UNIVERSITI PUTRA MALAYSIA

IMPACT OF LAND CONVERSION ON MACROFUNGAL DIVERSITY IN NORTH SELANGOR PEAT SWAMP FOREST IN MALAYSIA

SITI NOOR SHUHADA BINTI RAJIHAN

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By

SITI NOOR SHUHADA BINTI RAJIHAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

IMPACT OF LAND CONVERSION ON MACROFUNGAL DIVERSITY IN NORTH SELANGOR PEAT SWAMP FOREST IN MALAYSIA

By

SITI NOOR SHUHADA BINTI RAJIHAN

November 2017

Chairman : Sabiha Salim, PhD
Faculty : Forestry

Conservation status of macrofungal diversity in the tropical peat swamp forest, particularly in Southeast Asia is still incomplete due to the paucity of information about this taxa. Especially when the peat swamp forest is being degraded and rapidly reduced due to forest fire (El-Nino) and oil palm expansion. North Selangor Peat Swamp Forest (NSPSF) is among the remaining peatlands which are actively threatened by this catastrophe and anthropogenic activities. This study aimed to determine the effects of forest conversion area to oil palm plantation on macrofungal biodiversity. In January 2016, a total of 757 collections of macrofungal sporocarps from 127 genera or known as morphospecies were found in 60 circular units, each 0.79 ha in size. The macrofungal morphospecies and abundance in four different habitats namely logged peat swamp forest, large-scale oil palm plantation, monoculture and polyculture smallholdings were compared using one-way Analysis of Variance (ANOVA) Tukey's test, while morphospecies composition was examined using non-metric multidimensional scaling (NMDS) ordination. Environmental factors namely air temperature, relative humidity, soil pH, soil moisture and wind speed; as well as canopy closure, canopy cover and substrate availability were analyzed using simple linear regression to investigate their association with macrofungal diversity. The results show that macrofungal diversity of logged peat swamp forest were significantly (P<0.001) higher than macrofungal communities of oil palm based area. Through analysis of similarities (ANOSIM) logged peat swamp forest was found to exhibit variety of macrofungal composition which are not familiar to large-scale plantation, monoculture and polyculture smallholdings (P < 0.001). Macrofungal communities of all habitats were found to show a strong correlation with substrate. Monoculture smallholding was the only habitat showing positive association with two other variables i.e., temperature and soil moisture. The results demonstrated that all habitats support a great value of macrofungal biodiversity. Nevertheless, since the results found that peat swamp forest supports greater macrofungal diversity than oil palm lands, it is important that further expansion of oil palm plantations are to be prohibited on forest land and be shifted to wasted land as an initiative for the land improvement.

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KESAN PERUBAHAN GUNAAN TANAH DI HUTAN PAYA GAMBUT SELANGOR UTARA DI MALAYSIA KEPADA DIVERSITI KULAT MAKRO

