substrate for the majority of macrofungi, particularly in the dry season. Wood debris acts as a reservoir of moisture, facilitating the growth and survival of macrofungi by absorbing water (Komura et al. 2017; Sefidi & Etemad 2015; Tomao et al. 2019). In contrast, managed secondary forests and cow pastures exhibited limited macrofungi abundance, with decaying logs being the only favorable substrate left from former land clearing and burning practices (Fujisaka & White 1998; Tomao et al. 2019). The challenging microclimates of these environments further contribute to the observed patterns. The absence of canopy coverage and consistent sun exposure in the cow pasture led to soil desiccation, creating unfavorable conditions for macrofungi (Barros et al. 2004; Putra et al. 2023). Similarly, the low canopy coverage in secondary forests presents challenging environments for macrofungi, particularly during the dry season (Komaru et al. 2017; Putra et al. 2023; Tomao et al. 2019). Furthermore, the scarcity of macrofungi growing directly on the soil can be attributed to the low moisture levels in both the soil and air, making it difficult for fungi, which heavily rely on water, to develop fruiting bodies. Most fungi tend to delay production of fruiting bodies until more favourable conditions, typically during the rainy season (Adeniyi et al. 2018; Cavalcante et al. 2021; Komura et al. 2017; Putra et al. 2023). The high abundance of macrofungi growing under the aguaje palm (Mauritia flexuosa) can be explained by the significant accumulation of leaves and other plant debris resulting from previous harvesting activities. Covering the forest floor from intense sunlight, plant debris can significantly reduce soil evaporation, change dynamic processes of rainfall infiltration and runoff generation. Possibly changing the fungal community structure creating beneficial environments for fungal fruiting (Karavania et al. 2018, Miura et al. 2015, Qiu et al. 2020).

Conclusion

This study demonstrated a positive relationship between the abundance of macrofungi and the accumulation of debris, as well as the significance of primary forests for the development of macrofungi. Additional research comparing the moisture content, diversity, and quantity of macrofungi between disturbed and undisturbed sites can reveal important information on the effect. To learn more about the effects of the harvesting activities of the aguaje fruits, it is also important to study the fungal composition beneath the aguaje palm (Mauritia flexuosa).

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