UNIVERSITI PUTRA MALAYSIA

GROUND FUEL CHARACTERISTICS OF BURNT PEAT IN RAJA MUSA FOREST RESERVE, SELANGOR, MALAYSIA

DAYANG NUR SAKINAH MUSA

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By

DAYANG NUR SAKINAH BINTI MUSA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science (*Forest Management and Conservation*)

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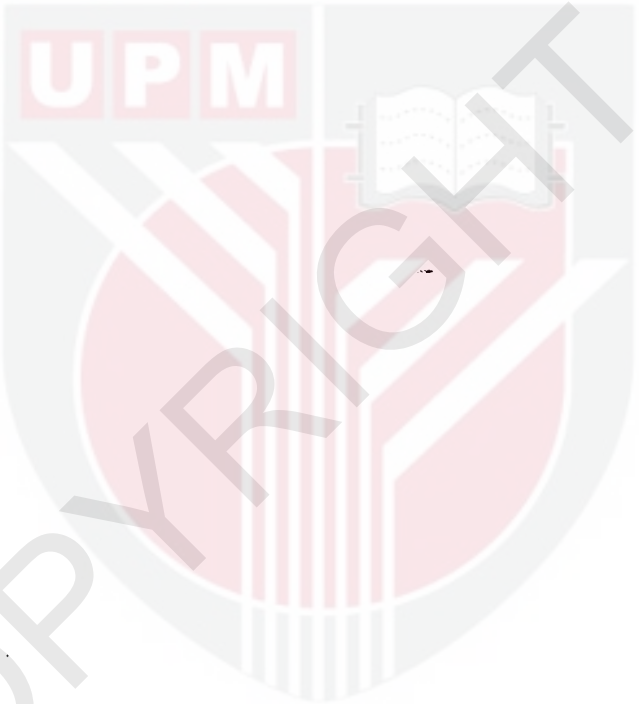

DEDICATION

To my beloved parents,

Musa and Asnia

This humble work is a sign of my love to you❤

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science (*Forest Management and Conservation*)

GROUND FUEL CHARACTERISTICS OF BURNT PEAT IN RAJA MUSA FOREST RESERVE, SELANGOR, MALAYSIA

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MARCH 2016

Chair: Prof. Dr. Ahmad Ainuddin Nuruddin, PhD

Faculty: Faculty of Forestry

Peat swamp forest in Malaysia is an important ecosystem that acts as flood mitigation, climate change mitigation, and carbon storage. Nowadays, peat having an issues especially on fire. The study of burnt peat characteristics were still insufficient, thus, the study on burnt and unburnt peat in Raja Musa Forest Reserve (RMFR) were done. Additionally, the seasonal influence between dry and wet season also examined in this study, as well as the peat depth impacts on the RMFR peat. With these information, the fuel characteristic (physical, chemical, thermal ad burning properties) can be determined in comparison with the type of peat, seasonal affect and also influenced of peat depth in RMFR. Peat samples were collected in compartment 99 for burnt area, and compartment 1 for unburnt area. The peat samples of dry season from both areas were obtained in February, 2014, and the wet season in May, 2014.These samples were collected using an auger at four layers of peat, i.e., at the surface, and below ground of 0.5m, 1.0m and 1.5m depths. The physical properties includes bulk density, moisture content, and LOI which indicates the organic matter of peat. Bulk density indicates the compaction of the peat, the findings shows highest bulk density in burnt peat of dry season with 0.35 g/cm3 (at 1.0m), and lowest on the surface of unburnt peat during dry season with 0.27 g/cm3. The bulk density shows no significant differences among the depths, peat types, and seasons. The moisture content shows significant difference between peat types, wherein burnt peat was higher in moisture content compared to unburnt peat with 712.45% in burnt peat, and 498.16% in unburnt peat. Similar to moisture content, LOI shows significantly different between burnt and unburnt peat, where burnt shows higher organic matter with 29.31%, and lower in unburnt peat with 18.06%. Moreover, LOI shows significantly different amongst the depths of burnt peat where 1.5m depth shows the highest organic matter with 26.50%. For chemical properties, pH values indicates the acidity of the peat, and the results shows high significant difference

