UNIVERSITI PUTRA MALAYSIA

CHANGES IN SOIL MICROBIAL POPULATION AND BIOCHEMICAL PROPERTIES OF UNDISTURBED AND DISTURBED SECONDARY FORESTS CONVERTED TO OIL PALM- CULTIVATED AREA IN BELAGA, SARAWAK, MALAYSIA

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FP 2019 41

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

December 2018

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

CHANGES IN SOIL MICROBIAL POPULATION AND BIOCHEMICAL PROPERTIES OF UNDISTURBED AND DISTURBED SECONDARY FORESTS CONVERTED TO OIL PALM- CULTIVATED AREA IN BELAGA, SARAWAK, MALAYSIA

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December 2018

Chairman : Professor Radziah Binti Othman, PhD
Faculty : Agriculture

Changes in microbial populations and biochemical activities can be affected by changes in the soil physical and chemical properties of soils. Assessment of the properties of soil in Belaga, Sarawak studies were conducted with the following objectives; i) to determine the populations of bacteria, actinomycetes, fungi and functional microbes (phosphate solubilizing bacteria and nitrogen-fixing bacteria) from secondary forests (BS1 and BS2) and oil palm cultivated areas in Belaga, Sarawak at different sampling periods, ii) to determine the changes in the biochemical , physico- chemical properties of soils in the three areas, iii) to determine the soil degradation indices in comparisons with secondary forests soil (BS1 and BS2) and oil palm cultivated areas and iv) to determine relationships between the changes in microbiological properties and the soil physico-chemical properties in secondary forests (BS1 and BS2) and oil palm cultivated areas. Samples of soils were obtained at 0-15 cm and ten replications were made in three different areas namely, undisturbed secondary forests (BS1), disturbed secondary forest (BS2) and oil palm cultivated area (OP) at three different sampling times (June 2012, January 2013, June 2013). A spread plate technique was used to determine the populations of microbes. Soil microbial biomass carbon (MBC), fluorescein diacetate assay (FDA) hydrolysis, β-glucosidase activity assay, urease activity assay, phosphatase activity assay, dehydrogenase assay were carried out to observed changes in biochemical properties of the soils. Results showed that microbial populations were significantly affected by location and time of sampling. Oil palm area showed the highest populations of bacteria (6.57 Log10 cfu g^{-1}) and fungi (5.57 Log10 cfu g^{-1}) in June 2013. Population of phosphate-solubilizing bacteria was consistently low in oil palm area compared to that in secondary forests (BS1 and BS2) in all sampling times. Oil palm area demonstrated consistently the lowest MBC in June 2012 and January 2013. The area also showed the lowest FDA (4.72 µg g^{-1}) in June 2012, whilst phosphatase (4265 ug pnp g $soil^{-1}$ hr^{-}) in January 2013. Most soil

properties responded to the different locations and were time dependent. There were strong effects of location, time and interactions of location and time in actinomycetes populations, MBC, moisture content and total C. Use of soil deterioration index showed that soils deteriorated severely (DI=-239.7 and -274.5) under oil palm cultivated area when compared to secondary forests (BS1 and BS2 respectively) and gradually recovered to positive values (DI= +16.6 and +4.9). This study indicated that oil palm cultivated area is resilience, where the soil has the ability to recover from perturbation. There were significant correlations amongst the soil properties indicating their interactions in sustaining the soil quality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk of Master of Science

PERUBAHAN DALAM POPULASI MIROB TANAH DAN CIRI-CIRI BIOKIMIA HUTAN SEKUNDER TERGANGGU DAN TIDAK TERGANGGU KEPADA PENUKARAN KAWASAN PENANAMAN KELAPA SAWIT DI BELAGA, SARAWAK, MALAYSIA

