UNIVERSITI PUTRA MALAYSIA

SEDIMENT CARBON STORAGE AND RELATED CHEMICAL PROPERTIES OF MANGROVE FOREST IN SARAWAK, MALAYSIA

EMPI RAMBOK

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By

EMPI RAMBOK

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

July 2013

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DEDICATION

Dedicated to my lovely family, for my parents, Rambok Entingang and Rampu Gani, my beloved sister, Evelyn Intik and my beloved brother, Augustine Inyang.

It is also dedicated to anyone who contributed to my study by sharing their knowledge, time, concerns, and ideas.

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

SEDIMENT CARBON STORAGE AND RELATED CHEMICAL PROPERTIES OF MANGROVE FORESTS IN SARAWAK, MALAYSIA

By
EMPI RAMBOK
July 2013

Chairman : Associate Professor Seca Gandaseca, PhD
Faculty : Agriculture and Food Sciences

Mangrove forest is one of the fifth forest types found in Sarawak and its existence is beneficial for economic activities and ecology balancing. A study of a mangrove forests in sequestering carbon and related chemical soil properties was conducted at Wildlife Sanctuary Sibuti, Miri (WSSM) Mangrove Forest and Awat-Awat Lawas, Limbang (AALL) Mangrove Forest. The objectives of this study were to: (i) compare selected soil chemical properties of the two mangrove forests and (ii) compare their carbon storage with time. A total of 320 soil samples were collected from WSSM and AALL, 40 soil samples were collected from each study site for 4 sampling time. The first soil sampling were conducted in December 2009 (WSSM) and January 2010 (AALL), the second soil sampling was carried out in June 2010, the third soil sampling was conducted in August 2013, and the fourth sampling was carried out in October 2013. The first part of this study was to determine soil chemical properties of the mangrove forest in Sarawak. A contemporary mangrove soil condition is essential for addressing mangrove forest for carbon storage, and environmental balance. Mangrove soil samples were taken from Miri and Limbang Division of Sarawak at 0-30 cm depth in a 0.5 hectare plot. Selected soil chemical properties were determined and data obtained were analyzed using Statistical Analysis System (SAS) Version 9.2. Soil pH was determined using water and 1N KCl, soil organic matter and total carbon were analyzed using CHNS analyzer, total N was determined using Kjeldahl method, total P was determined using Aqua Regia method, cation exchange capacity was determined using leaching method, and humic acids were isolated using standard procedures. The soil acidity, total N, total P, CEC, and humic acid of both locations were significantly different except for total carbon and organic matter. Regional diversity has significant effects on the soil acidity, total N, total P, CEC and yield of humic acids of the study areas. Data obtained can be useful for further study on carbon stock and nutrients content. The second part of the study was to determine the potential of mangrove soil to store carbon and the soil condition between intervals of vegetation growth. This study examined the potential of the two mangrove forests soil to store carbon. Soil sampling was conducted in December 2009, January 2010, June 2010, August 2013, and October 2013, respectively, to study the effects of location and time. Soil carbon, soil organic matter, and stable carbon from humic acids were analyzed using CHNS analyzer. Bulk density was determined using coring method. Soil pH, total P, total N, CEC, and humic acids were determined as previously outlined. There were significant effects on soil total C at WSSM and AALL. The quantities of total C recorded at WSSM ranged from

29.50 Mg ha^{-1} (December 2009) to 90.16 Mg ha^{-1} (October 2013) while those of for AALL ranged from 38.94 to 48.49 Mg ha^{-1}. The quantity of stable carbon in humic acids for WSSM in December 2009 was 1.34 Mg ha^{-1}, June 2010 was 1.65 Mg ha^{-1}, August 2013 was 1.69 Mg ha^{-1}, and October 2013 was 1.12 Mg ha^{-1}, For AALL; January 2010 was 1.95 Mg ha^{-1}, June 2010 was 1.28 Mg ha^{-1}, August 2013 was 0.56 Mg ha^{-1}, and October 2013 was 0.48 Mg ha^{-1}. The soil in both mangrove forests was acidic as pH values were as follows; (i) WSSM: 2.67 to 4.90 (in water) and 2.51 to 4.44 in pH (in KCl), and (ii) AALL: 2.44 to 3.73 (in water) and 2.40 to 3.68 (in KCl). The value of C:N ratios of the two sites were also very high ranging between 35.93 to 182.86. Based on comparison between WSSM and AALL, it was concluded that there were significant differences of soil pH in water and in KCl, total N and total P for first and second sampling. The soil at WSSM was more acidic than AALL and had higher amounts of soil organic matter, total N and total P. Soil of WSSM mangrove forest was better than AALL mangrove forest because when comparison was made between location during first soil sampling, WSSM showed higher content of organic matter, total C, total N, total P and cation exchange capacity. The significant difference of total soil C and stable C in humic acid were recorded at both study areas and comparison between times suggests that the mangrove soil has the potential to store carbon. However the ability of the mangroves to store C sediment depends on forest performance, the rate of decomposition, plant residue, locality, vegetation density and organic compounds.

