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EFFECTS OF CONVERTING SECOND TROPICAL PEAT SWAMP FOREST INTO OIL PALM PLANTATION ON SOIL CHEMICAL PROPERTIES IN SIBU, SARAWAK, MALAYSIA

MUHAMAD ISMAWI BIN SALIMIN

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By

MUHAMAD ISMAWI BIN SALIMIN

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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Malaysia is among the largest oil palm producer in the world. High demand of palm oil industry, lead to the land clearing for oil palm plantations. However, excessive land clearing destroys fragile ecosystem of unique flora and fauna biodiversity especially peat swamp forests. In general, various activities involved when peat swamp forest cleared into oil palm plantation e.g., timber harvesting, drainage, land clearing, biomass, waste management, earthworks, planting and replanting. These activities affect chemical properties of soil, which can't be avoided during conversion. To understand those chemical changes, a study was carried out to determine the effect of converting secondary tropical peat swamp forest (TPSF) into oil palm plantation on selected soil chemical properties. This study was conducted in secondary TPSF in Sibu, Sarawak, Malaysia. The soil samples were taken in 3000 m^2 of experimental plot which were set up in secondary TPSF before and after timber harvesting, secondary TPSF has been drained and cleared land, two and three years old of young oil palm plantation (YOPP) and mature oil palm plantation (MOPP). The peat soils were sampled randomly using a peat auger at standard depth (0 cm to 15 cm) and labelled. A total of 48 samples for each site were taken at each corner and the middle of a plot. Samples were then air-dried at room temperature, homogenized and sieved for further analysis. Soils chemical properties i.e., soil acidity, cation exchange capacity (CEC), soil organic matter (SOM), total carbon, total nitrogen, total phosphorus, total potassium and exchangeable potassium

(K) were determined using standard laboratory procedures. The alterations of secondary TPSF to agriculture begin with logging activities. Therefore, the first part of this study was to determine the comparison of selected chemical properties of peat swamp soil before and after timber harvesting. Throughout this study, it showed there were significant difference on selected soil chemical properties before and after logging e.g., soil pH H_2O, CEC, SOM, total carbon, total nitrogen, total phosphorus and exchangeable K. Soil pH KCl and C:N ratio showed there were no significant changes. During the land clearing, soil nutrients and chemical properties changes as land converted into agriculture or for urbanization. Therefore, the second part of the study was to determine the effect of land clearing on selected soil major macro-nutrient and other selected chemical property of secondary TPSF. This study showed there were significant difference of soil chemical properties such as decreasing of soil pH H_2O, CEC, SOM, total carbon, total nitrogen, total phosphorus, total potassium and C:N ratio. However, there were increases in soil pH KCl and C:P ratio. After clearing land of the secondary TPSF, peat soil chemical properties continue to change as land preparation and application of fertilizer activities for oil palm planting. Therefore, the third part of the study was to determine the effect of cultivation at different age's oil palm plantation on selected chemical properties. This study, showed there were no significant different in CEC, total carbon and SOM. Otherwise for soil pH showed significantly difference from each other by YOPP (three years) the lowest and MOPP the highest. In total N, YOPP (three years) showed significantly the highest, followed by MOPP and YOPP (two years) was the lowest. While for total phosphorus, both YOPP (two years) and MOPP share significant higher compare to YOPP (three years). Total potassium, MOPP showed significantly highest compared to both YOPP. For C:N and C:P ratio there were mixed significant different by YOPP (two years) was the highest in C:N ratio and YOPP (three years) highest in C:P ratio. For conclusion, the chemical properties of peat soil reacted to the changes that occur during land clearing, drainage, and planting process as peat soil undergoing a degradation process. Beside the negative impact of timber harvesting operation to secondary TPSF soil, there were also several positive impacts on harvesting operation in terms of nutrients such as increasing of total nitrogen, total phosphorus and available potassium in peat swamps forest soil. The common effect of logging and land clearing in the peat soil are lost of carbon storage to the atmosphere and changing in soil chemical properties, removal of plants that responsible in maintaining the balance of the carbon cycle in peat soil. Consequently, alteration of secondary TPSF for agriculture purpose was one of the causes in increasing the earth temperature and global warming. Conversion into oil palm plantation has disturb the chemical properties of peat soil e.g., application of lime and fertilizer especially NPK fertilizer. For recommendation, changes of peat soil chemical properties should be also observed with soil physical properties and good management of land clearing should minimize the degradation of peat soil.

