



UNIVERSITI PUTRA MALAYSIA

***DISTRIBUTION, DEPOSITION AND SPATIAL VARIABILITY OF
CARBON IN SOIL USING CARBON AND NITROGEN STABLE
ISOTOPES***

FATHIA AHMAD M. ALASWAD

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By

FATHIA AHMAD M. ALASWAD

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

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DEDICATION

“And they ask you about the Sprit. Say: “The Sprit by command of my Lord: and you are not given aught of knowledge but a little.”

(Al-Quran Alkareem, Surat Al-Israa, 85)

Every challenging work needs self-effort as well as the guidance of elders especially those who are close to our heart. Whose affection, love, encouragement and praise through day and night make me able to reach such success and honor and the reason of what I become today. I dedicate my humble effort I to my sweet and loving

Almarhom Father& Mother

Whom always have been my epitomes of strength

My Husband

Who has been very understanding and patient

My Kids, My Family, My Friends

I am really grateful to you all!

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor Philosophy

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February 2018

Chairman : Ferdaus Mohamat Yusuff, PhD
Faculty : Environmental Study

Soil carbon (C) storage has gained much attention in the past decade due to its potentially huge impact on climate change mechanisms. However, there is still a lack of knowledge about the contribution of different C sources to soil organic carbon (SOC) formation, particularly in the subsoil. Land-use conversion to agricultural systems can affect soil C storage in terrestrial ecosystems by altering either the biotic or the abiotic processes involved in carbon cycling, such as the distribution of SOC in size at different depth of profile. The focus of this thesis was to; determine the impacts of land-use conversion on soil carbon distribution and dynamics, as well as (2) provide an understanding of the sources of C in the investigated site.

In this study, the organic carbon (OC) contents and their $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotopes of three soil profiles (0-30, 30-60 and 60-90 cm) under different land uses in the Selangor State in Southwest Malaysia were analyzed using (i) physical fraction of soil into different particle-size, (ii) natural abundance of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotopes and (iii) FTIR spectroscopy.

Regarding the effect of land use change on soil chemical and geo-physical properties, a two way MANOVA was used to analyses the data, with respect to spatial and depth variations, with Tukeys post-hoc tests to separate the means. Same analysis was also done for the distribution of SOC and ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) in different particle size fractions. Furthermore, Person correlation was used to determine the relationship between SOC and chemical and geo-physical properties of soil under different land use. Finally, discriminant analysis was applied to the data to predict the model of TOC (%) and SOC contents with respect to land use and depth. The results from MANOVA showed that, the conversion of secondary forest to rubber plantation caused significant decline

of SOC on top soil (0-30cm). Conversely, converting rubber to oil palm plantation and pasture lead to net gain of SOC. Relative to the soil depth, the top soil 0-30 had greater contents of SOC than sub soil of 30-60 and 60-90 cm.

However, in relation to $\delta^{13}\text{C}$ & $\delta^{15}\text{N}$ in different land use and depth, the value of $\delta^{13}\text{C}$ was enriched by increasing the depth of profile. According of different plant species, the value of $\delta^{13}\text{C}$ at top soil in pasture site indicted that the source of carbon in this site was from pasture $\delta^{13}\text{C}$ (-19.38), by increasing the depth of profile, the source of carbon was attributed to rubber plantation as revealed by $\delta^{13}\text{C}$ (-26.67) value. Interestingly, unusual value of $\delta^{15}\text{N}$ was reported on topsoil 0-30cm, which might be a useful indicator of the source and limited level of nitrogen in the area of study. Regarding to physical fraction, the highest value of SOC, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ were found in fine particles (clay and silt). Meanwhile, FTIR result revealed that, land use and soil texture plays the significant role for SOC composition.

This study concluded that, the relative distribution of SOC, its fractions, carbon $\delta^{13}\text{C}$ and nitrogen $\delta^{15}\text{N}$ stable isotopes and FTIR absorbance can be good indicators of the soil organic matter (SOM) quantity and quality. This study therefore recommended that, conversion of rubber to other plantation has more advantage to gain more carbon rather than conversion of secondary forest to plantation, and to quantify the effects of land-use changes and soil texture on soil organic carbon distribution, carbon stored in subsoil and chemical composition of SOM should be taken into account.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENGAGIHAN, PEMENDAPAN DAN KEBOLEHUBAHAN SPATIAL
KARBON DALAM TANAH PERLADANGAN UPM LADANG
PENGUNAAN ISOTOP STABIL KARBON DAN NITROGEN**

