UNIVERSITI PUTRA MALAYSIA

EFFECTS OF OIL PALM PLANTATION DEVELOPMENT ON PEAT PHYSICAL PROPERTIES OF SECONDARY PEAT SWAMP FOREST IN IGAN, SARAWAK, MALAYSIA

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FSPM 2012 1

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By

MOHD SUFFIAN BIN FIRDAUS

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

January 2012

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

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January 2012

Chairman: Seca Gandaseca, PhD

Faculty: Faculty of Agriculture and Food Sciences (Bintulu)

There are several activities related to oil palm plantation development on peat land such as drainage, land clearing, biomass management, earthworks and planting. These activities inevitably change the physical properties of the peat soil and lead to the changes on other soil properties which are contributing to peat land degradation. Therefore, it is important to investigate the degradation severity of secondary peat swamp forest caused by the conversion to oil palm plantation in terms of its peat soil physical properties. This study was conducted in a drained secondary peat swamp forest (DSPSF) at Igan, Sibu, Sarawak, Malaysia. Soil sampling and data collection were done in 300 m^2 experimental plots of drained secondary peat swamp forest and cleared site of the DSPSF, young oil palm plantation (YOPP) and mature oil palm plantation (MOPP). In each site, thirty random data points were used to measure saturated hydraulic conductivity, soil bearing capacity and surface soil temperature. Thirty undisturbed cores and bulk samples

were also collected randomly for laboratory analysis of bulk density, specific gravity, gravimetric and volumetric water content, fiber content, loss on ignition, ash content, liquid limit and total porosity. After the draining, land clearing was done to remove the remaining vegetation before the peat land will be prepared for oil palm planting process. Therefore, the first part of this study was to determine the effect of land clearing on the selected peat soil physical properties of the DSPSF. Drainage in the secondary peat swamp forest decreased the fibre content, gravimetric water content, loss on ignition, total porosity and surface soil temperature. After the land clearing, gravimetric water content, liquid limit and total porosity continued to decrease, while surface soil temperature increased as well as ash content, bulk density and bearing capacity. However, fiber content, volumetric water content, specific gravity and saturated hydraulic conductivity in the DSPSF were not affected. Climate could influences the changes of peat soil physical properties and it related to the disturbance occurred on the peat land. Therefore, the second part of the study was to determine whether local climate influences peat soil physical property changes in the DSPSF and cleared site of the DSPSF. In this study, soil sampling and data collection were done under humid and dry season of the local climate. In DSPSF, volumetric water content, ash content and bulk density were significantly higher under the dry season while loss on ignition and total porosity were significantly higher under the humid season. The other properties were statistically similar between the two seasons. In the cleared site of DSFSF, bulk density was significantly higher under the dry season while gravimetric water content and total porosity were significantly higher in the humid

season. The other properties were statistically similar between the two seasons. After clearing the DSPSF, the land preparation for oil palm planting and fertilizer application will continuously change the peat soil physical properties. Therefore, the third part of the study was to compare the peat soil physical properties of DSPSF and YOPP. Two years after oil palms planting have continuously increased surface soil temperature, bulk density, ash content and bearing capacity as well as continuously decreased loss on ignition, liquid limit, total porosity and saturated hydraulic conductivity. However, fiber content (degree of decomposition), gravimetric and volumetric water content and specific gravity were not affected. The effect of the conversion on peat soil physical properties probably prolonged after the oil palm plantation establishment. Therefore, the last part of this study was to compare selected peat soil physical properties of YOPP and MOPP. Peat soil decomposition was continued after the oil palm plantation has been established. The decomposition process was enhanced by the lower water table and increase of mineral content (ash content) in YOPP. Increase of degree of decomposition of peat soil and higher fertilization rate in the MOPP caused continuous increase of bulk density and ash content as well as continuous reduction of fiber content, loss on ignition, total porosity and liquid limit. However, high water table in the MOPP has reduced the bearing capacity and restored the water content in the peat soil. For the conclusion, developing oil palm plantation on secondary peat swamp forest increased the decomposition rate of peat soil which caused increase of degree of decomposition and volumetric water content, reduction of loss on ignition and liquid limit as well as increase of ash content due to the increase rate of

mineralization and fertilizer application. The soil compaction and the reduction of organic matter content caused by the development also increased the bulk density and reduced the total porosity. Gravimetric water content, surface temperature and bearing capacity were increased after the land clearing but then decreased after the plantation was established and the effects were more influenced by the environment factors. Effect of the development on saturated hydraulic conductivity was hardly to determine due to the presence of partially decomposed residues in the peat soil. The changes occurred on the selected peat soil physical properties indicated that the peat soil was undergoing a process of degradation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN-KESAN PEMBANGUNAN LADANG KELAPA SAWIT KE ATAS SIFAT-SIFAT FIZIKAL GAMBUT DALAM HUTAN PAYA GAMBUT SEKUNDER DI IGAN, SARAWAK, MALAYSIA

