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SYNOPSIS

"Reducing greenhouse gas emissions from peatlands cultivated to oil palm" by Prof. Abdul Hadi, Ph.D.; Prof. Luthfi, Ph.D.(Lambung Mangkurat University); Prof. Dr. Dedi Nursyamsi (Ministry of Agriculture of Indonesia), and Prof. Dr. Kazuyuki Inubushi (Chiba University).

This book consists five chapters. The first chapter is Introduction chapter. This chapter explains the definitions of peat soil, the species of greenhouse gas (GHG), and prior studies related to GHGs' issues. This chapter also updates the status of oil palm market and development in Borneo Island, as well as the global.

Introduction chapter is followed by a chapter about People View in GHG Issues (Chapter 2). This chapter was mainly composed from the primer and secondary data. The primary data was obtained through interview, while the secondary data was mainly statistics published by Statistics Center Agency. Some students of Lambung Mangkurat and Chiba Universities participated in the interview. Farmers in South Kalimantan had also involved as respondent.

Chapter 3 is on The Soil Profile and Modes of GHG Emissions. The background of this chapter was the fact that there are few reports on the profile and the modes of GHG emissions from peat soil, especially those cultivated to oil palm (*Elaeis guenensis* Jarq.). The emissions of CO2 and CH4 increased in the first 12 minutes of chamber closure bur decreased onward. The N2O emissions increased consistently with time.

The authors realized that report on microbial aspect of tropical peat soil, especially those studied by molecular techniques was very limited. This was inspired the authors to elucidate the soil molecular profile. The results of the study is presented in Chapter 4.

Mitigation options has been tested and the results are presented in Chapter 5. Great efforts have been done to test the use of soil ameliorant in suppressing GHG emissions from oil palm fields to atmosphere. Agronomic technique (i.e., the insertion of rice in between oil palm) has been tested and is reported in this chapter. The authors introduced the insertion of rice in between oil palm as IRIAN system. Formulation of microbes with charcoal as carriers was designed.

Last chapter (chapter 6) of this book presents the conclusions and recommendations. The insertion of rice in between oil palm (IRIAN system) eliminated the greenhouse gas emissions from the field to the atmosphere, meanly due to the CO_2 uptake by rice. Averaged N_2O emission was lower in rice-husk charcoal treatment (0.56 mg $N/m^2/h$) as compared to control treatment (4.01). As recommendation the author suggest that biochar can be developed further in order to minimize greenhouse gas emissions from oil palm field.

PREFACE FROM EDITOR

Oil palm are among the hot agricultural issues. It is because oil palm is thought to increase greenhouse gas concentration and causes related climatic disturbance. In the other hand, oil palm is the most efficient oil producing plant that is hoped to overcome the food crisis and a way to achieve sustainable development goals. Therefore, I very much welcome a book entitled "Reducing greenhouse gas emissions from peatlands cultivated to oil palm" written by Prof. Abdul Hadi, Prof. Dedi Nursyamsi, Prof. Luthfi, and Prof. Kazuyuki Inubushi.

This book is basically a conversion of research report entitled "Reducing greenhouse gas emissions (>26%) from peatlands cultivated to oil palm. The research was funded by Ministry of Education, Culture, Research, Technology, and Higher Education through Foreign Research Collaboration and International Publication program. Researchers from Lambung Mangkurat University (Prof. Abdul Hadi, Ph.D. and Prof. Luthfi, Ph.D.), Ministry of Agriculture of Indonesia (Prof. Dr. Dedi Nursyamsi), and Chiba University (Prof. Dr. Kazuyuki Inubushi) took part. The research was carried out in Indonesian part, as well as Malaysian part of Borneo Island.

The authors have made the research grand very much productive. They have published two article in international journals (i.e., International Journal of Tropical Soil, Volume 17 No 2 and Malaysian Journal of Soil Science Volume 16) as output of the research. Two workshops have also been organized (i.e., Workshop on the Future of Peatlands at Farmers Perspectives, and a workshop was to disseminate the results to stakeholders.

I also proud because during the execution of the research, the Japanese research counterpart has came and delivered a general lecture attended by the students, as well as faculties of Lambung Mangkurat University.

I do hope that this book will give inside the development of oil palm on peat soil in Borneo Island, particularly techniques to reduce greenhouse gas emissions from soil to the atmosphere.