Oleh

FATHIA AHMAD M. ALASWAD

Februari 2018

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Penyimpanan karbon (C) tanah telah mendapat banyak perhatian sejak sedekad yang lalu disebabkan oleh kesannya yang berpotensi besar terhadap mekanisme perubahan iklim. Walau bagaimanapun, masih terdapat kekurangan dari sudut ilmu pengetahuan mengenai sumbangan sumber C yang berbeza kepada pembentukan karbon organik tanah (SOC), terutamanya di lapisan bawah tanah. Penukaran penggunaan tanah kepada sistem pertanian dapat mempengaruhi penyimpanan tanah C pada ekosistem daratan dengan mengubah sama ada proses biotik atau abiotik yang terlibat di dalam kitaran karbon, seperti taburan saiz SOC pada kedalaman profil yang berbeza. Fokus kajian ini adalah untuk (1) menentukan kesan-kesan penukaran kegunaan tanah ke atas pengagihan dan dinamik karbon tanah dan (2) memberi pemahaman tentang sumber C di tapak yang dikaji. Dalam kajian ini, kandungan karbon organik (OC) serta kandungan isotop $\delta^{13}\text{C}$ dan $\delta^{15}\text{N}$ bagi tiga profil tanah (0-30, 30-60 dan 60-90 cm) yang berlainan di Negeri Selangor iaitu Barat Daya Malaysia dianalisis dengan menggunakan (i) pecahan fizikal tanah ke atas saiz zarah yang berbeza, (ii) kelimpahan semula jadi bagi isotop stabil $\delta^{13}\text{C}$ dan $\delta^{15}\text{N}$ dan (iii) spektroskopi FTIR.

Bagi kesan perubahan penggunaan tanah ke atas sifat kimia tanah dan geofizikal, MANOVA (two way MANOVA) digunakan untuk menganalisis data yang berkaitan dengan perbezaan spasial dan kedalaman, manakala ujian post-hoc Turkey pula digunakan untuk memisahkan data min. Analisis yang sama juga dilakukan bagi taburan SOC dan ($\delta^{13}\text{C}$ dan $\delta^{15}\text{N}$) pada saiz zarah yang berbeza. Selain itu, korelasi Pearson digunakan untuk menentukan hubungan antara SOC dan sifat kimia serta geofizikal tanah pada penggunaan tanah yang berbeza. Akhir sekali, analisis diskriminasi (discriminant analysis) telah digunakan pada data bagi meramalkan model kandungan TOC (%) dan SOC pada penggunaan tanah dan kedalaman.

Keputusan dari MANOVA menunjukkan bahawa penukaran hutan sekunder untuk perladangan getah menyebabkan penurunan SOC yang ketara pada tanah atas (0-30cm). Sebaliknya, penukaran penanaman getah ke ladang kelapa sawit dan padang rumput menyebabkan penambahan SOC. Berkenaan dengan kedalaman tanah, tanah pada lapisan atas iaitu yang berketinggian dari 0-30 cm mempunyai kandungan SOC yang lebih besar daripada tanah yang berada di ketinggian 30-60 cm dan 60-90 cm.

Walau bagaimanapun, berhubung dengan $\delta^{13}\text{C}$ & $\delta^{15}\text{N}$ dalam penggunaan dan kedalaman tanah yang berbeza, nilai $\delta^{13}\text{C}$ semakin bertambah dengan peningkatan kedalaman profil tanah. Mengikut spesies tumbuhan yang berlainan, nilai $\delta^{13}\text{C}$ pada lapisan tanah atas di kawasan padang rumput menunjukkan bahawa sumber karbon di tapak ini adalah dari padang rumput $\delta^{13}\text{C}$ (-19.38), dengan peningkatan kedalaman profil, sumber karbon adalah disebabkan oleh ladang getah seperti yang dinyatakan oleh nilai $\delta^{13}\text{C}$ (-26.67). Menariknya, nilai $\delta^{15}\text{N}$ yang luar biasa dilaporkan pada lapisan tanah 0-30cm, yang mungkin merupakan penunjuk berguna sumber dan tahap nitrogen yang terhad dalam kawasan kajian. Mengenai pecahan fizikal, nilai tertinggi SOC, $\delta^{13}\text{C}$ dan $\delta^{15}\text{N}$ dijumpai dalam zarah halus (tanah liat dan lumpur). Sementara itu, hasil FTIR mendedahkan bahawa, penggunaan tanah dan tekstur tanah memainkan peranan penting bagi komposisi SOC.

