UNIVERSITI PUTRA MALAYSIA

EFFECTS OF WATER TABLE FLUCTUATION ON CARBON DIOXIDE AND METHANE EMISSION FROM A TROPICAL PEAT SOIL CULTIVATED WITH PINEAPPLE (Ananas comosus L. Meer.)

WENDY LUTA

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By

WENDY ANAK LUTA

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

December 2016

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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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December 2016

Chairman : Professor Ahmed Osumanu Haruna, PhD
Faculty : Agriculture and Food Sciences (Bintulu Campus)

Tropical peatlands are important buffer for climate change as they absorb atmospheric carbon and store large carbon reserve, both above and below ground. Inappropriate drainage and agricultural development on peatlands result in greenhouse gas emissions such as carbon dioxide and methane. This process could shift the peatlands ecosystem from that of carbon sink to carbon source and subsequently expedite the rate of global warming and climate change. The objectives of this study were to: (i) quantify CO_2 and CH_4 losses in a tropical soil under simulated water table fluctuation and (ii) determine the relationship between depth of water table and CO_2 and CH_4 losses of a tropical soil cultivated with pineapple. Greenhouse gases emitted from field and lysimeter study were measured using closed chamber method. Soil CO_2 and CH_4 emitted were captured using closed chamber method after which they were quantified using gas chromatography. Carbon dioxide and CH_4 gases were measured in the early morning I, afternoon, evening, midnight, and early morning II to obtain 24 hour CO_2 emission. The flux measurements were carried out in July, August, September, and December 2015 for dry and wet seasons, respectively. Soil CO_2 emission in the field study was higher compared with that of the lysimeter study with lower water table in the dry period. Soil CH_4 emission from the lysimeter study with lower water table was higher compared with that of the field study for the dry period. The moderate temperature fluctuation is related to CH_4 emission. Soil CO_2 emission from the lysimeter study with high water table was higher compared with that of field study in the wet period. It is believed that higher CO_2 emission occurs in low water table as peat soil surface is exposed to oxidation process. The total soil CO_2 emission in the dry season during low water table was higher compared with that of wet season meanwhile CH_4 emission in the dry season was higher compared with that of wet season during high water table. The total soil CO_2 emission in lysimeter during low water table was lower compared with that of high water table meanwhile CH_4 emission in lysimeter during low water table was higher compared with that of high water table. Peat soil water table fluctuation does affect the emission of greenhouse gases in pineapple cultivation on tropical peatland. Regardless of season and

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depth of peat soil water table, CO_2 and CH_4 emission occurs in pineapple cultivation of peat soils. The finding of this study will contribute to the understanding of the effect of water table management on carbon loss in peat soils under pineapple cultivation.

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

KESAN TURUN NAIK PARAS AIR TERHADAP PELEPASAN KARBON DIOKSIDA DAN METHANA DI TANAH GAMBUT DITANAMI DENGAN NANAS (*Ananas comosus* L. Merr.)

Oleh

WENDY ANAK LUTA

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Tanah gambut memainkan peranan sebagai penampan kepada perubahan iklim untuk menyerap dan menyimpan karbon samaada di permukaan atau di dalam tanah. Sistem perparitan dan pembangunan pertanian yang tidak terancang menyebabkan kesan rumahhijau seperti karbon dioksida dan metana.Proses ini mampu menukar ekosistem tanah gambut daripada penyimpanan dan sumber karbon seterusnya mempercepatkan kadar pemanasan global dan perubahan iklim. Objektif bagi kajian ini ialah: (i) mengukur kehilangan karbon dioksida dan metana dalam tanah tropika di bawah keadaan paras air yang terkawal dan (ii) menentukan hubungan antara kedalamanan paras air dan pembebasan karbon dioksida dan metana dari tanaman nanas di tanah gambut. Gas rumahhijau daripada kajian lapangan dan lysimeter diukur menggunakan kaedah kebuk wasap. Karbon dioksida dan metana dilaksanakan pada awal pagi I, tengahari, petang, tengahmalam, and awal pagi II bagi tempoh 24 jam. Pengukuran gas rumahhijau dijalankan pada Julai, Ogos, September, dan December 2015 bagi musim panas dan hujan. Pembebasan gas karbon dioksida di kajian lapangan lebih tinggi berbanding kajian lysimeter yang paras airnya dikawal rendah semasa musim kering. Pembebasan gas metana dari lysimeter yang paras airnya rendah lebih banyak berbanding kajian lapangan semasa musim kering. Pelepasan karbon dioksida dari lysimeter yang mempunyai paras air yang tinggi lebih banyak berbanding kajian lapangan semasa musim hujan. Pembebasan karbon dioksida lebih tinggi semasa paras air rendah kerana permukaan tanah gambut terdedah kepada proses pengoksidaan. Jumlah pembebasan karbon dioksida semasa paras air rendah di musim kering lebih tinggi daripada musim hujan manakala pembebasan metana semasa air tinggi lebih tinggi di musim kering. Jumlah pembebasan karbon dioksida di lysimeter semasa paras air rendah lebih rendah berbanding dengan paras air tinggi manakala pembebasan metana semasa paras air rendah lebih tinggi berbanding dengan paras air tinggi. Kesederhanaan turun naik suhu tanah mempengaruhi pembebasan gas karbon dioksida dan metana di tanaman nanas. Tanpa mengira musim dan kedalaman aras air tanah gambut, pelepasan karbon dioksida dan metana dari penanaman nanas di tanah gambut

tetap berlaku. Hasil kajian ini akan menyumbang kepada pemahaman kesan pengurusan saliran dan mitigasi terhadap pembebasan karbon dari penanaman nanas di tanah gambut.