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

KESAN PEMBANGUNAN HUTAN TROPIKA PAYA GAMBUT SEKUNDER KEPADA LADANG KELAPA SAWIT KE ATAS SIFAT-SIFAT KIMIA TANAH TERPILIH DI SIBU, SARAWAK, MALAYSIA

Oleh

MUHAMAD ISMAWI BIN SALIMIN

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Malaysia adalah antara pengeluar minyak sawit terbesar di dunia. Permintaan yang tinggi terhadap industri minyak sawit, membawa kepada pembukaan tanah untuk penanaman kelapa sawit. Walau bagaimanapun, pembukaan hutan yang berlebihan memusnahkan kepelbagaian bio ekosistem unik flora dan fauna terutamanya di hutan paya gambut. Secara umumnya, pelbagai aktiviti terlibat apabila hutan paya gambut dibuka kepada ladang kelapa sawit misalnya, pembalakan, perparitan, pembersihan tanah, biomas, pengurusan sisa, kerja-kerja tanah, penanaman baru dan penanaman semula. Semua aktiviti ini memberi kesan kepada sifat kimia tanah yang tidak dapat dielakkan semasa penukaran. Untuk memahami perubahan kimia tersebut, satu kajian telah dijalankan untuk menentukan kesan penukaran hutan tropika paya gambut (HTPG) sekunder kepada ladang kelapa sawit ke atas sifat kimia terpilih dalam tanah gambut. Kajian ini telah dijalankan di HTPG sekunder Sibu, Sarawak, Malaysia. Sampel tanah telah diambil dalam plot eksperimen seluas 3000 m^2 yang dibuat di HTPG sekunder sebelum dan selepas penebangan hutan, HTPG sekunder yang telah dikeringkan dan tanah yang telah dibersihkan, ladang kelapa sawit (LKS) muda dengan usia dua tahun dan tiga tahun, dan LKS matang. Tanah gambut telah disampel secara rawak menggunakan auger gambut pada kedalaman biasa (0 cm hingga 15 cm) dan dilabelkan. Sebanyak 48 sampel telah diambil di setiap sudut dan ditengah lapangan. Sampel kemudiannya dikekering pada suhu bilik, dihomogen dan disaring untuk analisis selanjutnya. Sifat kimia tanah iaitu, keasidan tanah, kapasiti pertukaran