between the season, wherein wet season (4.69) shows less acidic compared to dry season (4.19). Similarly to pH values, CEC shows significant difference between season, where wet seasons (106.39cmol/kg) higher in CEC and lower in dry season (49.14 cmol/kg). CEC also shows significantly different between peat types, where unburnt shows higher CEC with 89.87 cmol/kg, and lower in burnt peat with 65.65 cmol/kg. The total carbon content in RMFR shows significant difference amongst the depths in burnt peat where it increasing down the depth with 31.77% (surface), 42.61% (0.5m), 45.06% (1.0m), 47.32% (1.5m). Besides, the total N content shows significant difference between peats types, wherein unburnt peat (1.33%) higher in N content compared to burnt peat (1.02%). The total N content also shows significantly difference amongst the depth, where it reducing down the depth with 1.62 (surface), 1.26 (0.5m), 1.23 (1.0m), and 1.21 (1.5m). Total P content shows significantly difference between burnt and unburnt peat, where the burnt peat (0.06%) was higher in total P content compared to unburnt peat (0.03%). Moreover, total P content shows significantly different amongst the depths in burnt and unburnt peat, where it reducing down the depth. Burnt peat shows 0.11% (Surface), 0.05% (0.5m), 0.04% (1.0m), and 0.04% (1.5m); unburnt peat shows 0.05% (Surface), 0.03% (0.5m), 0.03% (1.0m), 0.02% (1.5m). The extractable K amount shows highly significant difference between seasons and peat types, wherein dry season (142.39 µg/g) was higher in K amount compared to wet season (80.02 µg/g), and burnt peat (138.02 µg/g) was higher than unburnt peat (84.39 µg/g). Extractable K amount shows significantly different among the depths in unburnt peat where it reducing down the depths 204.46 µg/g (surface), 50.71 µg/g (0.5m), 45.99 µg/g (1.0m), and 36.41 µg/g (1.5m). Similar to K, the extractable Ca amount shows significantly higher in dry season (845.75 µg/g), compared to wet season (106.41 µg/g); and the Ca amount were significantly different, in where burnt peat were higher in Ca amount with 819.22 µg/g, compared to unburnt peat with 132.94 µg/g. The extractable Mg amount also shows significantly different between seasons, wherein dry season (263.41 µg/g) was higher in Mg amount compared to wet season (56.20 µg/g). Moreover, extractable amount of Na shows significant difference between peat types wherein, the unburnt peat were significantly higher in Na amount compared to burnt peat with 140.64 µg/g and 55.92 µg/g, respectively. For the thermal properties, TGA and DSC analyses for dry and wet season indicated that in burnt peat, surface peat was more thermally stabled compared to the 1.5m depth, however, in unburnt peat, the 1.5m depth. Burning properties shows significantly different of burning time between the peat types, wherein the unburnt peat (173.38 minutes) took longer time to completely turn into ashes compared to burnt peat (99.83 minutes). The burning time also shows significantly different amongst the depths where, 130.33 minutes (surface), 171.83 minutes (0.5m), 201.50 minutes (1.0m), and 189.83 minutes (1.5m). In a conclusion, some of the characteristics were significantly influenced by the type of peat, the season and different layers of peat depth. For instance, the P content was higher in burnt peat than unburnt peat, the pH was less acidic during wet season than in dry season, and N content was higher at the surface and decreased down to below ground.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains (*Pemuliharaan dan Pengurusan Hutan*)