Oleh

SITI NOOR SHUHADA BINTI RAJIHAN

November 2017

Pengerusi : Sabiha Salim, PhD
Fakulti : Perhutanan

Status pemuliharaan dan pemeliharaan biodiversiti hutan paya gambut khususnya di Asia Tenggara masih belum lengkap ekoran kurangnya kajian terhadap beberapa komponen biodiversiti, antaranya kulat makro. Akibat daripada fenomena El-Nino dan penukaran guna tanah, iaitu daripada kawasan hutan kepada kawasan perladangan kelapa sawit, keluasan kawasan hutan paya gambut terutamanya di Hutan Paya Gambut Selangor Utara (NSPSF) kini semakin merosot. Oleh itu, kajian ini dijalankan untuk mengkaji kesan penukaran guna tanah daripada kawasan hutan kepada kawasan perladangan kelapa sawit terhadap diversiti kulat makro. Pada bulan Januari 2016, sebanyak 757 koleksi kulat makro daripada 127 genus atau dikenali sebagai *morfospesies* ditemui di dalam 60 plot kajian berbentuk bulat dengan setiap satunya berkeluasan 0.79 hektar. Taburan *morfospesies* dan bilangan kulat makro di empat habitat yang berbeza iaitu hutan paya gambut yang pernah dibalak, perladangan kelapa sawit berskala besar, kebun kelapa sawit dengan pengurusan berbeza (monokultur dan polikultur) telah dibandingkan dengan menggunakan Analisis Varian Sehala (ANOVA) Ujian *Tukey's*, manakala komposisi *morfospesies* kulat makro dikaji dengan menggunakan Penskalaan Dimensi Ganda Bukan Metrik (NMDS). Faktor-faktor persekitaran iaitu suhu udara, kelembapan relatif, pH tanah, kelembapan tanah, kelajuan angin, celahan kanopi, penutupan kanopi dan substrat dianalisa menggunakan Analisis Regresi Linear Sederhana untuk menyiasat hubungan di antara faktor-faktor tersebut dan diversiti kulat makro. Kajian ini menunjukkan diversiti kulat makro di hutan paya gambut yang pernah dibalak adalah lebih tinggi secara signifikan ($P<0.001$) daripada jumlah diversiti kulat makro di kawasan perladangan kelapa sawit. Berdasarkan Analisis Persamaan (ANOSIM), hutan paya gambut yang pernah dibalak mempunyai komposisi kulat makro yang lebih banyak dan *morfospesies* yang lebih pelbagai daripada komposisi kulat makro di perladangan kelapa sawit skala besar, kebun kelapa sawit monokultur dan polikultur ($P <0.001$). Komuniti kulat makro daripada kesemua habitat yang dikaji menunjukkan kebergantungan secara linear yang kuat dengan pemboleh ubah substrat. Bagi pemboleh ubah suhu dan kelembapan tanah, perkaitan secara positif antara pemboleh ubah tersebut dan diverisiti kulat makro dapat dilihat di habitat kebun kecil yang diuruskan secara monokultur sahaja. Hasil kajian ini menunjukkan bahawa kesemua habitat yang dikaji

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mempunyai nilai biodiversiti kulat makro yang tinggi. Walau bagaimanapun, dengan terbuktinya diversiti kulat makro adalah lebih tinggi di hutan paya gambut daripada perladangan kelapa sawit, pembangunan kawasan ladang kelapa sawit yang akan dijalankan seterusnya tidak wajar disasarkan di tanah hutan tetapi di kawasan yang terbiar sebagai inisiatif untuk memajukan tanah tersebut.

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~To embark on the journey towards your goals and dreams requires bravery. To remain on that path requires courage. The bridge that merges the two is commitment~
Dr. Steve Maraboli

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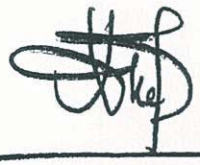
I certify that a Thesis Examination Committee has met on 29 November 2017 to conduct the final examination of Siti Noor Shuhada binti Rajihan on her thesis entitled "Impact of Land Conversion on Macrofungal Diversity in North Selangor Peat Swamp Forest in Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Mohamad Azani bin Alias, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Nur Ain Izzati binti Mohd Zainudin, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Mahmud Sudin, PhD
Associate Professor
Universiti Malaysia Sabah
Malaysia
(External Examiner)



NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 February 2018

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Sabiha Salim, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Badrul Azhar Md Sharif, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Member)

_____
ROBIAH BINTI YUNUS, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

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This is to confirm that:

- The research conducted and the writing of this thesis was under our supervision;
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Signature: _____
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LIST OF ABBREVIATIONS

ANOSIM	One-way Analysis of Similarities
ANOVA	Analysis of Variance
AOV	Angle of View
ECM	Ectomycorrhizal
GHG	Greenhouse Gas
IMCG	International Mire Conservation Group
MPOB	Malaysian Palm Oil Board
NSPSF	North Selangor Peat Swamp Forest
NMDS	Non-metric Multidimensional Scaling
PSF	Peat Swamp Forest
RSPO	Roundtable on Sustainable Palm Oil
SEPPSF	South-east Pahang Peat Swamp Forest
SIMPER	Similarity Percentages
TED	Technology, Entertainment and Design