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

PENYIMPANAN KARBON DI DALAM MENDAPAN TANAH DAN SIFAT-SIFAT KIMIA TANAH PADA HUTAN BAKAU DI SARAWAK, MALAYSIA

Oleh
EMPI RAMBOK
Julai 2013

Pengerusi : Profesor Madya Seca Gandaseca, PhD
Fakulti : Sains Pertanian dan Makanan

Hutan bakau merupakan salah satu daripada lima jenis hutan yang terdapat di Sarawak dan kewujudannya penting untuk aktiviti ekonomi dan alam sekitar. Satu kajian telah dilakukan di hutan bakau berkenaan pontensinya untuk menyimpan karbon and status semasa sifat-sifat kimia tanah di Santuari Hidupan Liar Sibuti, Miri (WSSM) dan Awat-Awat Lawas, Limbang (AALL). Objektif kajian ini adalah untuk: (i) membandingkan sifat-sifat terpilih kimia tanah dua hutan bakau dan (ii) membandingkan kadar penyimpanan karbon dalam tempoh suatu masa. Sejumlah 320 sampel tanah telah dikumpulkan dari WSSM dan AALL, di mana sebanyak 40 sampel tanah telah diambil dari setiap satu kajian tapak untuk pensampelan sebanyak empat kali. Pensampelan tanah yang pertama telah dijalankan pada Disember 2009 (WSSM) dan Januari 2010 (AALL), dan pensampelan tanah kedua telah dijalankan pada bulan Jun 2010, pensampelan tanah ketiga pada Ogos 2013, dan pensampelan tanah keemapat pada Oktober 2013 bagi kedua-dua plot kajian. Bahagian pertama kajian ini adalah untuk menentukan sifat-sifat kimia tanah hutan bakau di Sarawak. Sampel tanah hutan bakau telah diambil dari hutan bakau yang terdapat di bahagian Miri dan Limbang pada kedalaman 0-30 cm di dalam plot yang bersaiz 0.5 hektar. Sifat-sifat kimia tanah terpilih telah dikaji dan hasil yang diperolehi telah dianalisis menggunakan 'Statistical Analysis System' (SAS) Versi 9.2. pH tanah telah ditentukan dengan menggunakan kaedah 1N KCl dan air, bahan organik dan jumlah karbon telah dianalisis menggunakan 'CHNS analyzer', jumlah N telah ditentukan menggunakan 'Kjeldahl method', jumlah P ditentukan menggunakan kaedah Aqua Regia, kapasiti pertukaran kation telah ditentukan dengan menggunakan kaedah larut lesap, dan asid humik dengan menggunakan kaedah yang dibuat oleh Stevenson dan Ahmed. Keasidan tanah, jumlah N, P, CEC dan asid humik bagi kedua-dua lokasi menunjukkan perbezaan yang ketara manakala jumlah karbon dan bahan organik di dalam tanah adalah sama. Perbezaan lokasi menunjukkan kesan yang signifikan terhadap keasidan tanah, jumlah N, P, CEC dan jumlah asid humik. Data yang diperolehi dapat digunakan untuk kajian yang seterusnya bagi penyimpanan karbon dan kandungan nutrien. Bahagian kedua kajian telah menyelidik potensi tanah hutan bakau untuk menyimpan karbon dan kualiti tanah dalam jangka masa tertentu pertumbuhan di hutan. Pengambilan sampel tanah telah dilakukan pada Disember 2009, Januari 2010, Jun 2010, Ogos 2013 dan Oktober 2013 untuk menentukan kesan perbezaan lokasi dan masa. Karbon di dalam tanah, bahan organik dan karbon stabil dari asid humik telah dikaji melalui 'CHNS analyzer'. Ketumpatan pukal telah ditentukan menggunakan kaedah 'coring'. pH tanah, P, N, CEC, dan asid humik