Oleh

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Perubahan dalam populasi mikrob dan aktiviti biokimia boleh terjejas disebabkan oleh perubahan ciri-ciri fizikal dan kimia tanah. Penilaian dan kajian ciri-ciri tanah di Belaga, Sarawak telah dijalankan dengan tujuan yang berikut: i)untuk menentukan populasi bakteria, aktinomisetes, kulat dan mikrob yang berfungsi (bakteria pelarut fosfat dan bakteria penukar nitrogen) dari hutan-hutan sekunder (BS1 dan BS2) dan kawasan penanaman kelapa sawit di Belaga, Sarawak dalam tempoh masa yang berbeza, ii)untuk menentukan perubahan dalam ciri-ciri biokimia, fizikal-kimia tanah di ketiga-tiga kawasan, iii)untuk menentukan indeks kerosakan tanah dengan perbandingan tanah di hutan-hutan sekunder dan iv)untuk menentukan hubungan di antara perubahan dalam ciri- ciri mikrob dan fizikal-kimia tanah di hutan-hutan sekunder (BS1 dan BS2) dan kawasan penanman kelapa sawit. Sampel tanah telah diambil dalam kedalaman 0-15 cm serta 10 replikasi dilakukan di tiga kawasan yang berlainan dinamakan; hutan sekunder tidak terganggu (BS1), hutan sekunder terganggu (BS2) dan kawasan penanaman kelapa sawit (OP) pada masa pengambilan sampel yang berbeza (Jun 2012, Januari 2013, Jun 2013). Kaedah sapuan petri telah dilakukan untuk menentukan populasi mikrob. Biojisim karbon mikrob (MBC), kaedah fluorescein diasetat (FDA) hydrolisis, aktiviti β-glukosida, aktiviti ureas, aktiviti fosfatas, aktiviti dehidrogenas telah dilakukan untuk melihat perubahan dalam ciri-ciri biokimia dalam tanah. Keputusan kajian menunjukkan populasi mikrob secara signifikan terjejas dengan perbezaan kawasan dan masa. Kawasan kelapa sawit menunjukkan populasi bakteria (6.57 Log10 cfu g^{-1}) and kulat (5.57 Log10 cfu g^{-1}) tertinggi pada Jun 2013. Populasi bakteria pelarut fosfat secara konsisten rendah di kawasan kelapa sawit dibandingkan dengan hutan-hutan sekunder. Kawasan kelapa sawit menunjukkan nilai yang rendah secara konsisten untuk MBC pada Jun 2012 dan Januari 2013. Kawasan kelapa sawit juga menunjukkan nilai yang rendah menerusi enzim FDA (4.72 µg g^{-1}) pada Jun 2012, manakala fosfatas (4265 ug pnp g $soil^{-1}$ hr^{-}) pada Januari 2013. Sebahagian besar ciri-

ciri tanah menunjukkan respon dengan lokasi yang berbeza dan ciri-ciri tersebut bergantung kepada masa. Terdapat kesan yang nyata pada lokasi, masa dan hubungkait lokasi dan masa bagi populasi aktinomisetes, MBC, kandungan kelembapan dan jumlah karbon. Penggunaan indeks kerosakan tanah telah menunjukkan kerosakan tanah yang sangat teruk (DI=-239.7 dan -274.5) di kawasan penanaman kelapa sawit berbanding dengan hutan-hutan sekunder (BS1 dan BS2), namun beransur pulih kepada nilai yang lebih positif (DI= +16.6 dan +4.9). Kajian ini menunjukkan bahawa kawasan penanaman kelapa sawit mempunyai ciri berdaya tahan di mana, tanah tersebut mempunyai kebolehan untuk pulih dari kerosakan. Terdapat korelasi yang signifikan di antara ciri-ciri tanah membuktikan bahawa terdapat hubungkait dalam pengekalan kualiti tanah.

ACKNOWLEDGEMENTS

This is the section which I was looking forward to write in the whole thesis. Alhamdulillah all praise to Allah, although life has its challenges, He is the one who make it happen. Finally, this has come to an end.The journey of finalizing this thesis is not paved in a single day, weeks or even years. Therefore I would like to thank so many people in taking their part in this sweet farewell of my master journey. First and foremost, I would like to thank my parents for their never ending support for the path that I chose to take. Thank you ayah, for driving me to school and fetch me up late at night. Thank you ibu who always pamper me like a little girl. I am thankful for so many things in my life, but mostly without my parents, I'd have nothing else to be thankful for. This thesis is certainly dedicated for you guys.

I also would like to thank my dearest brothers and sisters, who in their way support and pray for my wellbeing. Thank you so much helping me throughout my days as a student. Special thanks to Kak Ngah, for her time and effort in proofreading this thesis without any fees. To my dearest KakLong, for her some pocket money you spend on your broke sister. To my brothers, Abg Chik and Ami who willing to drive me to school back and forth. May Allah bless you all. Thank you for my babies, Husni, Aqeel, Khayla, Umar, Saufee, Iman, and Amir for bright up my sorrow days with all your silliness. Makteh really love you guys. I also would like to say thank you to my supervisor Professor Radziah who has supported me in terms of ideas in correcting this thesis and of course financially to make all the analysis possible in this study. Thank you for every opportunity you have given to me to attends all the conferences and publishing my paper. Although, I was not a bright student of yours, you never failed to encourage me to finish this study. Thank you so much for all the efforts you did to all the way up till now.

Last but never least, thank you my dear friends Kak dayah, Jah, Ain, Kak Ayu, Mimi, Kakwa, Za, Laily, Amin and Fami. I thought our relationship was remained as labmates no more or less. But you guys has become a part of my life (by the duration we took to finish the studies) where we witnessed each other's sadness and happiness. The room that filled all the laughter has now being occupied by new people. When one by one person left that room, it was a bit gloomy without all your presence. Thank you for becoming my second supervisor as well as, unauthorized all-rounded advisors. Compared to my degree days, masters days really teaches us independency and appreciation to scientific study. To that, I will always treasure this moments in my entire life. Without these fellow friends, I think my days in UPM will be all dark and plain, thank you for light up my days guys!

At times, I was regret of this path that I took. Somehow, I believe there would be reasons behinds all these to happen. Maybe the silver lining was for me to found an amazing guy named Nizam. I deliberately leave this last paragraph just for you, just to tell you how much you mean to me. Thank you for all your assistance. We made it bro!