kation (KPK), bahan organik tanah, jumlah karbon, jumlah nitrogen, jumlah fosforus, jumlah kalium dan kalium boleh ditukar telah ditentukan dengan menggunakan prosedur makmal biasa. Perubahan daripada HTPG sekunder kepada tanah pertanian bermula dengan aktiviti pembalakan. Oleh itu, bahagian pertama kajian ini adalah untuk menentukan perbandingan antara sifat-sifat kimia terpilih HTPG sekunder sebelum dan selepas pembalakan. Sepanjang kajian ini, ia menunjukkan terdapat perbezaan yang ketara pada sifat-sifat kimia tanah terpilih HTPG sekunder sebelum dan selepas pembalakan, contohnya, penurunan pH air tanah, KPK, bahan organic tanah, jumlah karbon, jumlah nitrogen, jumlah fosforus, dan kesediaan kalium. pH KCl dan nisbah C:N tanah menunjukkan tiada perubahan ketara. Semasa pembukaan tanah, nutrien dan sifat-sifat kimia tanah berubah semasa tanah ditukar kepada pertanian atau perbandaran. Oleh itu, bahagian kedua kajian ini adalah untuk menentukan kesan pembukaan tanah terhadap makro-nutrien utama tanah dan lain-lain sifat kimia terpilih HTPG sekunder. Kajian ini menunjukkan terdapat perbezaan yang ketara sifat-sifat kimia tanah seperti pengurangan pH air tanah, KPK, bahan organic tanah, jumlah karbon, jumlah nitrogen, jumlah fosforus, jumlah kalium dan nisbah C:N. Walau bagaimanapun, terdapat peningkatan untuk pH KCl dan nisbah C:P tanah. Selepas pembukaan tanah daripada HTPG sekunder, sifat kimia tanah gambut terus berubah berikutan penyediaan tanah dan aktiviti aplikasi baja untuk penanaman kelapa sawit. Oleh itu, bahagian ketiga kajian ini adalah untuk menentukan kesan penanaman di ladang kelapa sawit pada usia yang berbeza terhadap sifat-sifat kimia tahan terpilih. kajian ini menunjukkan tidak terdapat perbezaan yang ketara dalam KPK, jumlah karbon, dan bahan organic tanah. Selain itu, pH tanah menunjukkan perbezaan ketara antara satu sama lain dengan LKS muda (tiga tahun) yang paling rendah dan LKS matang tertinggi. Dalam jumlah N, LKS muda (tiga tahun) menunjukkan tertinggi secara ketara diikuti oleh LKS Matang dan LKS muda (dua tahun) adalah yang paling rendah. Manakala bagi jumlah fosforus, kedua-dua LKS muda (dua tahun) dan LKS matang adalah lebih tinggi berbanding dengan LKS muda (tiga tahun). Jumlah kalium, LKS matang menunjukkan tertinggi secara ketara berbanding dengan kedua-dua LKS muda. Untuk nisbah C:N dan C:P, terdapat perbezaan ketara bercampur-campur di mana LKS muda (dua tahun) adalah yang tertinggi pada nisbah C:N dan LKS muda (tiga tahun) tertinggi pada nisbah C:P. Sebagai kesimpulan, sifat-sifat kimia tanah gambut bertindak balas kepada perubahan yang berlaku semasa pembersihan tanah, penyaliran, dan proses penanaman kerana tanah gambut mengalami proses degradasi. Selain kesan negatif operasi pembalakan terhadap tanah HTPG sekunder, terdapat juga beberapa kesan positif daripada operasi pembalakan dari segi nutrien seperti meningkatkan jumlah nitrogen, jumlah fosforus dan kalium yang terdapat di tanah hutan paya gambut. Kesan biasa pembalakan dan pembersihan kawasan di tanah gambut adalah kehilangan penyimpanan karbon ke atmosfera dan perubahan dalam

sifat-sifat kimia tanah, penebangan tumbuh-tumbuhan yang memainkan peranan dalam mengekalkan keseimbangan kitaran karbon di dalam tanah gambut. Oleh itu, pengubahan HTPG sekunder untuk tujuan pertanian merupakan salah satu punca kepada peningkatan suhu bumi dan pemanasan global. Penukaran kepada ladang kelapa sawit mengganggu sifat kimia tanah gambut contohnya, penggunaan kapur dan pembaja terutamanya baja NPK. Untuk cadangan, perubahan pada sifat-sifat kimia tanah gambut perlu juga diperhatikan bersama sifat-sifat fizikal tanah dan pengurusan yang baik semasa pembukaan tanah yang mampu meminimumkan degradasi pada tanah gambut.

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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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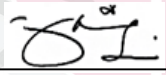
Signature:  Date: 21 Jun 2017

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This is to confirm that:

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ha	Hectare
%	Percentage
±	plus minus
cm	Centimeter
μm	Micrometer
nm	Nanometer
mL	Milileter
mm	Milimeter
m	Meter
^{o}C	Degree Celsius
ppm	Part per million
L	Liter
Gt	Gigatone
mg L^{-1}	Miligram per liter
meq 100g-1	Mill equivalent per hundred gram
cmol(+)/kg	Center mole per kilogram
g	gram
g/cm^3	gram per cubic centimetre
N	Newton
M	Mole

pH	Acidity
CEC	Cation Exchange Capacity
SOM	Soil Organic Matter
SOC	Soil Organic Carbon
SIC	Soil Inorganic Carbon
SAS	Statistical Analysis System
C	Carbon
N	Nitrogen
P	Phosphorus
K	Potassium
USDA	United State Development Agriculture
TPSF	Tropical Peat Swamp Forest
YOPP	Young Oil Palm Plantation
MOPP	Mature Oil Palm Plantation

CHAPTER 1

INTRODUCTION

1.1 Background

In general peat soil can be described as a large amount of organic material (100%) or consist of 65% organic matter or less than 35% mineral content, but there is no clear distinction between soil and vegetative accumulation (Andriesse, 1992; Muhamad *et al*., 2010; Firdaus *et al*., 2011). Peat formed when decomposition of plant residues under lack of oxygen condition due to the waterlogged conditions, lead to low nutrients and very acidic pH (Deboucha *et al*., 2008), and buildup of organic matter deposit is greater than decomposition (Paavilainen and Paivanen, 1995).

