GREENHOUSE GAS EMISSIONS FROM TROPICAL PEAT FOREST AND PEAT OIL PALM PLANTATION – A REVIEW

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This project is submitted in partial fulfillment of
the requirements for the Degree of Bachelor of Engineering with
Honours (Civil Engineering)

To my beloved parents and family

ACKNOWLEDGEMENT

I would like to take the opportunity to express my sincere appreciation to people that have given contributions towards the success of this thesis. First and foremost, I would like to thank God for His grace and mercy throughout this project. It is by His hands and wisdom in guiding me to finish my work within study period.

My appreciation also goes to my FYP supervisor, Professor Ir. Dr Law Puong Ling for his academic guidance throughout this project. Thanks for gave out a lot of precious time for discussion and checking errors in my thesis.

I would also like to thank Universiti Malaysia Sarawak for providing a resourceful library that enabled me to gain adequate information for my thesis.

Last but not least, I would like to thank my family members and friends for all your support and care.

Thank you.

ABSTRAK

Ulasan jurnal telah dibuat bagi menentukan pembebasan gas rumah hijau (GHG) dari hutan gambut and penanaman kelapa sawit di kawasan gambut. Kebanyakan GHG adalah terdiri daripada CO_2, CH_4, dan N_2O, dengan CO_2 mangandungi 90% daripada keseluruhan GWP manakala CH_4 dan N_2O hanya mengandungi <1% daripada jumlah GWP. Kebanyakan kawasan gambut berada di Asia Tenggara (69%) yang mana Indonesia menyumbang 53.1% daripada potensi karbon tenggelam global dengan karbon simpanan dianggarkan bernilai 20.28 Mt C yr^{-1}. Kawasan gambut yang telah ditebang mempunyai pembebasan GHG yang lebih tinggi daripada hutan gambut semulajadi disebabkan pertambahan pembebasan CO_2 daripada pembakaran (1.42 - 4.32 Gt/y) dan juga daripada penguraian semula di parit (700 Mt yr^{-1}, tahun 2009). Penanaman kelapa sawit di tanah gambut telah menyebabkan hutang karbon yang tinggi (melebihi 3000 Mg ha^{-1}) untuk dibayar disebabkan oleh pembebasan carbon yang tinggi kepada udara semasa penebangan (648 ± 337 Mg ha^{-1}) dan juga daripada penguraian semula di tanah (55 Mg of CO_2 ha^{-1} yr^{-1}). Walaubagaimanapun, penanaman kelapa sawit di kawasan berrumput telah didapati berupaya mengurangkan CO_2 dengan nilai 135 Mg ha^{-1} CO_2. Jadi, penanaman kelapa sawit di kawasan berrumput adalah lebih sesuai bagi mengurangkan pembebasan GHG.

ABSTRACT

Reviews had been carried out on related journals in determining the GHG emissions from tropical peatlands and peat oil palm plantations. Majorities of GHG are CO_2, CH_4, and N_2O, with CO_2 consisted of 90% of total GWP while CH_4 and N_2O contributed <1% of total GWP. A majority of tropical peatlands are located in Sourtheast Asia (69%) while Indonesia alone has accounted for 53.1% of global potential carbon sink with estimated carbon storage of 20.28 Mt C yr^{-1}Degraded peatlands have relatively higher GHG emissions than natural peat forests due to additional CO_2 emissions from peat fire (in range of 1.42 to 4.32 Gt/y) and soil decomposition in drainage (approximately 700 Mt yr^{-1}, year 2009). Establishment of oil palm plantation on peat soil resulted in a high carbon debt (over 3000 Mg ha^{-1}) to pay due to large amount of carbon losses into atmosphere during land clearing (648 ± 337 Mg ha^{-1}) and soil decomposition in drainage (approximately 55 Mg of CO_2 ha^{-1} yr^{-1}). However, oil palm plantation established on grassland rehabilitation acted as carbon sink with a net sequestration of 135 Mg ha^{-1} CO_2. Therefore, it is preferable for establishing oil palm plantations on grassland rehabilitation.