Oleh

MOHD SUFFIAN BIN FIRDAUS

Januari 2012

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Terdapat beberapa aktiviti yang berkaitan dengan pembangunan ladang kelapa sawit di atas tanah gambut seperti penyaliran, pembersihan kawasan, pengurusan sisa pokok, penyediaan tanah dan penanaman. Aktiviti-aktiviti ini menyebabkan perubahan kepada sifat-sifat fizikal tanah gambut yang menyebabkan perubahan sifat-sifat tanah yang lain ke arah degradasi tanah gambut. Oleh itu, kajian terhadap keseriusan degradasi tanah gambut dari segi sifat-sifat fizikalnya disebabkan oleh pembangunan ladang kelapa sawit adalah penting. Kajian ini telah dijalankan di dalam hutan paya gambut sekunder yang telah dikeringkan di Igan, Sibu, Sarawak, Malaysia. Pengambilan sampel tanah dan data dilakukan di dalam plot-plot eksperimen bersaiz 300 m^2 pada kawasan hutan paya gambut sekunder yang telah dikering, kawasan hutan paya gambut sekunder yang telah dikering dan dibersihkan, ladang kelapa sawit muda dan ladang kelapa sawit matang. Dalam setiap kawasan, tiga puluh data rawak telah dipilih bagi pengukuran

konduktiviti hidraulik tepu, bearing kapasiti tanah dan suhu permukaan tanah. Tiga puluh teras tanah yang tidak terganggu dan sampel pukal tanah gambut juga telah diambil secara rawak untuk analisis ketumpatan pukal, graviti spesifik, berat dan isipadu kandungan air, kandungan fiber, kehilangan atas nyalaan, kandungan abu, had cecair dan jumlah keliangan. Selepas penyaliran, pembersihan kawasan telah dilakukan bagi mengalihkan sisa tumbuhan sebelum kawasan tanah gambut disediakan untuk penanaman kelapa sawit. Oleh itu, bahagian pertama kajian ini adalah untuk menentukan kesan pembersihan kawasan ke atas sifat-sifat fizikal terpilih tanah gambut dalam hutan paya gambut sekunder yang telah dikeringkan. Penyaliran telah mengurangkan kandungan fiber, berat kandungan air, kehilangan atas nyalaan, jumlah keliangan dan suhu permukaan tanah. Selepas pembersihan kawasan, berat kandungan air, had cecair, jumlah keliangan semakin berkurangan, manakala suhu permukaan tanah, kandungan abu, ketumpatan pukal dan bearing kapasiti meningkat. Walaubagaimanapun, kandungan fiber, isipadu kandungan air, graviti spesifik dan konduktiviti hidraulik tepu tidak terjejas. Iklim mempengaruhi perubahan sifat-sifat fizikal tanah gambut dan ia berkaitan dengan gangguan yang telah berlaku terhadap kawasan tanah gambut. Oleh itu, bahagian kedua kajian ini adalah menentukan samada iklim tempatan mempengaruhi perubahan sifat-sifat fizikal terpilih tanah gambut di dalam kawasan hutan paya gambut sekunder yang telah dikeringkan dan kawasan hutan paya gambut yang telah dikering dan dibersihkan. Dalam kajian ini, pengambilan sampel tanah dan data dilakukan pada musim lembab dan musim kering. Di dalam hutan paya gambut sekunder yang telah dikeringkan, isipadu kandungan air, kandungan abu dan