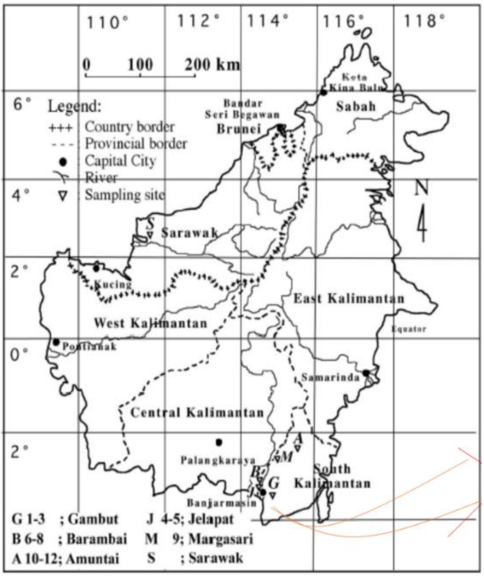
Banjarbaru, June, 2024

Prof. A. Rizalli Saidy

DAFTAR ISI

CHAPTER I. INTRODUCTION

Borneo Island (Picture 1) covers an area about 744 thousand km^2, and is inhibited by about 19 mill people. The island comprises four provinces of Indonesia (Kalimantan Barat, Kalimantan Tengah, Kalimantan Selatan dan Kalimantan Timur), two states of Malaysia (Sarawak and Sabah) and Brunei. In addition to Malay people which is dominant, significant number of Chinese, Javanese and other society are also distributed in Borneo island (Jamalie, 2007). The soils of Borneo differ from other island in sense that the volcanic affect less during the formation of Borneo"s soils (Hadi 2007).



Picture 1. Borneo island

Peat, organic soil, or Histosols are technically all soils which contain appreciable quantities of organic matter that is considered to dominate the soil properties. Peat soils are formed when the rate of organic matter accumulation exceeds the rate of decomposition. In the formation of peat soil, water saturated environment for extended period of time coupled with low quantities of O is required (Martur and Farhan, 1985). Peat soils are generally poorly drained and associated with a high water table for most of the year. Because of their appreciable amount of organic matter, the peat soils are naturally decomposed slowly but continuously. Decomposition of organic matter is basically the degradation process of complex organic compounds converting to the simpler form of organic matter. Because these soils remained water saturated, obviously anaerobic decomposition predominates.

Pedological definition of this group of soil, however, is different among different soil classification systems. Food and Agriculture Organization (FAO) defines organic soil as the soil that contain organic matter, at least 30 % by weight, in accumulative layer of 40 cm or more (FAO, 1988). Soil Taxonomy details the definition as soil that contains at least 18 % organic carbon if the mineral fraction is composed of 60% or more of clay, and at least 12 % if the mineral fraction contains no clay, within 50 cm depth (USDA, 1976).

There are various terminologies used to classify peatlands. Andriesse (1988) classified peatland based on the six basic characteristics. These are (1) topography and geomorphology, (2) covering vegetation, (3) chemical properties of peat, (4) origin of the peat material, (5) physical properties or (6) genetical formation of peat. Based on topography and geomorphology peatlands are classified as either low moor, transitional moor or high moor.

Based on their chemical fertility, peatlands are classified to either eutrophic (highly fertile), mesotrophic (moderately fertile) and oligotrophy (infertile). The third classification of peatland (i.e. origin of the peat material) refers to the types of vegetation forming the peat. In this regard, moss peat (formed of moss), saw-grass peat (formed of grass), cyperacea peat (formed of Cypracea family), forest or woody peat (formed of forest vegetation) are recognized. Physical classification of peatlands refers to the decomposition stages of peat material. The stages can be fibric, hemic or sapric. Genetical classification refers to climatic zones influencing the formation of peat, includes tropical peat and temperate peat.

FAO classify peat soils based on their decomposition stages (i.e. fibric, hemic or sapric) (FAO, 1988). Meanwhile, USDA soil taxonomy tries to combine geomorphological characteristics, which includes presence of rock, climatic zones, decomposition stages etc. On sub-order level, USDA recognizes Fibrist, Hemist and Saprist. USDA uses the term "Tropo", "Sulfi" to define the peat soil at great group level (USDA, 1976). Despite what method to be used to analyze the decomposition rate, the organic matter decomposition causes the loss of mass, commonly stated as subsidence. The ground subsidence has caused many dry lands become flooded. Organic matter in peat soil is essential to sustain the nutrient cycling, the gaseous loss of organic matter from peat soil also mean a nutrition loss.

Peatlands of Indonesia and Malaysia are mainly found in low-lying basins situated between the lower courses of the main rivers and the coastline. It appears that a combination of conditions (including suitable topography, equatorial rainfall with precipitation exceeding evaporation and low silt content in the river) caused the development of these tropical peatlands. These peatlands occur in waterlogged or water saturated environment accompanied by other soil conditions inhibitive to microbial activity. Initially, topogenous peat is formed owing to prevailing anaerobic conditions, but subsequently the rising deposits produce a formation of ombrogenous peat. The processes of tropical peatland formation has been explained in detail by Andriesse (1988).

Recent estimate showed that Indonesia's peatlands covered a total area nearly 15 million ha (Ritung et al. 2023). They are distributed mainly in Sumatra, Kalimantan and Irian Jaya. While in Malaysia, peatlands are estimated to cover about 2.4 million ha and distributed mainly in Sabah and Sarawak states (Takai, 1997). Although only about 3% of Indonesian peatlands have been converted to agriculture field, the conversion was very fast (Radjagukguk, 1993). In Malaysia, about half of peatlands area have been converted to oil palm plantation mostly by companies (Ahmad et al., 1986; Soon, 2007).

Nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) are the most important greenhouse gas derived organic matter in peat soil (Hadi et al. 2000; Inubushi et al.2003; Hadi et al. 2005). Because peat is flat and the land is own by country, many oil palm estates have been established on peat in Malaysian part of Borneo Island since last decade (Ahmad et al. 1986). This trend has also been occurring in the Indonesian part of Borneo Island recently (Hernowo, 2009). Apart from it benefit, oil palm on peat resulted a high greenhouse gas emissions (Melling et al. 2006; Hadi et al. 2010), particularly nitrous oxide (N_2O) (Hadi et al. 2010). Calculating the global warming potential from these three gases, peat is considered as the third contributor of greenhouse gas emissions from in Indonesia at present and the deep peat has been banned of further oil palm development.

In soil, N_2O is formed by nitrifying and or denitrifying bacteria. Methane is formed by a group of bacteria known as methanogens, while CO_2 are formed by almost all microbes in soil (Bouwman, 1990). Organic matter input, concentration of nitrate and reduced conditions are found to be the main factors controlling these gas formations in soil and their emission to the atmosphere (Hadi et al. 2010). A giant N2O emissions as high as 1.4 mg/m2/h has been observed in peat forest in South Kalimantan (Hadi et al., 2001), presumably through nitrification of organic nitrogen. The formation of N2O from organic nitrogen possibly follow the reaction below:

Heavy and continuous application of rock phosphate and potash is commonly practiced in oil palm plantation to overcome the P and K deficiencies which are commonly occurred in peat soil. The urea and lime applications are also needed, especially at early sate of palm growth when the mineralization of organic N is still limited. Copper, zinc and boron are also applied regularly though in small amounts (Singh, 2008). Addition of urea increases the emission of N_2O in Sarawak (Melling, 2006). This problem in corn on mineral soil in South Kalimantan can be overcame by mixing the urea with nitrification inhibitor DCD (Hadi et al. 2008). The addition of lime stone suppressed CH_4 and N_2O emissions from peaty paddy soil, though $ZnSO_4$ increased the emissions of both gases (Susanti, 2006). Addition of iron material suppresses the formation of CH_4 in mineral soil probably through the increase in soil Eh created by the oxygen contained in ferrous oxide (Furukawa and Inubushi, 2004).

Bio-charcoal is charcoal created by charring (pyrolysis) of biomass such as crop residues, food waste and sewage sludge (http://en.wikapedia.org/wiki/biochar). In Malaysia, the most abundant bio-waste and with potential for biochar production is oil palm empty fruit bunch (EFB). Dumping EFB on soil surface will increase CH4 production (Inubushi et al. 2007). Universitas Putra Malaysia (UPM) in collaboration with NASMECH Technology has successfully set up a pilot plant to produce EFB bio-char and was in full operation by the end of year 2012 (http://www.biochar-international.org/malaysia/2010).

Application of bio-charcoal will increase soil's retention of nutrients, improve water holding capacity and reduce leaching and run-off to ground and surface waters (Baldock and Smernik, 2002). Few studies have been carried out on the effect of bio-charcoal on the dynamics of greenhouse gases in peat soil. In a laboratory incubation experiment using mineral soils, Yanai et al (2007) reported N_2O suppression following the charcoal incorporation; charcoal addition reduced N_2O emissions by 80% of the value of the no-added control.

CHAPTER II. PEOPLE VIEW ON GHG ISSUES

In 2008 Population in Kabupaten Batola reaches 272.332, comprised of 137.007 male and 135.255 female. Household is recorded at 75.378 units. Education situation is indicated by the number of school. The recent data show that in 2008 there are 335 units of Public Schools consisting of 2 units Kindergarten, 269 units Primary Schools, 48 unit Junior High Schools, 14 unit High Schools, and 2 units Vocational Schools. Another indication of education situation is number of student. There are 29.745 at Primary Schools, 6.047 students at Junior High Schools, 2,717 students at Senior High Schools, and for Vocational Schools there are 669 students. Next indicator is number of teachers. At Primary School there are 2.281 teachers, at Junior High Schools 672 teachers, Senior High Schools 305 teachers, and Vocational Schools have 68 teachers.

To indicate income we looked at Kabupaten's Gross Domestic Regional Product (GDRP). At the current price of 2008, GDRP Kabupaten Batola was recorded at 2.858.311 million rupiahs, while at constant price 2000 the GDRP was recorded at 1.754.712 million rupiahs. In 2008 economic growth was estimated at 3.14%.

A study on Kalimantan people view on greenhouse gas issues has been carried out by Mukhlis et al., (2019; Table 1). The people understanding on environmental issues was traced by structured interviews. Brief descriptions of their study are summarized below (Table 2).