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

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LIST OF ABBREVIATIONS

CEC	Cation Exchange Capacity
Cfu	Colony forming unit
CRD	Completely Randomized Design
DI	Deterioration index
NA	Nutrient Agar
NBRIP	National Botanical Research Institute's phosphate
PSB	Phosphate-solubilizing bacteria
SAS	Statistical Analysis System
%	Percent
°C	Celcius
$CaCO_3$	Calcium carbonate
CEC	Cation exchange capacity
cm	Centimetre
g	Gram
Kg	Kilogram
mg/L	Miligram per litre
mL	Mililiter
mM	Mili molar
TC	Total Carbon
uL	Micro litre
uM	Micro molar

CHAPTER 1

INTRODUCTION

The expansion of oil palm plantations in the past few decades has been subject to significant criticism due to deforestation, increase in greenhouse gasses (GHG) emissions and loss of biodiversity (Khatiwada *et al.,* 2018). Such concerns are particularly focused in Sabah and Sarawak where, 4.2 million hectares of old-growth has been deforested over the last four decades between 1973- 2015 (Gaveau *et al.,* 2016). Deforestation precipitate a loss of above-ground biomass which also would lead to a decreased of carbon stocks (Guillaume *et al.,* 2016). Moreover, peatland conversion to oil palm plantation is the main cause of GHG emitted in the atmosphere (Ramdani & Hino, 2013). Oil palm expansion also has played significant role in extinction of telecoprid species (dung-rollers) (Edwards *et al.,* 2014) and major reduction of imperiled bird species (Edwards *et al.,* 2010).

Malaysia and Indonesia emerged as major producers of palm oil in Southeast Asia (Tripathi *et al.,* 2012). Currently, oil palm planted area accounts for 5.81 million hectares or 17.7 % of the total 32.86 million hectares of land area of Malaysia (MPOB, 2018). However, oil palm is largely grown on highly weathered tropical soil with low fertility. Therefore, to ensure its productivity in such condition, an external input like fertilizer is essentials. Besides, to combat and protect the plantation from any harm from diseases, the usage of pesticide is also involved. However, the application of pesticide and fertilizer in agriculture has been identified to greatly influence on soil biota, their activities and diversity (Masirah *et al.,* 2013).

Soil physical, chemical, biological and biochemical properties are considerably critical, since they are closely related to various functional processes of soil (Lu, *et al.,* 2013). Soil microbial properties can be illustrated to display a sensitive indicator in which they provide a useful insights into rapid towards short–term changes of land use (Moeskops *et al.,* 2010). It has been shown that changes in the microbial community composition of soils can be brought either by abusive or improved management practices. Study made by several authors, regards that, oil palm cultivation in Borneo majorly causes extinction of ectomycorrhizal fungal communities (McGuire *et al.,* 2015). However on other circumstances, oil palm promotes more diversity for most bacteria when compared to forest soil (Lee-Cruz *et al.,* 2013; Tripathi *et al.,* 2012). The effects of forest conversion to oil palm plantation describing the changes of microbial population and biochemical properties together with soil physico-chemical properties are less discovered in Sarawak since the evaluation of soil quality which comprises of those soil attributes can be regarded as a useful tool to assess the effect of soil management (Allen *et al.,* 2011).

Consequences of agriculture practices gave profound impact on physical and chemical properties of soil which cause irreversible effects on soil biological communities and their functions, such as Total C and N and total microbial biomass

were all reduced (Islam & Weil, 2000). Soil quality is more likely to decline following the differences of land use such as forest conversion to plantation (Dawoe *et al.,* 2013; Firdaus *et al.,* 2010; Lee-Cruz *et al.,* 2013; Meng *et al.,* 2013). Contrary to these findings, other reports have also emphasized that soil quality remain approximately perpetual during most land conversion practices in the tropics (Wang *et al.,* 2012). These results indicates that soil quality can be maintained despite of plantation management, although the change of land use in a relatively short period of time is also expected to have a significant impact to soil properties. Due to inconsistent result and knowledge scarcity on the effects of plantation management and agricultural practices on soil properties particularly in oil palm plantation thus, it is necessary to understand the changes of soil microbial population, biochemical and physico-chemical properties of in secondary forests and oil palm cultivated area.

The objectives of the study were as below:

1. To determine the populations of bacteria, actinomycetes, fungi and functional microbes (phosphate-solubilizing bacteria and N-fixing bacteria) from secondary forests and oil palm cultivated areas in Belaga, Sarawak at different sampling periods.
2. To determine the changes in the biochemical, chemical and physical properties of soils in the three areas.
3. To determine the soil degradation indices in comparisons with secondary forests soil and oil palm cultivated areas.
4. To determine relationships between the changes in microbiological properties and the soil physical and chemical properties in secondary forests and oil palm cultivated areas.

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Conferences:

Nur Hanani, M.N., Radziah, O., and Roslan, I. Changes of enzymatic properties in different land use in Belaga, Sarawak. *International Conference on Crop Improvement 2015 (ICCCI2015).* Serdang, UPM.

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