CIRI BAHANAPI BAWAH TANAH BAGI GAMBUT TERBAKAR DI HUTAN SIMPAN RAJA MUSA, SELANGOR, MALAYSIA

Oleh

DAYANG NUR SAKINAH BINTI MUSA

Mac 2016

Pengerusi: Prof. Dr. Ahmad Ainuddin Nuruddin, PhD

Fakulti: Fakulti Perhutanan

Hutan paya gambut di Malaysia merupakan sebuah ekosistem hutan yang berperanan penting sebagai pencegah banjir, mitigasi terhadap perubahan iklim, serta sebagai pusat penyimpanan karbon. Gambut sering berdepan dengan masalah berkenaan dengan api. Walaubagaimanapun, kajian mengenai ciri-ciri gambut terbakar dan tidak terbakar masih berkurangan, oleh yang demikian, kajian berkenaan perkara tersebut telah dilaksanakan di Hutan Simpan Raja Musa (HSRM) bagi menjawab permasalahan tersebut. Selain itu, pengaruh musim hujan dan kering, serta kedalaman gambut di HSRM turut dikaji bagi menambah pengetahuan berkenaan ciri gambut di hutan tersebut. Ciri yang dikaji termasuklah ciri fizikal, kimia, haba, dan masa pembakaran. Sampel gambut terbakar diambil di kawasan kompartmen 99, manakala gambut tidak terbakar diambil dikawasan kompartmen 1. Musim dibahagikan kepada musim kering dimana sampel diambil pada bulan Februari, 2014, manakala sampel musim hujan diambil pada bulan Mei, 2014. Sampel gambut diambil pada permukaan, kedalaman 0.5m, 1.0m, dan 1.5m dengan menggunakan auger. Ciri fizikal yang dikaji ialah ketumpatan pukal, kandungan lembapan, dan kehilangan pencucuhan (LOI). LOI akan menentukan kandungan bahan organik didalam gambut. Ketumpatan pukal menunjukkan kepadatan gambut, dimana gambut terbakar pada musim kering adalah yang tertinggi dengan purata 0.35 g/cm3 (1.0m), manakala permukan gambut tidak terbakar adalah yang paling rendah (0.27 g/cm3). Kandungan lembapan gambut menunjukkan perbezaan yang signifikan diantara jenis gambut, dimana gambut terbakar (712.45%) lebih tinggi kandungan lembapan berbanding gambut tidak terbakar (498.16%). LOI turut menunjukkan perbezaan yang signifikan diantara jenis gambut, dimana gambut terbakar mempunyai lebih kandungan organik (29.31%) berbanding dengan gambut tidak terbakar (18.06%). Tambahan lagi, perbezaan yang signifikan turut dinyatakan pada peringkat kedalaman dimana kandungan organik adalah paling