ketumpatan pukal lebih tinggi pada musim kering manakala kehilangan atas nyalaan dan jumlah keliangan lebih tinggi pada musim lembab. Sifat-sifat fizikal terpilih yang lain adalah sama antara dua musim tersebut. Di dalam kawasan hutan paya gambut sekunder yang telah dikering dan dibersihkan, ketumpatan pukal lebih tinggi pada musim kering manakala berat kandungan air dan jumlah keliangan lebih tinggi pada musim lembab. Sifat-sifat fizikal terpilih yang lain adalah sama antara musim lembab dan kering. Selepas pembersihan kawasan, penyediaan kawasan bagi penanaman kelapa sawit dan aplikasi pembajaan akan berterusan mengubah sifat-sifat fizikal tanah gambut. Oleh itu, bahagian ketiga kajian ini adalah membandingkan sifat-sifat fizikal terpilih tanah gambut antara kawasan hutan paya gambut yang telah dikeringkan dan ladang kelapa sawit muda. Dua tahun selepas penanaman kelapa sawit berterusan meningkatkan suhu permukaan tanah gambut, ketumpatan pukal, kandungan abu dan bearing kapasiti dan juga berterusan mengurangkan kehilangan atas nyalaan, had cecair, jumlah keliangan dan konduktiviti hidraulik tepu. Namun, kandungan fiber (darjah penguraian), berat dan isipadu kandungan air serta graviti spesifik tidak terjejas. Kesan penukaran hutan terhadap sifat-sifat fizikal tanah gambut mungkin berpanjangan selepas ladang kelapa sawit dibuka. Oleh itu, bahagian terakhir kajian ini adalah untuk membandingkan sifat-sifat fizikal terpilih tanah gambut antara ladang kelapa sawit muda dan ladang kelapa sawit matang. Penguraian tanah gambut berterusan selepas pembukaan ladang kelapa sawit. Proses penguraian itu dibantu oleh aras air bawah tanah yang rendah dan peningkatan kandungan mineral tanah (kandungan abu) dalam ladang kelapa sawit muda. Peningkatan darjah penguraian dan

kadar pembajaan yang lebih tinggi di dalam ladang kelapa sawit matang telah menyebabkan peningkatan ketumpatan pukal dan kandungan abu serta pengurangan kandungan fiber, kehilangan atas nyalaan, jumlah keliangan dan had cecair secara berterusan. Namun, aras air bawah tanah yang tinggi di dalam ladang kelapa sawit matang telah mengurangkan bearing kapasiti dan mengembalikan kandungan air dalam tanah gambut. Kesimpulannya, pembangunan ladang kelapa sawit di hutan paya gambut sekunder telah meningkatkan kadar penguraian tanah gambut yang telah meningkatkan tahap penguraian dan isipadu kandungan air, pengurangan kehilangan atas nyalaan dan had cecair serta peningkatan kandungan abu disebabkan oleh peningkatan kadar mineralisasi dan penggunaan baja. Pemampatan tanah dan pengurangan kandungan bahan organik yang disebabkan oleh pembangunan ladang kelapa sawit juga telah meningkatkan ketumpatan pukal tanah dan mengurangkan jumlah keliangan. Berat kandungan air, suhu permukaan dan bearing kapasiti telah meningkat selepas proses pembersihan kawasan tetapi telah berkurang selepas ladang kelapa sawit itu dibangunkan dan kesan-kesan tersebut lebih dipengaruhi oleh faktor-faktor persekitaran. Kesan pembangunan ladang kelapa sawit ke atas konduktiviti hidraulik tepu adalah sukar untuk ditentukan disebabkan oleh kehadiran sisa-sisa separa reput di dalam tanah gambut. Perubahan-perubahan yang telah berlaku ke atas sifat-sifat fizikal tanah gambut yang terpilih menunjukka bahawa tanah gambut tersebut sedang mengalami proses degradasi.

ACKNOWLEDGEMENTS

I am deeply indebted to my supervisor Dr. Seca Gandaseca and my co-supervisor, Associate Prof. Dr. Ahmed Osumanu Haruna, for their patience and guidance in helping me to complete this thesis.

I would like to express my gratitude to all family members especially my beloved mother, Puan Rodiyah, my brother, Mohd Redhuan and my little brother and sister, Mohd Hisyam and Aimi Fathiha and my loved one, Nurul 'Ain.

Not to forget, my appreciation to all my friends especially Mohd Rakib, Mohammad Ismawi, Mohd Syukri, Mohd Arif Syaffiq, Muhamad Fuad, Fakhruldin, Regis, Chandra and to the staffs of Universiti Putra Malaysia, Bintulu Campus for their assistance and support throughout my study.