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CHAPTER 1

INTRODUCTION

1.1 Background of study

North Selangor peat swamp forest (NSPSF) located at North Western part of Selangor is second largest remaining peat swamp forest after South-east Pahang peat swamp forest (SEPPSF). The area of NSPSF is about 73,593.05 ha and comprises 90% of total peat swamp forest in Selangor (Rengasamy et al., 2013). Tropical peat swamp forest ecosystem provides various ecosystem services, rich in endemic species of flora and fauna (Yule, 2010) and known well as global carbon stores (Posa, Wijedasa & Corlett, 2011). Nevertheless, comparing to other forested areas such as dipterocarp forest, mangrove and others, peat swamp forest is more sensitive to disturbance, especially anthropogenic activities and forest fire (Cole, Bhagwat & Willis, 2015; McGuire et al., 2015). In 2008, due to El-Nino phenomenon, 1,231 ha of NSPSF was reduced due to extensive forest fire (Yule & Gomez, 2008). This resulted in a large area of NSPSF being converted into profitable oil palm (*Elaeis guineensis*) plantation area since then.

The oil palm cultivation industry is expanding rapidly with Malaysia as one of the largest producer of palm oil that contribute more than 50% of the world's oil palm production (Sumathi, Chai & Mohamed, 2008). Due to increase demand for palm oil-based products, in 2015, the planted area of oil palm plantation in Malaysia has covered about 5.74 million ha (MPOB, 2016). Currently, large-scale plantations and smallholdings have surrounded at least 60% of the NSPSF perimeter and more land will be cleared to make way for the plantation, most of this oil palm plantation area extending across the continuous tract of forest including Raja Musa Forest Reserve, North Selangor (Azhar et al., 2011). This scenario might change the biodiversity of flora and fauna in peat ecosystem, including fungi. Documentation of their taxa might hold some significant importance towards understanding the biodiversity of organism found in natural forest and cultivation plantation.

Fungi represent the most biodiverse groups of organism in the earth and are one of the main biodiversity in various ecosystems. In regards to the plantation, fungi are recorded as powerful primary decomposers and plant-nutrient facilitator (mycorrhizae) in global forest ecosystem as well as an agricultural plantation. Fungi serve many important ecological roles, especially in litter decomposition, nutrient cycling, soil genesis and food source for anthropoids, small vertebrates, and others (Adekunle & Oluyode, 2005). However, the abundance and richness of fungi in a habitat is limited by their favourable conditions (Bader, Jansson & Jonsson, 1995; Paz, Gallon, Putzke & Ganade, 2015). Nevertheless, study on the biodiversity of macrofungi is still lacking, and data for macrofungal biodiversity are usually available from temperate countries (Winterhoff, 1992; Mueller et al., 2004; Berndt, 2012).

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By studying the morphological characteristics of macrofungi distributed at converted oil palm plantation from logged peat swamp forest, a baseline understanding of macrofungal biodiversity will be ascertained. Basic knowledge of plantation disease management will also be facilitated (Rungjindamai, Pinruan, Choeyklin, Hattori & Jones, 2008). This might improve agronomics of cultivated industry and fulfill fungal knowledge gap in Malaysia. Generally, to the best of my knowledge, this study is the first in Malaysia to obtain a comprehensive and complete understanding of macrofungal biodiversity in different landscapes covering the peat swamp forest area.