telah ditentukan seperti yang digariskan sebelum ini. Terdapat kesan perbezaan bagi peyimpanan karbon di tanah untuk AALL antara jarak pertumbuhan hutan selama enam bulan. Kuantiti jumlah C yang dicatatkan untuk WSSM ialah di antara nilai 29.50 Mg ha^{-1} (Disember 2009) hingga 90.16 Mg ha^{-1} (Oktober 2013) dan nilai yang diperolehi di AALL bermula dari 38.94 hingga 48.49 Mg ha^{-1}. Kuantiti karbon stabil dari asid humik dalam Mg ha^{-1} di WSSM; Disember 2009 ialah 1.34 Mg ha^{-1}, Jun 2010 ialah 1.64 Mg ha^{-1}, Ogos 2013 ialah 1.69 Mg ha^{-1} dan Oktober 2013 ialah 1.12 Mg ha^{-1}, manakala untuk AALL; Januari 2010 ialah 1.95 Mg ha^{-1}, Jun 2010 ialah 1.28 Mg ha^{-1}, Ogos 2013 0.56 Mg ha^{-1}, Oktober 2013 ialah 0.48 Mg ha^{-1}. Mendapan tanah di kedua-dua lokasi kajian adalah berasid dan terletak dalam lingkungan: (i) WSSM, 2.67 hingga 4.90 (dalam air) dan 2.51 hingga 4.44 (dalam KCl), dan (ii) AALL: 2.44 hingga 3.73 (dalam air) dan 2.40 hingga 3.68 (dalam KCl). Nilai nisbah C:N yang dicatatkan bagi kedua-dua hutan bakau adalah sangat tinggi yakni di antara 35.93 hingga 182.86. Perbandingan antara WSSM dan AALL menyimpulkan bahawa terdapat perbezaan yang ketara bagi keasidan tanah dalam air dan dalam KCl, nitrogen, dan fosforus untuk kajian pertama dan kedua. Tanah di WSSM adalah lebih berasid jika dibandingkan dengan tanah di AALL dan juga mempunyai kandungan bahan organik, nitrogen dan fosforus yang tinggi. Disimpulkan bahawa tanah di WSSM adalah lebih baik dari AALL. Perbezaan yang signifikan dari jumlah karbon di dalam tanah dan karbon stabil dari asid humik telah dicatatkan di kedua dua lokasi dan perbezaan antara masa pertumbuhan menyimpulkan bahawa tanah di hutan bakau berpotensi untuk menyimpan karbon di dalam tanah. Walaubagaimanapun, kebolehannya bergantung kepada pertumbuhan hutan, kadar penguraian, sisa-sisa tumbuhan, lokasi, masa, sebatian dan bahan organik.

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I certify that a Thesis Examination Committee has met on 5 July 2013 to conduct the final examination of Empi anak Rambok on his thesis entitled "Sediment Carbon Storage and Related Chemical Properties of Mangrove Forests in Sarawak, Malaysia" 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 degree.

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

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DECLARATION

Declaration By Graduate Student

I hereby confirm that:

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This is to confirm that:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1 AALL - Awat-Awat, Lawas Limbang

2 AEP - Atlantic East Pacific

3 C - Carbon

4 CEC - Cation Exchange Capacity

5 CHA - Stable carbon from humic acid

6 CHNS – Carbon, Hidrogen, Nitrogen and Sulfur

7 CO_2 - Carbon dioxide

8 HA - Humic acid

9 H_2SO_4 - Sulfuric Acid

10 HCl - Hydrochloric Acid

11 IWP - Indo-West Pacific

12 IPCC - Intergovernmental Panel on Climate Change

13 IPIECA - International Petroleum Industry Environmental Conservation Association

14 K - Potassium

15 K_2SO_4 - Potassium Sulfate

16 KCl - Potassium Chloride

17 N - Nitrogen

18 NaOH - Sodium Hydroxide

19 $(NH_4)_6\ Mo_7O_{24}$ - Ammonium Molibdate

20 NH_4OAc - Ammonium Acetate

21 OM - Organic Matter

22 P - Phosphorus

23 SAS - Statistical Analysis System

24 SOM - Soil Organic Matter

25 TC - Total Carbon

26 WSSM - Wildlife Sanctuary Sibuti, Miri

CHAPTER 1

INTRODUCTION

1.1 Background

Mangrove forests have productive role in the ecosystems and majority of them are found in the sheltered shores in tropical areas. In Sarawak Malaysia, there are approximately 172,792 hectare (ha) of mangrove forests along the coastline regions (Bennett and Reynolds, 1993; IPIECA, 1993). They are responsible for the ecosystems development due to their high values. They also provide valuable services and goods such as timber, tourism, and aquaculture to human and also for protection of the environment (Bennett and Reynolds, 1993).