Tabel 2. Persepsi petani tentang plasma PT. PBB

No.	**Parameter**	
1.	Knowledge on food self sufficient	
	Know (%)	25.0
	Don’t know (%)	75.0
2.	Knowledge on integrated farming	
	Know (%)	20.8
	Don’t know (%)	79.2
3.	Knowledge on incertion rice in between oil palm	
	Know (%)	79.2
	Don’t know (%)	20.8
4.	Incertion rice in between oil palm practice	
	Practicing (%)	37.5
	Don’t practicing (%)	62.5
5.	Knowledge on the use of rice straw as cow feed	
	Know (%)	54.2
	Don’t know (%)	55.8
6.	Usage of rice straw for feeding cow	
	Use (%)	20.8
	Don’t use (%)	79.2
7.	Oil palm corporation arround	
	Know (%)	75.0
	Don’t know (%)	25.0
8.	Responce on the presence of oil palm corporation	
	Welcome (%)	87.5
	Don’t welcome (%)	12.5

9.	Socialication from government on collaborative oil palm program	
	Present (%)	41.7
	Absen (%)	58.3
10.	Socialization from corporation on collaborative oil palm program	
	Presence (%)	54.2
	Absent (%)	45.8

According to BPS-Statistics of Banjar Regency, number of household in the mid 2008 has reached 128.427 households, with the population of 470,160 people consisting 240,823 men and 248,233 women, sex ratio 105 which means that there is no significance differences on sex sector. The most densely populated is in Martapura sub-regency; it has 2,078 people per kilometer square. Martapura's population increases compared to last year population. It can be seen through the increasing of the population density, in 2007 the density noted 2,068 people per km^2. Paramasan and Aranio sub-regency which is the lowest density region has only 7 people/km^2.

One of important things in development achievement of nation is education attainment of its people. The higher the attainment, the better the future. Bright and educated people is become the subject to direct the development purpose. Therefore, one way to improve the quality of education is the availability of education means and facilities.

The numbers of state schools in Banjar Regency are 419 schools consisting 346 state elementary schools (SD), 53 junior high schools (SMP) and 10 senior high schools (SMA). There are 15 private schools. The total number of students is 58,617 students and teachers are 4,509, it means teachers : students ratio is 1:13. While the schools under Religion Department Office are 187 schools, 2,866 teachers and 26.621 students, teacher and student ratio is 1:9.

Educational facilities in State University is available because Lambung Mangkurat University of Banjarbaru region is located in Banjar regency, it has 5 faculties which are Fishery, Agriculture, Forestry, Technique, and Medical Faculty. Besides, health education is also available in Intan Nursing Academy of Martapura (Akademi Perawat Intan Martapura) and Martapura Obstetrics Academy (Akademi Kebidanan Martapura). While the private university are STAI Darussalam Martapura There are 112 libraries available as the educational support.

To indicate income we looked at Kabupaten's Gross Domestic Regional Product (GDRP). At the current price of 2008, GDRP Kabupaten Banjar was recorded at 5,278,669 million rupiahs, while at constant price 2000 the GDRP was recorded at 3,011,411 million rupiahs. In 2008 economic growth was estimated at 6.64%.

In 2008 Population in Kabupaten HSU reaches 216,181, comprised of 107,324 male and 108,857 female. Household is recorded at 53,679 units. Education situation is indicated by the number of school. The recent data show that in 2008 there are 304 units of Public Schools consisting of 81 units Kindergarten, 184 units Primary Schools, 31 unit Junior High Schools, 5 unit High Schools, and 3 units Vocational Schools. Another indication of education situation is number of student. There are 18,951 at Primary Schools, 2,822 students at Junior High Schools, 1,476 students at Senior High Schools, and for Vocational Schools there are 1,183 students. Next indicator is number of teachers. At Primary School there are 2,015 teachers, at Junior High Schools 421 teachers, Senior High Schools 122 teachers, and Vocational Schools have 123 teachers.

To indicate income we looked at Kabupaten's Gross Domestic Regional Product (GDRP). At the current price of 2008, GDRP Kabupaten HSU was recorded at 1,116,771 million rupiahs, while at constant price 2000 the GDRP was recorded at 768,866 million rupiahs. In 2008 economic growth was estimated at 4.54%.

In 2008 Population in Kabupaten BALANGAN reaches 107,702, comprised of 50,968 male and 51,744 female. Household is recorded at 29,334 units. Education situation is indicated by the number of school. The recent data show that in 2008 there are 206 units of Public Schools consisting of 2 units Kindergarten, 160 units Primary Schools, 21 unit Junior High Schools 4 unit High Schools, and 3 units Vocational Schools. Another indication of education situation is number of student. At Kindergarten there are 92 students. There are 13,684 at Primary Schools, 2,065 students at Junior High Schools, 929 students at Senior High Schools, and for Vocational Schools there are 634 students. Next indicator is number of teachers. At Kindergarten 11 teachers, at Primary School there are 1,439 teachers, at Junior High Schools 235 teachers, Senior High Schools 83 teachers, and Vocational Schools have 59 teachers.

To indicate income we looked at Kabupaten's Gross Domestic Regional Product (GDRP). At the current price of 2008, GDRP Kabupaten BALANGAN was recorded at 2,012,901 million rupiahs, while at constant price 2000 the GDRP was recorded at 1,316,536 million rupiahs. In 2008 economic growth was estimated at 5.07%.