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GHG	-	Greenhouse Gases
GWP	-	Global Warming Potential
CO_2	-	Carbon Dioxide
CH_4	-	Methane
N_2O	-	Nitrous Oxide
Ha	-	Hectare
Pg	-	Petagram (g x 10^{15})
Gt	-	Gigatonne (t x 10^{9})
Mg	-	Megagram (g x 10^{6})
mg	-	Milligram (g x 10^{-3})
%	-	Percent
FAO	-	Food and Agriculture Oragnization of the United Nations

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CHAPTER 1

INTRODUCTION

1.1 Greenhouse Gases (GHG)

Greenhouse effect is no doubt one of the major problems nowadays due to its contribution to the global warming. Greenhouse effect is caused by the trapping of heat from the sun in lower atmosphere of the earth. Greenhouse gases (GHG) are gases in the atmosphere which give rise to this greenhouse effect. GHG allow shortwave or solar radiation to penetrate down to the atmosphere and the Earth's surface (The Green Lane, 2003). GHG traps heat in the atmosphere which then causing the radiation been absorbed and the Earth's surface becomes warm.

Greenhouse gases can be produced either in natural or man-made. "Natural greenhouse effect" is an important phenomenon to biological life on Earth. "Enhanced greenhouse effect" is caused by human activities such as burning fossil fuels, deforestation or land surface change, industrial processes, etc. The additional GHG produced by enhanced greenhouse effect has increased the concentration of

GHG in the atmosphere at an alarming rate thus changing the temperature and climate system which then contribute to global warming. The main GHG fluxes are: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

1.2 Peat Forest

Tropical peatlands are major storage for carbon dioxide and source of atmospheric methane. The peat content in Southeast Asia is the highest among regions, as much as approximately 69% of overall global peat. According to Rieley et al. (2008), peat swamp forests in natural state have the ability to sequester carbon from the atmosphere during photosynthesis, retain this in plant biomass and store part of it in the peat. The change in peatland C storage results from changes in the balance between net exchange of CO_2, emission of CH_4, and hydrological losses of carbon (e.g. dissolved organic and inorganic C and particulate organic C) (International Peat Society, 2008). Net peatland flux is determined largely by the net balance between CO_2 uptake in photosynthesis and C release by ecosystem (autotrophic and heterotrophic) respiration (Rieley et al., 2008). Recently, GHG emissions released from peat forest have increased rapidly due to over deforestation for agricultural developments. Figure 1.1 shows the carbon cycle in natural peat forest.