Forest ecosystems are the most prominent carbon sink on the earth surface. Approximately 60% of carbon in forest is stored as organic material in the soils (Janssen *et al.*, 1999). Deforestation and land-use change affects soil carbon storage because soils are either carbon source or pool depending on the variable response of carbon pool to land-cover change (Power *et al.*, 2004). Thus, deforestation and inappropriate land-use practices have caused several environmental complications such as reduction of soil organic carbon through decreased carbon sequestration and increased carbon dioxide (CO_2) emission to the atmosphere (Paustian *et al.*, 2000).

Plants grow in the forest through the process of photosynthesis use solar energy to assimilate atmospheric CO_2 into organic compound. Rate of photosynthesis in mangrove forests are different depending on many factors, such as light intensity, temperature, nutrient and water availability, salinity, tidal range, stand age, species composition, wave energy and weather (Alongi, 2009).

Mangrove forests are recognized for their high primary production capacity. Vegetations growing in the mangrove forests leads to remove and absorb CO_2 from the atmosphere through photosynthesis and sequester soil organic carbon in the soil. The organic carbon in soils and sediment are released to atmosphere as CO_2 when mangrove forests are waterlogged or otherwise altered and the soil which is rich in organic matter oxidized. They also have a high carbon sink and could contribute relatively more to global carbon exchange (De La Cruz, 1986).

1.2 Problem Statement

The vast area of mangrove forests in Sarawak is decreasing. According to Ahmad, (1989) and Tan and Basiron, (2000) the 174 000 ha mangrove forest in Sarawak decreased to 104 181 ha in 2000. Conversion of mangrove forests in Sarawak was for ecological and economic purposes. Moreover, mangrove forest plays an important role to sustain the ecosystem and ecology. It can be beneficially used as buffer zone to protect shoreline, nutrient cycling, and carbon sequestration.

Generally, depletion of forest cover relates to issues of global warming. Plants during photosynthesis synthesize carbon dioxide together with solar radiation in the atmosphere to form glucose and release oxygen. Some of the carbon dioxide utilized and absorbed by plants are restored in their plant tissues and in soil in organic form. On this basis, the primary production and forest performance are the key factors to reduce the amount of CO_2 in the atmosphere. Carbon 'storage and carbon sequestration' in the mangroves ecosystem can be the best processes to reduce the impact of global warming as mangroves store and sequester carbon in belowground (soil C) and aboveground (plant) biomass. Mangrove which is one of the fifth forest types found in Sarawak is highlighted to determine the belowground (soil) carbon storage due to the high interest to investigate these forests potential.

There are few published data and study on the potential of mangrove forests as belowground carbon storage in Sarawak. Despite few studies of carbon storage of mangrove forests in Sarawak, the data are insufficient to facilitate direct comparison across the mangrove forests as carbon pools obtained from different locations of mangrove forests in Sarawak. This little information and output hinders any attempt to optimally utilize the findings of the studies. On this basis, the determination of mangrove forests as carbon pools from different forests location is important in addressing mangrove forests for carbon storage, and environmental issues. This study also looked into the capability of biomass as one of the approaches to assess atmospheric carbon utilized by trees.

Forest performance is highly related to the soil properties. It is necessary to determine the characteristics of soil in a mangrove ecosystem in order to understand how these selected soil chemical properties affect the mangrove's soil carbon sequestration. From the findings, hopefully the best strategy and management plan can be developed for the mangrove ecosystems.

1.3 Objectives

The objectives of this study were as follows:

1. To determine and compare selected soil chemical properties of the Wildlife Sanctuary Sibuti, Miri and Awat-Awat Lawas, Limbang mangrove forests.
2. To determine and compare sediment carbon storage with time of the Wildlife Sanctuary Sibuti, Miri and Awat-Awat Lawas, Limbang mangrove forests.

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