I certify that a Thesis Examination Committee has met on 20th January 2012 to conduct the final examination of Mohd Suffian bin Firdaus on his Master of Science thesis entitled **"Effect of Oil Palm Plantation Development on Some Peat Soil Physical Properties of Secondary Peat Swamp Forest in Igan, Sarawak"** 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 Examination Committee were as follows:

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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 the Supervisory Committee were as follows:

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Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MOHD SUFFIAN BIN FIRDAUS

Date:

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LIST OF ABBREVIATIONS

DSPSF	Drained secondary peat swamp forest
CL	Cleared site of drained secondary peat swamp forest
YOPP	Young oil palm plantation
MOPP	Mature oil palm plantation
UNDP	United Nation Development Programme
ESCAP	Economic and Social Commission for Asia and the Pacific
ASTM	American Society for Testing and Materials,
GLOBE	Global Learning and Observation to Benefit the Environment
LOI	Loss on ignition
ASH	Ash content
FC	Fiber content
BD	Bulk density
SG	Specific gravity
GWC	Gravimetric water content
VWC	Volumetric water content
Temp.	Surface soil temperature
BC	Bearing capacity
SHC	Saturated hydraulic conductivity
TP	Total porosity
LL	Liquid limit

CHAPTER 1

INTRODUCTION

1.1 Background

There is general confusion on the exact definition of peat and peat soil as the distinction between soil and vegetative accumulation is not clear (Makilan *et al*., 2009). Peat can be defined as organic matter composed from vegetation with 25 percent or less inorganic matter on a dry mass basis and consists of more or less fragmented plant residues deposited (Andrejko *et al*., 1983). In older soil classification system, peat soil can be defined as soil having more than 65 percent of organic matter (Andriesse, 1988). However, the soil division of Sarawak, Malaysia was adopting with more recent definition which is based on soil partition which has defined peat soil as soil that has 50 cm or more organic matter within 100 cm or more than twice that of mineral soil materials overlying bedrock within 50 cm (Muniandy *et al*., 2009).

Peat swamp forest or forested peat land is a waterlogged forest growing on dead leaves and plant materials up to 20 m thick (UNDP, 2006). It is a wetland area that is characterized by the accumulation of organic matter which is produced and deposited at a greater rate than it is decomposed and leading to the formation of peat (Paavilainen & Paivanen, 1995). An estimated of 1.54 million hectares of peat swamp forests are still remaining in Malaysia with more than 70 percent are in Sarawak, less than 20 percent in Peninsular Malaysia and the remaining are in Sabah (UNDP, 2006).

Nowadays, the total area of peat swamp forest in Malaysia is steadily decreasing as well as in Sarawak state. Estimated of 98.53 percent of the peat swamp forests in Sarawak are actually have been disturbed (Wong, 2002). The most significant disturbances are excessive logging and timber harvesting due to its importance as the main sources of timber (Satrio *et al*., 2009).

Peat swamp forest as present in Sarawak is the presence of submerged of least decomposed woods, stumps and logs. The ground water table is very high, bulk density is about 0.05 g cm^{-3} in fibric and total porosity is ranging from 80 to 90 percent resulting in high soil permeability. The soil organic matter content is about 97 percent and ash content is about 3 percent (Satrio *et al*., 2009). The high organic matter content and low ash content indicate the loss on ignition value exceeding 90 percent (Islam & Hashim, 2008a, b). The soil temperature is about 22.8 ^{o}C which is lower than air temperature (Ludang *et al*., 2007) to restrict microbial decomposition activity (Saha, 2004). The bearing capacity of the peat soil is about 7.68 kPa if the water table is at the surface (Murtedza *et al*., 2002). The moisture content is ranging from 200 percent to 700 percent (Hashim & Islam, 2008) and the value of saturated hydraulic conductivity is about 10^{-5} to 10^{-4} ms^{-1} (Huat *et al*., 2011). The generally high value of saturated hydraulic conductivity is due to its open structure (Murtedza *et al.*, 2002).

Secondary forest is a forest that has been disturbed in some way whether naturally or unnaturally (Butler, 2006). Most of peat swamp forests in

Sarawak have been disturbed by logging and timber harvesting which have turning them into secondary forest (Satrio *et al*., 2009). The logging and timber harvesting activities are inevitably caused environmental destruction especially on sensitive forest site with peat soil such as peat swamp forest (Nugent *et al*., 2003). The activities have caused physical and chemical changes in the peat soil of the secondary peat swamp forest (Firdaus *et al*., 2010). However, restoration of self regulating peat swamp forest was still possible after recovery of the recently changed hydrology due to logging and timber harvesting activities (Schumann & Joosten, 2008).