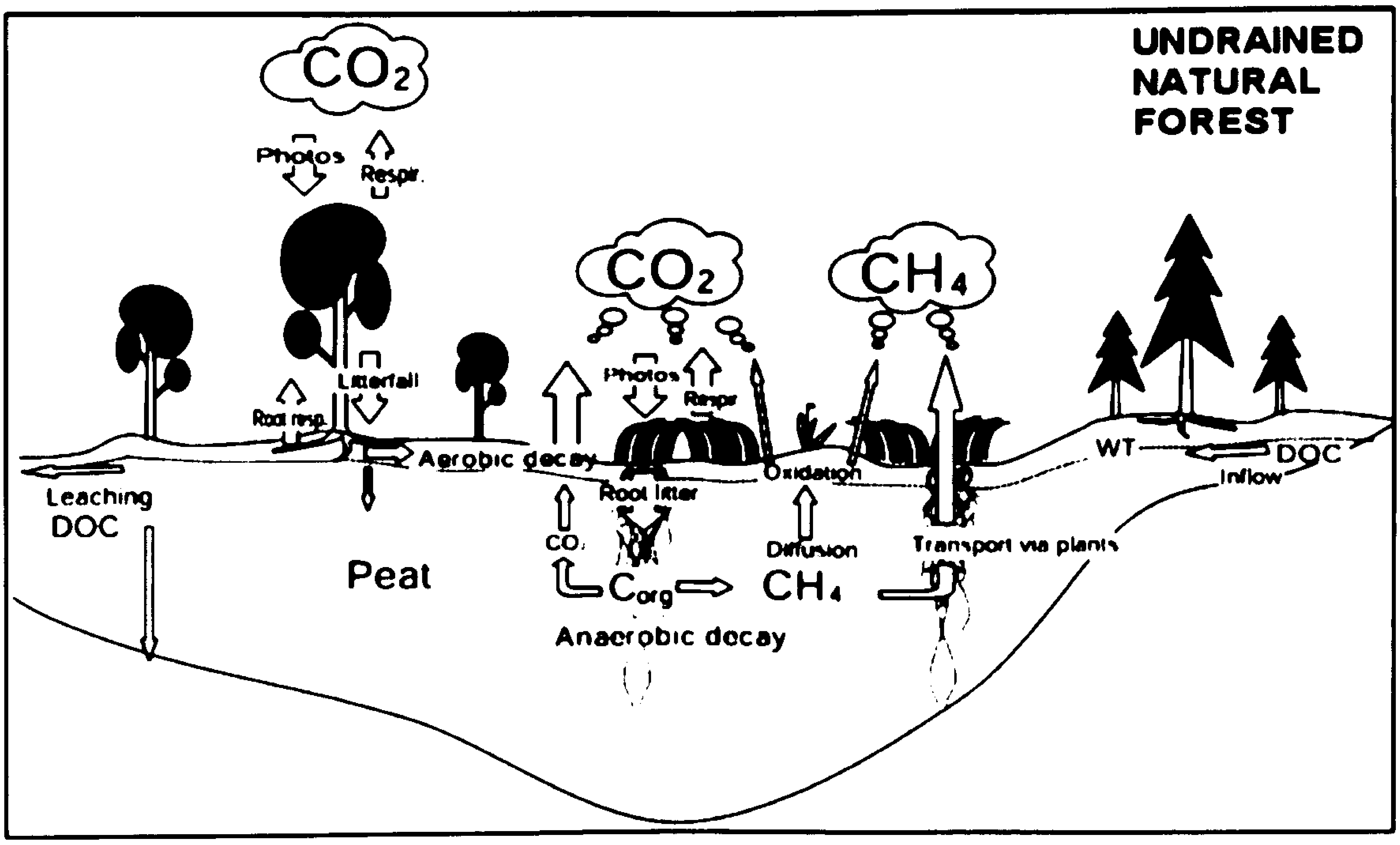

Figure 1.1: Carbon Cycle in Natural Peatforest
(Source: Minkkinen et al., 2008)

1.3 Oil Palm Plantation

Global palm oil production is increase by 9% every year due to the expanding of biofuel markets in European Union and by food demand in Indonesia, India and China (Clay, 2004; European Commission, 2006). Oil palm plantations are structurally less complex than natural forest with uniform tree age structure, low canopy, sparse undergrowth, less stable microclimate and greater human disturbance and are cleared and replanted on a 25-30 year rotation (Corley and Tinker, 2003; Danielsen et al., 1995; Peh et al., 2006). Oil palm is harvested in many tropical countries on more than 12 million hectares and yields over 32 million tonnes of oil annually. It accounts for more than one quarter of the global vegetable oil market and is the most important oil crop next to soy bean. (Germer and Sauerborn, 2000)

Indonesia and Malaysia own the largest oil palm production (over 80%) in global oil palm plantation. Oil palm plantations in Indonesia often replace forests which are previously degraded by fire and logging and illegal oil palm development has been increased by 4.4 million ha to 6.1 million ha with the total forest loss about 28.1 million ha in peatland and climate change (FAO, 2006; Hansen et al., 2005; McMorrow et al., 2001; Ministry of agricultural republic of Indonesia).

In Malaysia, oil palm was first planted commercially in Peninsular Malaysia since 1917 for replacing rubber plantations and forest (Corley et al., 2003; Abdullah et al., 2007). As land became scarce, its expansion was shifted to Sabah and Sarawak in association with logging and was facilitated by the reclassification of some state forest reserves to allow conversion to oil palm plantations (Hansen et al., 2005; McMorrow et al., 2001). Between 1990 and 2005, the oil palm plantation area in Malaysia has increased by 1.8 million ha to 4.2 million ha while 1.1 million ha of forest were lost (FAO, 2006; Malaysian Palm Oil Board). Oil palm establishments usually associated with deforestation, peat fire, and peat drainage which resulted in high amount of GHG emissions due to carbon losses in peat soil. Therefore, further studies should be done for determining oil palm plantation impact to the greenhouse effects.