The people understanding on environmental issues has been traced by interview. The work was done by researchers and by the help of trained enumerators. A training had been carried out for the enumerators prior to the interview. About 40 respondents have been interviewed for this purpose.

CHAPTER III. SOIL PROFILE & MODES OF GHG EMISSIONS

General Characteristics

The characteristics of peat include the peat carbon and nitrogen contents, soil pH, population of total bacteria and total fungi. Determinations of soil pH, peat carbon and nitrogen contents were followed methods described by Page et al (1982).

Average characteristics of soil and people were used to decide the location for experimental plots in second year activities. Combining the soil and people characteristics (Table 3) we found that site Barambai in Barito Kuala District is representative of the sites studied with five time occasions appeared around the middle sequence as compared to KW, P, AH, and K which appeared ones, respectively. It was then decided to use BB site (Barambai) for further studies.

Table 3. Sequence of soil and people properties of sites studied

Character / Magnitude	Diversity of nitrifying bacteria	Diversity of denitrifying bacteria	Denitrification enzyme activity	Population of nitrifying bacteria	People income
High	P	GH	K	GH	
		AH	GH	AH	GH
	BB	BB	AH	P	BB
	KW	P	BB	BB	K
		K	P	KW	P
Low		KW	KW	K	

The compositions of media used for determination of bacterial and fungal population are listed in Table 4.

Table 4. Compositions and amounts of media used for determinations of total bacteria and fungi

No	Item	Bacteria	Fungi
1.	Yeast extract (g)	1	-
2.	Glucose (g)	1	10
3.	Peptone (g)	-	0.5
4.	K_2HPO_4 (g)	0.3	0.5
5.	KH_2PO_4 (g)	0.2	-
6.	$MgSO_4.7H_2O$ (g)	0.2	0.5
7.	Agar (g)	15	20
8.	0.3 % rose Bengal (mL)	-	10
9.	1 % streptomycin	-	10
10.	Distilled water	1000	1000
11.	pH	6.8	6.8

Population of Nitrifying and Denitrifying Bacteria

In addition to these, conventional assessment of nitrifying and denitrifying bacteria was also carried out (i.e. most probable number, MPN). The medium used for determination of nitrifying bacteria are as described by Rowe et al (1977), while that for denitrifying bacteria was as described by Soil Sci. Soc. Japan (2007).

The population of nitrifying bacteria were estimated using micro plate technique. Briefly, **f**orty five mL distilled water was transferred to 100 mL screwed bottles and autoclaved at 121°C for 15 min (diluted 10 times). After cooling the bottles, 5 g of moist soil was transferred into the bottle and shaken by hand for 2 x 10 min. Nine mL of distilled water was transferred to reaction tubes and autoclaved (5 tubes for 1 sample). On clean bench, 1 mL of soil extract from BOD bottle was transferred to reaction a tube, and shake for 30 sec. One mL suspension from first reaction tube was transferred to a second reaction tube, and shake for 30 sec. This step was repeated until the last tube. The last tubes established the 10^{-6} dilution.

Aliquot (0.1 mL) of media was placed into each of the 8 by 6 wells of a sterile micro plate. Aliquot of soil suspensions (0.1 mL) to be tested were added by a pipette into each of the eight micro plates. The plated were covered with polypropylene tape and incubated at 30°C for 4 weeks for ammonium oxidizer and 8 weeks for nitrate oxidizer. At the end of incubation period each plate was scored positive. The positive tubes were considered and number of ammonium and nitrate oxidizers were computed on MPN tables.

Nine mL of medium was placed in incubation tube. Nine tubes were prepared for each sample. A Durham vial was withdrawn up side down. The tubes were then autoclaved at 121°C for 15 min. Using sterile automatic pipette, 1 mL of the 10^3, 10^4 and 10^5 dilution rates were inoculated after the medium was allowed to cool. The tubes were then placed in the dark at 30°C for 8 weeks. The positive tubes (i.e., tubes with gas bubble) were considered and the number of denitrifier were computed on MPN tables.

Conventional determination of some bacteria have been complated (Table 5) but some have not been complated, unless after 18 November, 2010. The need of long incubation period was one of the disadvantege of convensional methods as compare to the advance methods (i.e., DGGE-PCR) (Morris et al., 2002).

Denitrification enzyme activity (DEA) indicates the potential of soil in producing N_2O (Inubushi et al., 1996). Table 5 indicated that the DEA varied with location and ranged from 0.008 ugN_2O g^{-1} h^{-1} in Wanaraya site to 0.067 ugN_2O g^{-1} h^{-1} in Balangan.