tinggi pada kedalaman 1.5m (26.50%). Bagi ciri kimia, nilai pH gambut dikaji bagi menentukan tahap asid gambut. Perbezaan yang signifikan ditunjukkan diantara musim, gambut musim hujan (4.69) kurang berasid berbanding musimg kering (4.19). Kapasiti pertukaran kation (CEC) menunjukkan perbezaan yang signifikan diantara jenis musim, dimana musim hujan (106.39 cmol/kg) lebih tinggi CEC berbanding pada musim kering (49.14 cmol/kg). Perbezaan signifikan turut ditunjukkan diantara jenis gambut dimana gambut tidak terbakar (89.87 cmol/kg) mengandungi CEC lebih tinggi berbanding gambut terbakar (65.65 cmol/kg). Kandungan karbon di HSRM menunjukkan perbezaan yang signifikan diantara peringkat kedalaman pada gambut terbakar. Ianya menunjukkan penurunan kandungan karbon daripada permukaan ke kedalaman 1.5m; 31.77% (permukaan), 42.61% (0.5m), 45.06% (1.0m), 47.32% (1.5m). Selain itu, kadungan N menunjukkan perbezaan yang signifikan diantara jenis gambut dimana gambut tidak terbakar (1.33%) lebih tinggi kandungan N berbanding gambut terbakar (1.02%). Perbezaan yang signifikan turut ditunjukkan pada peringkat kedalaman. Ianya menurun dari permukaan (1.62%), seterusnya 0.5m (1.26%), 1.0m (1.23%), dan 1.5m (1.21%). Kandungan P menunjukkan perbezaan yang signifikan diantara jenis gambut, dimana kandungan P lebih tinggi pada gambut terbakar (0.06%) berbanding gambut tidak terbakar (0.03%). Perbezaan signifikan turut ditunjukkan mengikut peringkat kedalaman gambut terbakar dan tidak terbakar; gambut terbakar, 0.11% (permukaan), 0.05% (0.5m), 0.04% (1.0m), and 0.04% (1.5m); gambut tidak terbakar, 0.05% (permukaan), 0.03% (0.5m), 0.03% (1.0m), 0.02% (1.5m). Ekstrak K menunjukkan perbezaan signifikan pada jenis musim dan jenis gambut, dimana musim kering (142.39 µg/g) lebih tinggi kandungan K berbanding musim hujan (80.02 µg/g), manakala gambut terbakar (138.02 µg/g) lebih tinggi kandungan K berbanding gambut tidak terbakar (84.39 µg/g). Peringkat kedalaman pada gambut tidak terbakar menunjukkan perbezaan yang signifikan, 204.463 µg/g (permukaan), 50.71 µg/g (0.5m), 45.99 µg/g (1.0m), and 36.41 µg/g (1.5m). Ekstrak Ca menunjukkan perbezaan signifikan diantara musim kering (845.75 µg/g) dimana kandungan Ca lebih tinggi berbanding musim hujan (106.41 µg/g), dan gambut terbakar (819.22 µg/g) lebih tinggi kandungan Ca berbanding gambut tidak terbakar (132.94 µg/g). Ekstrak Mg menunjukkan perbezaan yang signifikan diantara musim, dimana musim kering (263.41 µg/g) mengandungi lebih tinggi kandungan Mg berbanding musim hujan (56.20 µg/g). Selain itu, kandungan ekstrak Na menunjukkan perbezaan yang signifikan diantara jenis gambut, dimana gambut tidak terbakar lebih tinggi kandungan Na berbanding gambut tidak terbakar dengan masing-masing purata 140.64 µg/g dan 55.92 µg/g. Ciri haba pada musim kering dan musim hujan dikaji dengan menggunakan analisis TGA dan DSC dimana kajian menunjukkan permukaan gambut terbakar mempunyai kestabilan haba lebih baik berbanding kedalaman 1.5m. Berlainan dengan jenis gambut tidak terbakar, kestabilan haba adalah lebih baik pada kedalaman 1.5m berbanding pada permukaan gambut. Ciri kebakaran menunjukkan perbezaan yang signifikan diantara jenis gambut, dimana gambut tidak terbakar (173.38 minit) mengambil masa yang lebih lama untuk terbakar sepenuhnya berbanding jenis gambut terbakar (99.83 minit). Masa kebakaran juga menunjukkan perbezaan yang signifikan diantara peringkat kedalaman; 130.33 minit (permukaan), 171.83 minit (0.5m), 201.50 minit (1.0m), dan 189.83 minit (1.5m). Kesimpulannya, beberapa ciri fizikal, kimia, haba, dan kebakaran terkesan atas pengaruh musim, jenis gambut, serta tahap kedalaman gambut di HSRM, seperti kandungan P kawasan terbakar tinggi berbanding tidak terbakar,

nilai pH gambut kurang berasid pada musim hujan bebanding musim kering, dan kandungan N yang lebih tinggi pada permukaan tetap makin berkurangan mengikut peringkat kedalaman.