Kajian ini menyimpulkan bahawa pengagihan relatif SOC, pecahannya, karbon $\delta^{13}\text{C}$ dan nitrogen $\delta^{15}\text{N}$ isotop stabil dan penyerapan FTIR boleh dijadikan sebagai penunjuk yang baik bagi kuantiti dan kualiti bahan organik (SOM). Oleh itu, kajian ini mencadangkan supaya penukaran getah ke ladang lain mempunyai lebih banyak kelebihan untuk mendapatkan lebih banyak karbon daripada penukaran hutan sekunder ke perladangan, juga untuk mengukur kesan perubahan penggunaan tanah dan tekstur tanah terhadap pengagihan karbon organik tanah, karbon yang disimpan dalam tanah selain perlu mengambil kira komposisi kimia SOM.

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I certify that a Thesis Examination Committee has met on 6 June 2018 to conduct the final examination of Fathia Ahmad M. Alaswad on her thesis entitled "Distribution, Deposition and Spatial Variability of Carbon in Soil Using Carbon and Nitrogen Stable Isotopes" 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 Doctor of Philosophy.

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LIST OF ABBREVIATIONS

BBOT	2, 5(Bis-tert-butyl-2-benzo-oxanol-2yl) thiophene.
DA	Discriminant Analysis
BD	Bulk Density
Cdp	Carbon derived from pasture
Cdr	Carbon derived from rubber
C	Carbon
$\delta^{13}\text{C Vp}$	Carbon stable isotope values in pasture (leaves and root).
C3	C3 photosynthesis: the type of carbon assimilation performed by most plants. This is the most efficient form of photosynthesis under moderate to cool temperatures, high CO ₂ concentrations, and high water availability.
C4	C4photosynthesis: a form of photosynthesis that is evolutionarily derived from C3 photosynthesis, but which includes an additional mechanism for actively transporting CO ₂ into specialized cells where photosynthesis occurs. This makes C4 plants particularly tolerant of high temperatures, low water availability, and/or low CO ₂ concentration. C4 photosynthesis is most common among grasses, including maize, millet, and sorghum.
$\delta^{13}\text{C srf}$	Carbon stable isotope value in soil under references area (rubber)
$\delta^{13}\text{C Sc4}$	Carbon stable isotope value in soil under pasture
CO ₂	Carbon Dioxide
$\delta^{13}\text{C}$	Natural abundance of Carbon Stable Isotope
CCr	Canonical Correlation
D	Depth
DIW	De Ionized Water
FTIR	Fourier-transform infrared
HCL	Hydrochloric Acid
LUC	Land Use Change

MRT	Mean Residence time
MAT	Mean annual temperature
MAP	Mean annual precipitation
NAP3	Third National Agriculture Policy
NaOH	Sodium Hydroxide
$\delta^{15}\text{N}$	Natural Abundance of Nitrogen stable Isotope
OM	Organic Matter
OC	Organic Carbon
OP15	15 years old oil palm plantation
OP5	5 years old oil palm plantation
P	Pasture
POM	Particulate organic matter
R	Rubber plantation
SOC	Soil Organic Carbon
SOCs	Soil Organic Carbon Stock
SF	Secondary Forest
SOM	Soil Organic Matter
TBG	Tropical Grass Biomass
V-PDB	Vienna Pee Dee Beleminte, Standard
WC	Water content

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Soils provide multiple ecosystem services, allowing sustained food and fibre production, and delivering climate regulation, flood regulation, improved air and water quality, reducing soil erosion, and provide a reservoir for biodiversity. Understanding and predicting the fate of OC in soils is a key focus for our society to understand not only the current but also the forecasted global changes. Soils are dynamic interactions of organic matter (OM), minerals, gases, water, and dissolved constituents. Recently the dynamics of SOC and the capacity of soil to accumulate and stabilize OC in response to land use change have become a focus of research in the scientific debate on global climate change.