Table 5. Population of methanogens, nitrifying and denitrifying bacteria and denitrification enzyme activity in peat soils in South Kalimantan

District	Sample code	Methano-gens (x 10^3 cfu g^{-1} soil)	Denitrfying bacteria (x 10^3 cfu g^{-1} soil)		Nitrfying bacteria (x 10^3 cfu g^{-1} soil)		Denitrification enzyme activity (ugN_2O g^{-1} h^{-1})	
			Average	SE	Average	SE	Average	SE
Banjar/ Batola dictrict	KW		73.59	14.71	0.97	0.00	0.008	0.001
	BB		<1		4.17	nd	0.016	0.001
	GH		<1		4.43	0.50	0.062	0.021
Balangan/ HSU district	K		1.00	nd	0.33	0.01	0.067	0.042
	P		86.16	24.62	1.41	0.18	0.011	0.002
	AH_1		<1		1.46	nd	0.047	0.006
	AH_2		<1		1.62	0.00	nd	nd
	AH_3		<1		6.07	1.53	nd	nd

Nd: not determined

Modes of Gas Emissions from Oil Palm Field

Methane, N_2O and CO_2 concentrations will be determined by a gas chromatograph (Shimadzu, GC-7A) equipped with FI or EC detectors, a gas sampler with 1 mL volume tube and an integrator (Shimadzu, C-R2A). The working conditions for the gas chromatograph will be as that described by Linkens and Jackson (1989; Table 6).

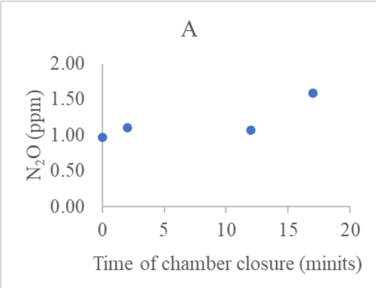
Tabel 6. The working conditions of gas chromatograph for N_2O, CH_4 and CO_2 determinations.

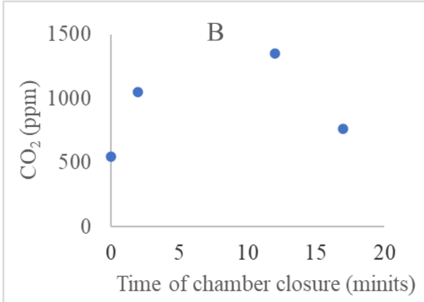
		N_2O	CH_4	CO_2
Detector		ECD	FID	TCD
Column		Porapak Q	Porapak Q	Porapak R
Temperature (C)	Column	60°C	50°C	40°C
	Detector	60°C	50°C	50°C
	Injector	350°C	100°C	50°C
Carrier gas	Type	Ar + CH_4	N_2	He
	Flow rate	20 ml min^{-1}	50 ml min^{-1}	25 ml min^{-1}
Retention time		2.5 min	0.7 min	3.0 min

The flux will be calculated from temporal increase of the gas concentration inside the chamber with time. The emissions of greenhouse gases will be calculated by integrating the fluxes with the duration of experiment (Yagi, 1997). Global warming potential (GWP) will be calculated based on formula (IPCC, 1996):

$$GWP\ (gCO_2\text{-}C\ equivalent) = CO_2 + 23xCH_4 + 296xN_2O$$

Figure 1 showed the N_2O, CH_4, and CO_2 emissions along with the time of oil palm encloser of chamber.





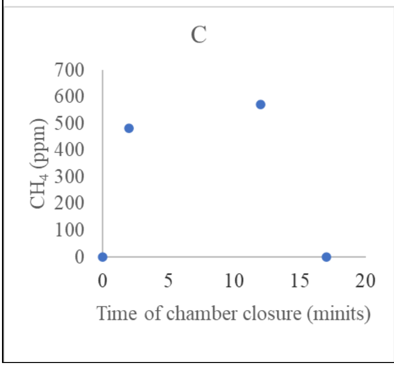


Figure 2. Changes in N_2O (A), CH_4 (C), and CO_2 (C) and concentrations in chamber covering oil palm plant.

The concentrations of N_2O, CH_4, and CO_2 changed with time (Figure 1). N2O emission constantly increase with the duration of chamber enclosure, while the concentrations of CH_4 and CO_2 increased in the first 12 minutes of chamber enclosure but decreased onward. The concentration of CO_2 decreased to the initial concentration (i.e., 0 ppm) 20 mins after chamber enclosure. This indicated that the CO_2 emitted by peatlands could be offset by plant through photosynthesis. A portion of CH_4 in the atmosphere may also be fixed by soil methanotrophic organisms, resulting a decrease of CH_4 concentration at 20 mins after chamber enclosure.

A linear increase of N_2O releases during the first 12 mins of chamber enclosure indicates that 12 mins duration is ideal time for N_2O sampling. This was then be practiced for measurements in following experiments.

A linear increase of N_2O emissions with time was observed. The emission of CO_2 and CH_4 increase during the first 12 minutes, but decrease afterward indicating plant uptake of CO_2 or microbial oxidation of CH_4 (Hadi et al. 2012). Effect of soil ameliorant on N_2O as taken within 12 minute period are shown in Figure 1, while the net primary production of CO_2 is shown in Figure 2.