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LISTS OF ABBREVIATIONS/ NOTATION/ GLOSSARY OF TERMS

%	Percent
±	Plus minus (Standard Error)
°C	Degree Celsius
µg/g	Microgram per gram
ANOVA	Analysis of Variance
ASEAN	Association of Southeast Asian Nations
BSI	British Standards Institute
C	Carbon
C/N	Carbon to Nitrogen Ratio
Ca	Calcium
CEC	Cation Exchange Capacity
cm	Centimeter
cmol/kg	Centimoles of charge per *kilogram*
CO_2	Carbon dioxide
COOH	Carboxyl
Cu	Copper
D_b	Bulk density
DSC	Differential scanning calorimetry
FAO	Forestry and Agriculture Organisation
FDPM	Forestry Department of Peninsular Malaysia
FDS	Forestry Department of Sarawak
Fe	Iron
g/cm^3	Gram per centimeter cube

GEC	Global Environment Centre
H+	Hydrogen plus
Ha	Hectare
HSRM	Hutan Simpan Raja Musa
IADP	Integrated Agricultural Development Project
IUCN	International Union for Conservation of Nature
J s^{-1}	Joule per second
K	Potassium
km	Kilometer
km^2	Kilometer per square
LOI	Loss on Ignition
m	Meter
MC	Moisture Content
mg C g^{-1}	Carbon Milligram per gram
mg kg^{-1}	Milligram per kilogram
mg L^{-1}	Milligram per litter
mg N g^{-1}	Nitrogen milligram per gram
Mg	Magnesium
MYSTAT	Statistical software package by SYSTAT for students
N	Nitrogen
N_2	Nitrogen gas
Na	Sodium
NGO	Non-Governmental Organization
NPO	Non-Profitable Organization
NSPSF	North Selangor Peat Swamp Forest
OH	Hydroxyl

OM	Organic Matter
P	Phosphorus
p.p.m	Parts per million
PSF	Peat Swamp Forest
RMFR	Raja Musa Forest Reserve
SE	Standard Error
SFD	Sabah Forestry Department
Sg.	Sungai
SOM	Soil Organic Matter
SPSS	Statistical Package for the Social Sciences
TA	Thermal Advantage Universal Analysis
TEs	Trace element
TG	Thermogravimetry
TGA	Thermogravimetry analysis
UNDP	United Nations Development Programme
Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 General Background

Peat swamp forest are waterlogged forests that grown on layers of dead leaves and plant material, and their continued survival are depended on natural high water level which prevents the peat from drying out and exposable as combustible peat matter (UNDP, 2006). These type of forest are important in climate mitigation and act as a carbon sinks which important in slowing down the global warming. Although peat swamp forest have relatively low in biodiversity compared to the inland rain forest, it is a habitat for some rare and endangered species such as Orang Utan, Proboscis monkey, Siamang, and Hornbill (Wösten *et al.*, 2006; Silvius and Suryadiputra, 2005).

The largest area of peat swamp forest in Malaysia was located in Sarawak with 750,000 ha, followed by the Peninsular Malaysia with 254,976 ha, and lastly, Sabah, with 26,011 ha of peat swamp forest areas (FDPM, 2013; SFD, 2014; FDS, 2015).The total peat swamp forest area in Malaysia were approximately 2,457,730 ha or 7.45% of the Malaysia's total land area, however, only 19% were categorised as undisturbed forest (Wetlands International, 2010).

The study area, Raja Musa Forest Reserve (RMFR) covers an area of 23,000 hectares (ha). The RMFR is part of the North Selangor Peat Swamp Forest (NSPSF). It is a significant block of remaining peat swamp forest in Peninsular Malaysia which is an important ecosystem for freshwater sources, flood mitigation and carbon storage. This reserve was gazetted in 1990 and prior to its gazettement, the area was part of state land forest and was intensively logged since 1950s (Ainuddin and Goh, 2010).