The utilization of peat swamp forest was usually continued with agriculture development after the logging and timber harvesting activities. As the proof, there are approximately 554,775 hectares of peat land under cultivation in the state of Sarawak and the most important crop at present is oil palm (Jaya, 2002). Steadily increasing demand of crude palm oil has made an opportunity for develop countries to involve in the palm oil industry for economic improvement. Nowadays, as one of the world's largest producer of palm oil, Malaysia has opened more than 3 million hectares of lands for oil palm cultivation with 13% (1.67 million hectares) were in Sarawak at the close of 2003 (Butler, 2006). Oil palm plantation development can be defined as opening up of land areas for the purpose of cultivating oil palm and carrying out other related activities such as draining (if in swamp area), land clearing, biomass management and disposal, earthworks, planting and replanting activities (Moduying *et al*., 2000).

Drainage in peat swamp forest has caused major changes on the peat soil physical properties (Kechavarsi *et al*., 2009). Hydrological characteristics of peat soil are highly related to drainage and several peat soil physical properties such as degree of decomposition and soil bulk density (Othman *et al*., 2010). Land clearing is required to develop new vegetation area for agricultural production (Eneji *et al*., 2003). Land clearing was inevitably disturbed the soil surface and the biomass remained were removed and gathered into non-cultivated strip (Moduying *et al*., 2000). This process involves tree felling assisted by heavy machinery which could affect the soil physical properties (Jaya, 2002).

Several earthwork activities are required before the planting process due to the low soil bulk density and bearing capacity of peat land. Drainage system and soil compaction using heavy machinery are aimed to compact the soil mechanically and improve the anchorage for oil palm. A field can only be considered ready for oil palm planting after all drains have been installed and planting paths as well as planting circles have been cleared and compacted (Mutert *et al*., 1999).

Physical deterioration, soil compaction, nutrient and biological degradation may become prominent within a few days after land clearing (Eneji *et al*., 2003). This might have indicated that the soil physical properties will be affected immediately after the land clearing. Furthermore, the changes on soil physical properties can probably lead changes on other soil properties such as chemical, carbon storage and biological properties.

Plenteous of researchers have reported that the conversion of peat land area into agricultural area causes major changes on peat soil physical properties. Draining, land clearing, fertilizing and cultivating are the most common and important processes that involve in the conversion of peat land area into agricultural areas which are inevitably affect the peat soil physical properties. Thus, the hypothesis of the study is the development of oil palm plantation on secondary peat swamp forest may affect the peat soil physical properties which can contribute to peat land degradation.

Policy on Environment seriously emphasizes that nature and natural resources should be preserved and land rich in natural diversity should be maintained (Dixon, 2008). In order to achieve an adequate demand of food supply and better economic level, there should be an effective way to manage and preserve the natural resources to prevent environment degradation. The knowledge on the physical properties of the peat soil affected by oil palm plantation development may be helpful to develop useful resources management plan for peat land areas as well as provides option for mitigation to overcome the any negative effects.

The effects of oil palm plantation development on selected peat soil physical properties of peat swamp forest were presented in some operational questions which cover the important issues and approaches planned to addressing the answers:

1. What are the effects of drainage and land clearing in secondary peat swamp forest on selected peat soil physical properties?

   Approach: Selected peat soil physical properties in drained secondary peat swamp forest and cleared site of drained secondary peat swamp forest were determined and compared together with the previous study of the study site.

2. Is the local climate influences the changes of the selected peat soil physical properties in the drained secondary peat swamp forest and the cleared site of the drained secondary peat swamp forest?

   Approach: Selected peat soil physical properties under two different season of the local climate were determined and compared separately in drained secondary peat swamp forest and cleared site of the drained secondary peat swamp forest.

3. What are the general effects of converting the drained secondary peat swamp forest into young oil palm plantation on selected peat soil physical properties?

   Approach: The selected peat soil physical properties in young oil palm plantation was determined and compared with the drained secondary peat swamp forest

4. Are the effects on peat soil physical properties continue after the oil palm plantation has been established?

   Approach: The selected peat soil physical properties of young oil palm plantation (2 years) and mature oil palm plantation (10 years) were determined and compared.

1.2 Objectives

The objectives of the study were as follows:

1. To determine the effect of drainage and land clearing on selected peat soil physical properties of drained secondary peat swamp forest.

2. To compare the effect of humid and dry seasons of the local climate on the selected peat soil physical properties in drained secondary peat swamp forest and cleared site of the drained secondary peat swamp forest.

3. To determine the effect of converting drained secondary peat swamp forest into young oil palm plantation on the selected peat soil physical properties.

4. To determine the changes on selected peat soil physical properties after the oil palm has been established.

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LIST OF PUBLICATIONS

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