Soil organic carbon (SOC) is the largest carbon pools on earth's surface and it plays an important role in global carbon cycling (Scharlemann et al., 2014; Xin et al., 2016). Therefore, any small change in the soil C pool can potentially affect atmosphere carbon dioxide (CO₂) concentration and regional or global C balances (Marin-Spiotta et al., 2009; Don et al., 2011; Zatta et al., 2014). Maintaining and increasing SOM is a prominent strategy for mitigation atmospheric CO₂ and adapting agriculture to climate change (Walthall et al., 2012; Xin et al., 2016). It has long been recognized that land cover change and management can alter the amount of OC stored in the soil and decomposition rate (Laganiere et al., 2010; Deng et al., 2014; Zhang et al., 2015; Zhu et al., 2016) and this in turn affects both soil fertility and atmospheric CO₂ concentrations (Powers et al., 2011; Yonekura et al., 2012; Zhang et al., 2015), and thus potentially affects C sequestration and loss (Deng et al., 2016; Zhu et al., 2016).

Land use changes are the second largest source of human induced greenhouse gas emission, mainly due to deforestation in the tropics and sub-tropics. In the tropics land use changes are responsible for 12-20% of the human induced greenhouse gas emissions (Van der Werf et al., 2009; Don et al., 2011), and 13 million ha being deforested per year (Don et al., 2013) and greatly impacts soil C dynamics by altering C inputs, decomposition, and turnover (Yonekura et al., 2012; Zhang et al., 2013). Due to increasing the attention upon the responses of C pools in different soil particle size fractions to climate change (Nian-Peng et al., 2014; Loss et al., 2016; Sistla et al., 2016) physical fraction of SOM has provided useful information about the dynamics in nature and agricultural environments (Chen et al., 2010; Shang et al., 2014; Sistla et al., 2016), also sensitive indicators of changes in soil quality (Wei et al., 2014), structure and function of SOC (Shang et al., 2014). Therefore, analysis of these fractions can provide important insight about how soil OC responds to changes in land use (Benites et al., 2010; Loss et al., 2016). An estimated 42,000 megatons of ancient carbon is stored in 12% of the total land area of Southeast Asia alone, making this of

the largest stores of terrestrial carbon on Earth (Tonks et al., 2017). The increase of agricultural land area in the tropics is ongoing mainly at the expense of primary and secondary forests (Gibbs et al., 2010; Guillaume et al., 2016). While tropical deforestation rates are tending to stabilize or to decrease in regions like Brazil, they are still increasing in Indonesia and Malaysia, driven by the international demand for cash crop plantation products such as wood, agro-biofuels (particularly oil palm) and commodity-based tree cash crop plantation (particularly rubber) (Mganga & Kuzyakov, 2014; Abood et al., 2015; van Straaten et al., 2015; Kurniawan et al., 2016).

Studies on the conversion of lowland tropical forest to rubber and oil palm plantations showed contrasting results with regard to SOC (Guillaume et al., 2015). Significant decreases of SOC under rubber and oil palm plantations were reported down to 1 m depth (Busch et al., 2015; Kotowska et al., 2015; Mande et al., 2015), or only in the topsoil (Schroth et al., 2002; Chiti et al., 2014). In contrast Patthanaissaranukool & Polprasert, (2011); Siangjaeo et al., (2011); Flynn et al., (2012); Frazão et al., (2013); Kho & Jepsen, (2015); van Noordwijk et al., (2015); Adugna & Abegaz, (2016); Burton et al., (2016) reported that, no differences or even slightly higher SOC stocks under oil palm plantations than in the surrounding forest. Those inconsistent results may depend primarily on multiple factors including previous land use change, climate and species planted (Laganiere et al., 2010; Burton et al., 2016). Particularly, species planted are expected to alter SOC stock by affecting the amount and quality of C inputs (Wei et al., 2010; Jiang et al., 2011). Detecting changes in bulk soil with complex compounds that differ in decomposition rates may, thus, be helpful to better understand soil C dynamic (Marin- Spiotta et al., 2009; Suryawanshi et al., 2018).