Peat swamp forests in Malaysia have been severely degraded as a result of logging, peat drainage, agricultural activities and fires. Drained peatlands are extremely prone to fire, and it is found that prolonged drought season associated with El Niño event has stimulated the fires widespread (Hirano *et al.,* 2012). Besides, abundance of fuel in the form of biomass and dry peat make the fires in the peat swamp forest spread faster, and this caused a global risk with social, economic, and environmental effects in both short and long terms (Wösten *et al.,* 2006; Rein *et al.*, 2009; Watss, 2013).In the case of RMFR, it had experienced severe fire incidents since 1996 (Ainuddin and Goh, 2010). Negative impacts associated with peatland fire are environmental pollution and the significant decrease or loss of important floral and faunal

populations. The impacts will be even more severe if the peat swamp forests are not properly managed. Therefore, understanding of the peat swamp forest characteristics is an important aspect to be taken on board in planning and preparation of its long-term management plan, including forest fire management plan. The plan provides clear guidelines and direction in managing the peat swamp forest, and hence operational activities such as monitoring and controlling peatland fires will be effectively and efficiently implemented.

For the purpose of this study, there were three characteristics of peat in Raja Musa Forest Reserve (RMFR) were examined, namely, physical properties, chemical properties, and thermal and burning characteristics. The study on physical properties includes bulk density, moisture content, and loss on ignition (LOI). The chemical properties examined were acidity (pH), cation exchange capacity (CEC), total nitrogen (N), phosphorus (P), carbon (C), as well as extractable (µg/g) of potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na). There were two methods of analysis conducted to determine the thermal characteristics, i.e., Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC).The burning time method was conducted to determine the burning characteristics of the peat. These properties were important to give knowledge on differences of peat in burnt and unburnt area, also seasonal effect on the physical, chemical, thermal and burning properties of peat.

1.2 Problem Statements and Justification

Malaysia's peat swamp forests are worlwide significant unique habitat for endemic species and a gene bank with unexploited resources for medicinal and other human purposes (UNDP, 2006).Besides, peat swamp forest plays a critical role as flood mitigation, as it acts like a giant sponges which absorbed and stored the wate during rainy season and released the water during dry season. Additionally, peat swamp forest also acts as world's carbon storage.

However, peat swamp forest facing a treats especially on fires that occurred almost every year during drought season, and even became severe with the El Nino events. Once the fire started on peat, it was difficult to extinguish and the fire incidents will linger on for a long period of time, then spread over an extensive areas of the peat swamp forest and deep into the peat (Rein *et al.*, 2008). The fire occurrences together with agricultural development, contributes to a rapid disappearances of the peat swamp forest areas (Phua *et al.*, 2007).This is the greatest threat to the remaining peat swamp forest areas in Peninsular Malaysia including the RMFR. Peat swamp forest are fragile ecosystem which needed protections, attentions, and proper planning from fire events. Currently, research activities pertaining to this subject matter were deficient. As matter to the issue, this study between burnt peat and unburnt peat was carried out in the RMFR, which focused on the physical, chemical, thermal and burning characteristics. Moreover, the relationship between fuel dynamics of burnt and unburnt area of the

RMFR can be determined too. The information collected are useful as an input in forest fire management plan. This helps to enhance management planning for the peat swamp forests as a whole, particularly on forest fire management planning and monitoring. The study of seasonal impact on peat, and peat depth influences in RMFR peat were still lacking. The seasonal affect between the dry and wet season can be examined in this study, as well as the peat depth effects on the RMFR peat. With this information, the fuel characteristic can be determined in comparison with the type of peat, seasonal affect and also influenced of peat depth in RMFR.

1.3 Objectives

The general objective of the study was to investigate the ground fuel characteristics of peat swamp forest of Raja Musa Forest Reserve, Selangor. Meanwhile, the specific objectives of this study were as follows:

a. To determine physical and chemical properties of burnt and unburnt peat during dry and wet season;
b. To examine thermal and combustion characteristics of burnt and unburnt peat during dry and wet season.

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