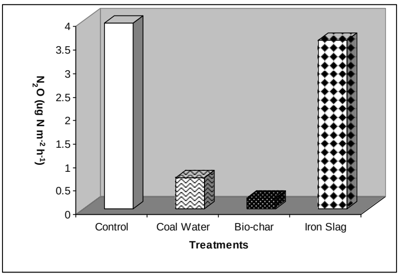


Figure 3. Emissions of N_2O from peatlands cultivated to oil palm as affected by soil ameliorants

Figure 1 showed that the addition of soil ameliorants reduced N_2O emission from soil to the atmosphere with the highest reduction achieved by the application of bio-char, followed by application of coal water. This result suggested that the use of acid water and bio-char may be applied to minimize the N_2O emission from peatlands cultivated to oil palm.

Figure 2 showed that the addition of soil ameliorants reduced the net primary production (NPP) of CO_2 from peatlands cultivated to oil palm, except bio-char which enhanced NPP of peatland cultivated to oil palm.

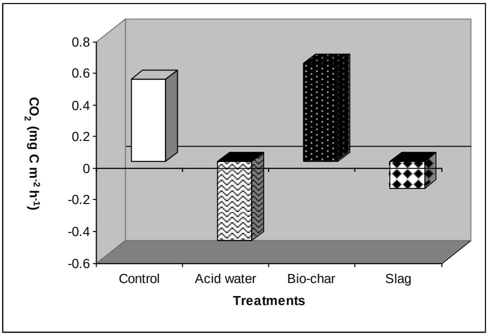


Figure 4. Net primary production of CO_2 emissions from peatlands cultivated to oil palm as affected by soil ameliorants.

Population of bacteria and fungi changed upon the application of different soil ameliorants onto oil palm field (Table 1). The population of bacteria increased in treated peat as compared to control. Similarly, the population of fungi increase upon the addition of soil emeliorants, except that received rice husk charcoal. Incorporation of acid water and bio-char did not change the diversity of bacteria, while the addition of slag increased the diversity of bacteria. In contrary, the diversity of fungi increased upon the application of acid water and bio-char. Fungi has been suspected as a responsible microbes in N_2O formation in peat soil (Agus, 2011; Soon et al. 2007). The high diversity coupled with low population of fungi may explain the low N_2O emission from peat receiving bio-char (Figure 7). This result agreed with the result from Hashidoko et al. (2009) which reported that the high microbial diversity will minimize the formation and subsequent emissions of greenhouses.

Table 7. Population of microbes as affected by the application of different soil ameliorants onto well established oil palm field

Soil Ameliorant	Bacteria		Fungi	
	Population	Form, color diversity	Population	Form, color diversity
Acidic coal water	72×10^5	2	17×10^5	4
Rice-husk charcoal	13×10^5	2	3×10^5	3
Iron slag	19×10^5	3	29×10^5	2
No ameliorant (control)	8×10^5	2	6×10^5	2

CHAPTER IV. SOIL MOLLECULAR PROFILE

Some microbes are specific to peat, probably due to the high organic matter contents which differ from mineral soils. The population and diversity of microbes are generally lower in peat soil than those in mineral soils. Producing greenhouse gases seems to be optional for microbes (Hadi, 2010). Hahidoko et al (2009) has observed plant-growth promotion activity from *Burkhorderia* sp. which is known as N_2O producing bacteria. This indicates a possible management of greenhouse gases' microbes for agricultural benefits.

Nitrogen-fixing bacteria, phosphor solublising bacteria and organic matter degrading bacteria are among the attracting bacteria to be develop for application on wetland soils presently. The development of microbes for agricultural purposes includes isolation, characterization, formulation, and quality assessment. Charcoal are some times used as a carrier in microbial formulation (Arshad and Frankenberger, 1996).

Nitrifying and Denitrifying Bacteria by PCR

The diversity of nitrifying and denitrifying bacteria were studied PCR-DGGE method as procedure described by Jumadi et al (2008) and Braker et al (1998), respectively. Briefly, DNA extraction was replicated three times using DNA spin kit (Qbio Gene). A soil sample of 0.5 g was mixed Qbi Gene solution in a spin tube. The tube was shaken horizontally at 5000 rpm for 30 s with a Mini-Beadbeater (Biospec Product, Bartlesville, OK, USA). Then the suspension was incubated at 4°C for 5 min and was centrifuged at 1200 rpm for 1 min at room temperature. All amounts of the supernatant were transferred into a 15-ml centrifuge tube and added with PPS solution (separating solution, Qbio gene). After centrifugation at 13000 rpm for 5 min at room temperature, 1 ml of binding matrix was taken and added to the supernatant in 10-ml centrifuge tube. The suspension was then shaken by hand for 2 min. The supernatant was transferred in to the filter of a spin tube. The spin tube with the filter inside was centrifuged at 13000 rpm for 1 min and the supernatant was removed. The pellet was wbehed with 0.5 ml of SEWS-M solution and then dried. The crude DNA was dissolved in DES solution. The DNA was stored at -20°C before use.