1.2 Problem statement

Conversion of peat swamp forest to oil palm plantation might change the ecology and present biodiversity of the forest community. Some revealed that the conversion of native forests to some tree monocultures reduced the macrofungal species (Hawksworth, 2001; Mueller & Schmit, 2007; Junninen & Komonen, 2011; Nordén, Penttilä, Siitonen, Tomppo & Ovaskainen, 2013; McGuire et al., 2015; Paz, Gallon, Putzke & Ganade, 2015).There are a number of studies done that investigate ecological impacts of oil palm expansion on biodiversity, but mostly limited to well-known taxa such as birds and insects (Koh & Wilcove, 2008; Brühl & Eltz, 2010; Edwards et al., 2010; Fayle et al., 2010; Azhar et al., 2011). Comprehensive and critical fungal oriented studies are however, still rare (Heilmann-Clausen et al., 2016). To date, no scientific study with empirical evidence on the effect of forest conversion to oil palm agriculture on macrofungal diversity has been reported. A few researchers reported on how the species richness and composition of fungi respond to different drivers such as forest management and tree species composition (Heilmann-Clausen et al., 2016; Dvořák et al., 2017). Nevertheless, this effort is far from being completed as exact understanding on landscapes requirement and environmental characteristics remained unclear (Heilmann-Clausen et al., 2016; Nurdiansyah, Denmead, Clough, Wiegand & Tscharntke, 2016).
In Malaysia, a proper documentation of macrofungal diversity with visible fruiting bodies in oil palm plantation could be the baseline to explore this knowledge gap. This is because fungi identification has always been difficult and full of uncertainties (Mueller et al., 2004). Field identification on macrofungi or fruiting body should be a better way in terms of accuracy and cost (Richard, Moreau, Selosse & Gardes, 2004; Schmit & Lodge, 2005; Brown, Bhagwat & Watkinson, 2006; Tóth & Barta, 2010; Paz, Gallon, Putzke & Ganade, 2015). A few researchers also suggest that more field fungal surveys are needed especially in tropical regions (Hawksworth, 2001, 2012; Brown, Bhagwat & Watkinson, 2006; Schmit & Mueller, 2007; Yamashita, Hattori, Lee & Okabe, 2015).

Therefore, the first hypothesis of this study is that macrofungal diversity from peat swamp forest is greater than oil palm plantation and smallholdings. Secondly, the substrate availability and vegetative structure such as canopy cover and canopy closure could contribute to the humidity and wind flow affecting biodiversity of macrofungi. Thirdly, microclimate, soil factors, vegetative structure and substrate availability could affect macrofungal diversity.

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1.3 Significance of study

Macrofungal role to the globe is very diverse, they are the main organism involved in forest ecosystem, agricultural plantation, food chain, pharmaceutical and others. Prior to their importance, records and documentation with empirical evidence on the macrofungal diversity and factors that influence them is necessary (Heilmann-Claussen et al., 2016). One of the knowledge gap in macrofungal studies is to understand the indicators which are fully related to the macrofungal composition. With that, efforts to provide valuable information of these fungal to the world will give benefits in many aspects.

Macrofungal are the key organism in maintaining the balance of forestry ecosystem. They provide important support towards forest health stability and resilience (Perry, Amaranthus, Borchers & Brainerd, 1989; Lin et al., 2015). This leads to suggestion that this fungi is available to be used as forest health indicators (Egli, 2011). By studying them, valuable information for forest conservation could therefore be provided and indirectly save present taxa from extinction before losing them. In addition, for future benefits, alternative for rehabilitation of degraded land in peat swamp forest can also be introduced for example inoculating macrofungal mycelium on degraded land to improve soil fertility.

For the oil palm agriculture industry, by understanding the vegetation structure, environmental factors and macrofungal characteristics inhabiting the forest, major problem such as *Ganoderma* infection occurring in the oil palm industry can be reduced through the suggestion of a proper oil palm plantation management. Type of vegetation and different types of ecological improvements in the plantations could be suggested based on macrofungal richness. Thus, the productivity of oil palm can be increased and improve Malaysia's agronomic of agricultural industry. This study is also another alternative to optimize the harvest of oil palm for our country's export and promotes green technology as recommended in the National Green Technology Policy (MATRADE, 2017).

1.4 Objectives

The primary purpose of this study is to investigate the effect of forest conversion area to oil palm agriculture plantation on macrofungal biodiversity. The specific objectives are as follows;

1. To quantify the macrofungal diversity of peat swamp forest, large-scale oil palm plantation (>50 ha; private business), monoculture and polyculture smallholdings (<50 ha; independent farmers).
2. To contrast substrate availability with macrofungal diversity between peat swamp forest, oil palm plantation, monoculture and polyculture smallholdings.
3. To examine the relationship between macrofungal diversity and independent variables (microclimate, soil factors, vegetative structure and substrate availability).

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