Land use and land cover transitions provide a unique opportunity to utilize the natural abundance of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotopes to evaluate changes in C and N dynamics (Zhang et al., 2015; Deng, et al., 2016; Sun et al., 2016; Liu et al., 2017; Muhammad et al., 2017). Stable isotopes provide one of the most effective means of constraining uncertain components of the global carbon (C) cycle, such as the net carbon exchange between the terrestrial biosphere and atmospheric reservoirs, and the size and partitioning of terrestrial carbon reservoirs (Lacey et al., 2015; Qiu et al., 2015; Zhang et al., 2015; McCorkle et al., 2016), monitoring environmental change (Balesdent et al., 1993; Deng et al., 2016), explore the mechanisms of new and old soil OC changes after land use changes especially when C3 vegetation is replaced by C4 vegetation (Balesdent et al., 1993; Yonekura et al., 2012; Mendez-Millan et al., 2014; Guillaume et al., 2015; Qiu et al., 2015; Zhang et al., 2015; Deng et al., 2016), sourcing SOM in natural and agricultural landscapes (Balesdent et al., 1996; Portenga & Bierman, 2011; Lacey et al., 2015; McCorkle et al., 2016), estimate the degree of decomposition and humification of SOM (Wynn et al., 2006; Peri et al., 2012), evaluate nitrogen transformation and mineralization (Nadelhoffer & Fry, 1994; Zhang et al., 2014; Busari et al., 2016), and processes of nitrogen cycling and fixation (Ryabenko, 2013; Unkovich, 2013; Zhang et al., 2014).

However, like many studies into SOC dynamics in Asia, (Yonekura et al., 2012; Guillaume et al., 2015, Zhang et al., 2015), these investigations focused on processes within the top 30 cm of soil. Subsoil organic carbon comprises a large (70%) of SOC is located below the top 20 cm, (Batjes, 2016; Hobbey et al., 2016) yet still poorly understood (Rumpel & Kögel-Knabner, 2011) component of the global carbon cycle. With increasing depth from the surface, SOM generally increases in age (Hobbey et al., 2013; Hobbey et al., 2016), implying enhanced stability, and its utilization as a carbon source by microorganisms (Kramer & Gleixner, 2008; Deng et al., 2014; Pérez-Pantoja, 2015) and hence more carbon dynamics at depth than at the surface. Understanding SOC dynamics and its role in the global carbon cycle therefore requires investigation of both topsoil and subsoil.

However, there is lack of investigation using the stable carbon isotope technique to explore new and old soil OC distribution in different depths relating to agricultural plantation in Malaysia, which are fundamental to our understanding the effects of land use change on the environment.

1.2 Statement of the Problem

The increase in the population and the resultant increase in the per capita consumption have resulted to the ecosystem degradation and decrease in biodiversity all over the world. As such agricultural intensification due to production of food, fuel, fibre and animal feed, has generated essential benefits for human well-being (Godfray et al., 2010). However, this comes with a multiplicity of externalities (Newbold et al., 2015). The externalities negatively affects human well-being eventually (Pullin et al., 2013; McKinnon et al., 2016), some of these they are linked to greenhouse gas emissions (Smith et al., 2008; Smith et al., 2016), causing decrease in biodiversity (Gibson et al., 2011; Drescher et al., 2016), and various ecosystem services degradation affecting air quality, water treatment, carbon storage or soil erosion (Obidzinski et al., 2012; van Straaten et al., 2015; Drescher et al., 2016; Smith et al., 2016).

Moreover, the growing concern among scientists and research in recent times on the accumulation of atmospheric CO₂ levels combined with the efforts to mitigate climate change have resulted considerably in the growing interest on the world's soil carbon (Pachauri & Reisinger, 2007; Fang et al., 2018). As land-cover change is believed to be the second most significant source of anthropogenic greenhouse gases (GHG) emissions. This led to the generation of nearly 7–14% of the total CO₂ emissions all over the world (Harris et al., 2012).

Furthermore, studies have shown that most significant contribution to global warming from land conversion to oil palm plantation emanates right from agricultural stages, which are 15% in cultivation, 17% at clearance stage and 18% at replanting stage. Most of this recent deforestation has taken place in tropical countries (Kim et al., 2015; Lawrence & Vandecar, 2015). It has also been shown that conversion of rubber estate

to oil palm plantation lead to synthetic production rubber from fossil fuel so as to meet the world rubber demand through industrial process that produces highest carbon emissions (Hansen et al., 2014). Yet, carbon emissions are less from the conversion of a rubber estate than the conversion of a tropical forest (high carbon stock land) into an oil palm estate (Castanheira et al., 2014; Hansen et al., 2014).