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This thesis was submitted to the Senate of the 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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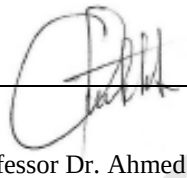
Signature: 
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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ANOVA	Analysis of Variance
CAM	Crassulacean Acid Metabolism
CEC	Cation Exchange Capacity
DOC	Dissolved Organic Carbon
GHG	Greenhouse Gas
HDPE	High Density Polyethylene
IPCC	Intergovernmental Panel on Climate Change
MARDI	Malaysian Agricultural Research and Development Institute
MRP	Mega Rice Project
MPOB	Malaysian Palm Oil Board
SOC	Solid Organic Carbon
TCD	Thermal Conductivity Detector

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CHAPTER 1

INTRODUCTION

Tropical peatlands are being developed for agriculture for economic reasons. According to Melling *et al*. (2005), reclamation of peatlands for agriculture involves lowering of water table and compaction to improve peat soil bulk density, soil surface load-bearing capacity, and water-filled pore space. However, several studies have for example shown that lowering of the water table of peats changes peatlands from carbon sinks to carbon sources (Couwenberg, 2011, Van Huissteden *et al.,* 2006; Furukawa *et al*., 2005). This is because of reversing C flux into net CO_2 emission. The process also decreases CH_4 emissions. According to Van Huissteden *et al.* (2006), the general consensus is that lowering water table increases peat decomposition rate due to enhanced microbial degradation of organic matter. The understanding of soil C flux based on studies conducted in boreal and temperate peats is not fully applicable as in the tropics due to differences in environmental factors, peat soil properties, vegetation, and microbial diversity and population, and management practices. For tropical peatlands, there are other factors affecting soil CO_2 flux other than water table (Jauhiainen *et al.,* 2011).

Greenhouse gases that emitted from peatlands are CO_2, CH_4, and N_2O. Studies by Florides and Christoudoulides (2008), Jassal *et al.* (2011), and Chen *et al.* (2014) showed that these gases contribute to global warming. Carbon dioxide, CH_4, and N_2O are emitted through aerobic and anaerobic microbial respiration, root respiration, peat oxidation, nitrification, and denitrification. The increase in water table depth, temperature, and fertilization increases CO_2 and CH_4 emission (Jauhiainen *et al.,* 2012; Berguland and Berguland, 2011; Abdul *et al.,* 2005; Chimner and Cooper, 2003). Greenhouse gases emissions are influenced by land use type (Ismail, 2010), peat type (Kechavarzi *et al.,* 2010), and photosynthetic activities (Makiranta *et al*., 2008). Samuel *et al.* (2006) and Fenner *et al.* (2007) reported that carbon in the form of dissolved organic carbon (DOC) is lost from peatlands through drainage water.

However, research findings on GHG emissions from tropical peats are usually controversial because of lack of standard procedures. Burrows *et al.* (2005) and Couwenberg (2011) suggested soil GHG emissions should be measured at the soil surface using the closed chamber method (Abdul *et al*., 2005; Zulkefli *et al*., 2010). Using the closed chamber method, GHG monitoring is carried out in very limited areas (few cm^2) and duration (few minutes) and results from this method are expressed in $tha^{-1}yr^{-1}$. Results sometimes are inconsistent and sometimes controversial. There is limited information on GHG emissions from peats cultivated with pineapples although pineapples are cultivated on tropical peatlands. Raziah and Alam (2010) reported that the contribution of pineapples cultivation on tropical peats to GHG emissions is important as 90% of pineapples are widely grown on peat soils of Malaysia.

Drainage of tropical peatland commonly results in loss of soil carbon reserve. The decomposition of organic materials and microbial activity result in the release of CO_2, CH_4, organic acids, and organic particulates. The rate of carbon loss is expected to be affected by climate change, particularly from the increased intensity of dry and wet periods. The resultant extreme water table fluctuation may affect the amount and nature of aerobic and anaerobic peat material, which subsequently will affect the decomposition of peat material and microbial activities, as well as crop performances. A study of this kind will provide greater understanding on the effect of climate change, particularly water table fluctuation and carbon loss in peatland ecosystem, so that mitigation measures can be identified and recommended. This is essential because there are limited studies on the relationship between depth of water table and carbon losses through CO_2, CH_4, DOC, and soil organic carbon (SOC). There is also dearth of information on soil CO_2 emission from pineapple cultivation on drained peat soils although pineapples are mostly grown on peat soils of Malaysia (Raziah and Alam, 2010). In this study, it was hypothesized that peat soil water table fluctuation will affect the emission of greenhouse gases in pineapple cultivation on tropical peat soils.

Objectives

The objectives of this study were to: (i) quantify CO_2 and CH_4 losses in a tropical soil under simulated water table fluctuation, and (ii) determine the relationship between depth of water table and CO_2 and CH_4 losses of a tropical soil cultivated with pineapples.

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