1.4 Problem Statement

There are uncertainties and knowledge gaps in determine GHG emissions from peatlands. According to Page et al. (2008), although tropical peatlands have global significant carbon sinks that store large amount of carbon, the data on this information are subjectd to uncertainly and errors due to inaccuracy of precise peatlands locations because of rapid land-use change developments in recent years.

Since the smog episode in 1997 in Southeast Asia, oil palm has been at the centre of an environmental controversy as oil palm was seen to be a polluter which use substantial input such as fertilizers and pesticides, discharging considerable amounts of effluent from oil mills, and consuming large amounts of water during processing (Lamade and Bouillet, 2005). However, oil palm itself has high carbon sequestration which can help to reduce atmospheric GHG through carbon fixation. Therefore, this paper focuses on determining the major GHG fluxes in peatforest and oil palm plantation establishment.

1.5 Scope of Study

This study focused on extensive literature review on the greenhouse gas emissions from tropical peat forest and peat oil palm plantation. It is concentrated on data compilation and statistical data analysis from journals, scientific magazines, news, engineering websites etc which is related about greenhouse gas emission from peat forest and oil palm plantation. GHG are compared based on its types, emission rate, and global warming potential under different situations such as waterlevel, types of vegetation, drainages, peat fire etc. By reviewing and comparing all the available data and information, it comes out with problem identification and recommendations.

1.6 Aim and Objectives

The purpose of this research is to compare the amount of GHG emissions from peat forest and peat oil palm plantation. It is essential for determining the effectiveness of carbon sequestration in peat forests and oil palm ecosystems in order to find the best solution to mitigate global climate change which caused by GHG emissions.

The main objectives are:

- To study the amount of greenhouse gases produced by peat forest and palm oil plantation under different situations.
- To determine the types of greenhouse gases produced by peat forest and palm oil plantation.
- To compare the emission rate of GHG in peat forest and oil palm plantation.
- To investigate the causes for GHG formations and emissions from peatforest and peat oil palm plantations.
- To study the effectiveness of peat oil palm plantations in reducing GHG emissions.
- To search for effective solutions for mitigating GHG emissions.

1.7 Structure of Thesis

This thesis consists of five chapters which aim to clarify the concepts in determining the major GHG emissions from peat forest and peat oil pal plantations.

Chapter 1 gives general information related to greenhouse gases effects, greenhouse gases (GHG) emissions from peat forest, and oil palm plantations in Southeast Asia. Figure 1 illustrate about carbon cycle in natural peat forest.

Chapter 2 is the literature review on journals and websites about greenhouses gases (GHG) emissions from natural peat forests, degraded peat forests, and peat oil palm plantation. It focuses on the major fluxes between sources and sinks of GHG in peatforest and oil palm plantation establishment. It also mentioned about peatland distribution and carbon storage in Southeast Asia. GHG formation and emissions from different peat ecosystems are also studied.

Chapter 3 describes the methodology which is formed from analysis of data and information collected. The steps are background study, data collections, results and discussions, and finally, conclusion and recommendations.

Chapter 4 focuses on the results and discussions of this study. Graphs and tables have been plotted for indicating the results. Discussions are made based on the given results.

Chapter 5 assimilates the conclusion of this research. It consisted of the overall results for GHG emissions from different land use in peatlands. Effectiveness and suitability of method to mitigate greenhouse gases emissions in oil palm plantations are discussed and recommendations are given for improving the problems.

CHAPTER 2

LITERATURE REVIEW

2.1 Tropical Peatland: Distribution and Carbon storage

Tropical peatlands are found in mainland East Asia, Southeast Asia, the Caribbean and Central America, South America and southern Africa with current estimate of the total area of undeveloped tropical peatland is in the range 30 45 million hectares, which is approximately 10-12% of the global peatland resource (Immirzi & Maltby, 1992; Rieley et al., 1996). In lowland Southeast Asia, peatlands form part of the mosaic of rain forest types that includes mangrove, lowland dipterocarp, heath, montane and cloud forests (Rieley et al., 1996; Page et al., 1999).

Most tropical peatlands are located at low altitudes where peat swamp forest occurs on top of a thick mass of organic matter, to which it has contributed over thousands of years, forming accumulated deposits up to 20 m thick (Anderson, 1983). According to Fargione et al. (2008), soil and plant biomass are the two largest biologically active stores of the terrestrial carbon which both of them contain