In Malaysia, the development of oil palm and rubber, are the primary causes of forest loss (Abdullah & Nakagoshi, 2008). The land conversion resulted in the loss of approximately 10,000 km² of forest cover (Otieno et al., 2016), also on former rubber and coconut plantations (Abdullah & Nakagoshi, 2007). This has resulted in a serious land cover challenges in Malaysia (Tao et al., 2013; Azizan et al., 2017). Also the oil palm plantation constitute about 77% of agricultural land or about 15 % of total land area (Board, 2012), the planted area increased from 5.23 million hectares in 2013 to 5.39 million hectares in 2014, an increase of 3.0 % (MPOB, 2015).

Hence, these conversions have affected soil C storage and there is still considerable uncertainty about soil CO₂ efflux and subsequently loss and accumulation rates in the tropical countries including Malaysia. Soil C pools change rapidly in response to land use change, and contributes to nearly 20% of GHG emissions Houghton et al., (2012). Soil C sequestration research has historically focused on the top 0–30 cm of the soil profile, ignoring deeper portions that might also respond to management (Syswerda et al., 2011; Meersmans et al., 2012).

However, the influence of soil depth on soil C dynamics as affected by land use changes still remain poorly understood. In particular, deep soils are a major reservoir of organic C in terrestrial ecosystems, thus are known to store more than half of the total soil C (Batej, 2016). Therefore, a small change in deep soil C can have a major effect on overall soil C dynamics (Lawrence et al., 2015; Wang et al., 2016). Consequently, a thorough understanding of how deep SOC mineralization is sensitive to fresh organic C input in relation to land use changes can be important for a better understanding of the responses of the soil C pools to global climatic changes (Perveen et al., 2014). This is because SOC mainly originates from terrestrial higher plants and the fractionation of SOC decomposition in soil is much lower than that of CO₂ fixation by plant photosynthesis (Natlhoffer & Fry, 1988; Zahang et al., 2014), the $\delta^{13}\text{C}$ of SOC is close to those of the plant from where it was derived.

Previous literature indicated proliferation of studies on the effect of land use on carbon distribution, about 45% abound from 1980- 2017. But studies relating to conversion of rubber to oil palm plantation are scarce. A United Nations Development Report indicated that carbon dioxide emissions in Malaysia has increased by 221% during the period of 1990 to 2004, and the country is included in the list of 30 biggest greenhouse gas emitters, Alam et al., (2015). Currently Malaysia ranks as the 26th largest greenhouse gas emitter in the world with a population of about 27 million, and it appears likely to move up the list quickly due to the growth rate of emissions (Alam et al., 2013).

In spite of this, knowledge of the impact of the different land conversion stages involved in the establishment of oil palm plantations, in terms of decomposition, C stocks and physico-chemical properties at subsoil is extremely limited, most previous work focused on binary comparison of intact forest and mature oil palm plantations at topsoil. In view of these, the objectives of this study were to determine the effect of soil depth and land cover on the soil physicochemical properties namely; bulk density (Bd), soil texture, pH, soil organic matter (SOM), total organic carbon (TOC), total organic nitrogen (TON) and their corresponding stable isotopes; $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ and the chemical composition of SOM.

1.3 Research Objectives

The general objective of this study is: To study the effect of land use change on the organic carbon distribution with regards to different soil depth.

Specific objectives:

1. **To** determine the effect of land use change on soil properties (Biochemical and physical properties).
2. **To** evaluate the effect of land use change on the amount and vertical distribution of C content and $\delta^{13}\text{C}$ & $\delta^{15}\text{N}$ in bulk soil and in different particle size fractions of the soil at selected agricultural land use (rubber (R), pasture (P), oil palm with different age of plantations (OP), and secondary forest (SF) and at relevant different depth of a soil profile.
3. **To** investigate the impact of land use change on the structure characteristics of OM in the studies soil.
4. **To** estimate the relation between SOC and physio-chemical properties and $\delta^{13}\text{C}$ & $\delta^{15}\text{N}$ of studied soil at selected sites.

1.4 Research Hypotheses

The hypothesis was put forward in this study according to the objectives of study:

H1: Impact of land use significantly changes in C storage as well as soil properties, and natural abundance of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotopes.

H2: There is a significant correlation among the soil characteristics, and natural abundance of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotopes.

H3: Soil organic carbon content, soil characteristics and natural abundance of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotopes significantly differ with depth increment across the land-use systems in agricultural soil, and secondary forest.

H4: Soil organic carbon content, nitrogen and natural abundance of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotopes significantly differ with particle size increment across the land-use systems in agricultural soil, and secondary forest.