Peat swamp forests (PSF) develop when sedimentations build up in behind a swamp as rivers flow out to the coast. In time, these areas developed and build a residue above water level. The organic matter deposits can extend up to 20 meters. They developed in three geomorphic situations, lowland coastal swamps, inland swamps and valleys and high altitude, which poor draining situations and highland swamps (Andriesse, 1988; Salimin *et al*., 2010), those areas either ombrogenous, or rains fed, and are recently developed (Morley, 1981). PSFs are vital components of wetland ecosystems where complex relationship between land and water, ever changing water flow zone, the nutrient cycles and the abundance of the sun's energy combined to form a unique ecosystem of hydrology, plants and soils (UNDP, 2006).

In Malaysia, peat was categories as one of main soil type. Peat areas comprise about 8% of or three million hectares. Vast peat land around 6.3 thousand hectares found Batu Pahat, Muar and Pontian in West Johor (Yulindasari, 2006). Overall PSFs in Sarawak were similar to those in Sumatra and Peninsular Malaysia in term of vegetative and edaphic characteristics. Vast area of peat can be found in Sarawak, east Malaysia around 1.66 million hectares or 13% of the state area (Anderson, 1983; Said and Taib, 2009). However, PSFs in Malaysia is steadily decreasing as well as in Sarawak state. Satrio *et al*., (2009a) reported that estimates about 98.53 percent of the PSFs in Sarawak are disturbed mainly by excessive logging and timber harvesting due to its importance as the main sources of timber.

In Sarawak, peat soils were formed inside vast swamps reservoir (basin) and isolated small internal valleys that have developed in comparatively recent times (Andriesse, 1988). Basin peats can form domes build up to 15 meter thick, whereas valley peats more flat and in many places mixed with mineral material from erosion (muck soils) or inter-layered with river deposits. Basin peats generally occupy extensive plains, mostly around low elevation at coastal areas between main river courses, while valley peats can be found in small river outlet valleys existing in the low dissected hilly landscape which forms a transition belt between the coastal plains and the steep terrain of the interior (Muttalib *et al*., 1991).

Butler (2006) described a secondary forests can be defined as the disturbed in some situation, whether naturally or unnaturally Peat swamp forests in Sarawak, mostly has become secondary forests which caused by logging activities. These activities are inevitably causing the environmental destruction, especially on venerable peat swamp forest (Nugent *et al*., 2003).

The conversion of natural peatlands either by converting to another land use, deforestation or drainage which is likely reduces peatland areas is contributing to inaccurate data and bias estimation such as in location and extent, depth or thickness of the soils sample (Firdaus *et al*., 2010). The utilization of the peat swamps forest does not stop with the logging and timber harvesting activities. In Sarawak, Malaysia, peat swamp were converted into oil palm plantation which involved various activities e.g., draining (if in swamp area), earthworks, and clearing, planting, biomass management, disposal and replanting activities (Moduying *et al*., 2000).

Land clearing activities on peat swamp forest can affect their physical and chemical properties (Othman *et al*., 2010). The transformation of peat soil in agriculture field involving drainage which reduced the peat moisture, thus accelerated peat degradation, compaction and mineralization (Okruszko and Ilnicki, 2003; Schwarzel *et al*., 2002). When changes applied, the mineralization of peat soil affects the chemical properties of soil, However mineralization of peat soil was differing between peat types (Inisheva and Dement'eva, 2000), it also reported that peat soil chemical characteristics were different depending on human activities and land use (Tong and Ling, 2014). So it is important to understand the chemical behavior of peat soil toward the changes occur during land transformation from secondary forest into agriculture plantations at different stages.

1.2 General Objective

To estimate the effects of converting secondary tropical peat swamp forest into oil palm plantation on soil chemical properties in Sibu, Sarawak.

1.3 Specific Objectives

1. To evaluate the effects of timber harvesting and land clearing on selected soil chemical properties of secondary tropical peat swamp forest.
2. To evaluate the effects of cultivation of different ages oil palm plantation on selected chemical properties of secondary tropical peat swamp forest.

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