1.5 Significant of the Study

It is a fact that conversion of rubber plantation to oil palm plantation will decrease the CO_2 emission or decrease the loss of OC storage from the soil (Allen et al., 2015). Therefore, this study will help in estimating the amount of C sequestered in the converted rubber plantation to oil palm plantation and pasture at different depth of profile and different age of plantation which is expected to be beneficial to the department of agricultural Malaysia in future planning and management of plantation.

The findings from this study will be significant to the realization of Malaysia's aspiration of reducing its GHG emissions intensity by 2020 as this study will provide an idea of different C sequestration levels at different agricultural plantation. This study is also expected to contribute to Malaysia policy thrust of increasing productivity as well as conservation and utilization of sustainable natural recourse base as outline in the Third National Agricultural Policy (NAP3).

Hence, using a precision, nontoxic, safe and fast method to measure C distribution and to remove the conflict about the emission of CO_2 from plantation is needed in soil and environmental research. This study will add data on C accumulation in sub soil. Furthermore, this study will contribute academically to the growing literature on the monitoring of the sources and the effects of land use on the accumulation of C in the soil.

1.6 Scope of the Study

Contribution of better understanding of C distribution with providing natural $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotope data in of both topsoil and subsoil during agricultural ecosystem development will increase our understanding of the effects of LUC on the environment. This study concerned about examines new and old soil OC distribution in different depth relating to agricultural plantation in Malaysia by using the natural $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotope technique.

This study was conducted in agricultural plantation of oil palm (*Elaeis guineensis*) aged five and fifteen years respectively as well as a rubber plantation (*Hevea brasiliensis*) and the pasture (*Panicum Maximum*) at the Universiti Putra Malaysia (UPM) farm, and the secondary forest one hundred years old at Puchong, Selangor (Ayer Hitam forest reserves in Puchong), as references material at various depth (0-30, 30-60 and 60-90 cm). Additionally, because SOC is more variable in space and time in oil palm plantation than other crops, the samples was collected from different

distance (1.5m (weed circle, 3m (inter -rows)) and 4.5m (fruit bunches)). Natural carbon stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$), soil carbon stock (SOCs), total organic carbon (TOC), total organic nitrogen (TON) in bulk soil and in each physical fraction, water content, soil pH, bulk density, cation exchange capacity (CEC), chemical composition of SOM and soil texture in bulk soil were determined.

The location of this research is within the agricultural plantation at Universiti Putra Malaysia (UPM) farm, Serdang, and at secondary forest at Puchong as reference site. This study will helpfully bridge the knowledge gap in terms of soil carbon distribution data from different plantation, grass and forest and from different soil series at different vertical depth, and its impact on the land use and soil texture on carbon storage in tropical soil in the Peninsular Malaysia.

1.7 Thesis Outline

In order to meet the aims and objectives outlined in Chapter 1.3 this thesis will take the following format:

The first chapter presents a brief background of the effects of land cover conversion on the environment with focusing on the vertical distribution of carbon in agricultural systems and highlights the research problems. Additionally, describing the objectives of research, and defines the significant of study, and finally defines the boundaries of the work.

Information on the carbon cycle, effects of land use changes on carbon storage, and C stock as well as carbon and nitrogen stable isotopes have been reviewed in Second chapter.

In the third chapter, description of the study area and general material and methods have been presented and discussed.

The Fourth chapter reports the results and discussions of the effects of land use change on variability and vertical distribution of SOC within sites and at different depth of profile. The first section of the chapter presents the effects of conversion secondary forest to rubber plantation on the physio-chemical properties at different depth of profile as well as presents the effects of conversion of rubber plantation to oil palm plantation with different age and pasture on the physio-chemical properties. The second section of the chapter present the effects of conversion secondary forest to rubber plantation, and then the conversion of rubber to oil palm plantation with different age and pasture on the natural abundance of carbon and nitrogen stable isotopes value at different depth of profile. The third section display the vertical distribution of SOC, SON and related natural abundance of carbon and nitrogen stable isotope in different particle size as effected by land use change. Fourth section visualizes the percentage

of carbon derived from rubber and pasture at bulk soil and different particle size by using mass balance equation, the last section demonstrate the correlation between SOC and different physiochemical properties and naturel abundance of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotopes at selected site.

The Fifth chapter provides summary and conclusions that were drawn from the research and recommendations for future study.



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