Polimerezation chain reaction (PCR) was run using a DNA thermocycler (Takara Bio Inc, Japan). All PCR reactions began with an initial denaturing at 94°C for 5 min. The annealing PCR for nitrifying bacteria was 35 cycles at 94°C for 50 sec, followed by 60°C for 1 min and 72°C for 1 min, while for denitrifying bacteria was 20 cycles at 53°C and 10 cycles at 43°C. Final extensions was 72°C for 6 min for both bacteria. Descriptions of primers used for determinations of nitrifying and denitrifying bacteria are summarized in Table 2. Five ul of PCR product was qualified on 2% agarose for 30 min at 100 V in 1 x TAE and visualized by UV transillumination (ITTO Printgraph) after staining with ethydium bromide for 30 min.

Table 2. Names and descriptions of primers used in this study

No	Name	Targeted microbe
1.	F-Lu-Cu/R3-Cu	Denitrifying bacteria

2.	CTO189F/CTO654R18	Nitrifying bacteria
3.	357F-GC/520R	
4.	533F/MethT2R-GC	Methanotrophs

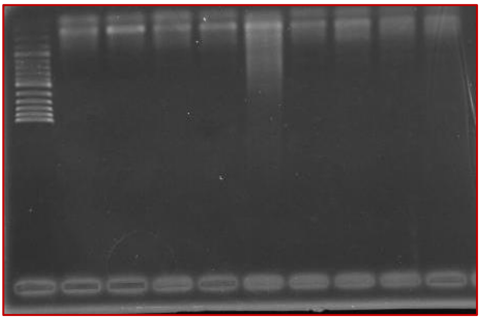
Denaturant gradient gel electrophoresis (DGGE) analysis was performed with a Dcode Universal Mutation Detection System (Bio Rad Laboratories, Hercules, CA, USA). PCR product (about 20 ul) was applied onto 8% (w/v) polyacrylamide gel in 1xTAE. The denaturant gradient range of the gel, in which 100% denaturant contained 7 M urea and 40% (v/v) formamide, was modified depending on the PCR products applied (Table 3). Electrophoresis was run for 14 h at 60℃ at 100 V. The gels were stained for 20 min with Ethidium Bromide. The stained gel was immediately photographed under UV light.

Table 3. Compositions of reagents for DGGE ranging from 50% to 70%

No	Reagent names	Amounts	
		50%	70%
1.	Urea (g)	4.0	5.88
2.	Acryl amide	4.2	5.6
3.	50xTAE (uL)	0.4	0.4
4.	6 x loading buffer (uL)	0	20
5.	APS 10% (uL)	160	160
6.	TEMED (uL)	16	16
7.	dH_2O (mL)	to 20	to 20

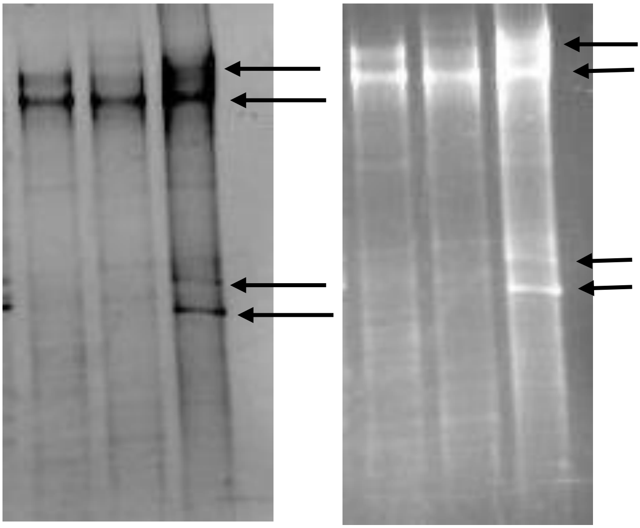
The diversities of nitrifying and denitrifying bacteria were determined in Chiba University by Dr Abdul Hadi and a research assistant, Dwi Purno Widegdo with the guidance and support by the foreign researcher (Prof Kazuyuki Inubushi). Appart from the laboratory work, the Material Transfer Agreement was also discussed during the meetting in Chiba (Appandix 5).

The reagents and PCR conditions were succesfully extracted and amplified the microbial gen from soil. This is indicated by clear zones of genom as flowed on agarose gel (Picture 2). Because the genes can not be separated, the use of agarose gel is not sutisfied hence needs to inprove by more dispersing material (Bodelier et al., 1998).



Picture 2. Genomes of nitrying bacteria on agarose gel

At this moment, only three samples (i.e., Kw, K and P) have been run on DGGE. So far, the used of denaturing gradient gel electroporesis (DGGE) following PCR has proven satisfied to study the diversity of nitrying bacteria in meneral soils (Jumadi et al., 2008). Our results indicated that the DGGE could separate the DNA of nitrifying bacteria extracted from peat soil. Both primers used (i.e., CTO189F/CTO654R18 and 357F-GC/520R) gave clear RNA band when they are photographed (Picture 3).

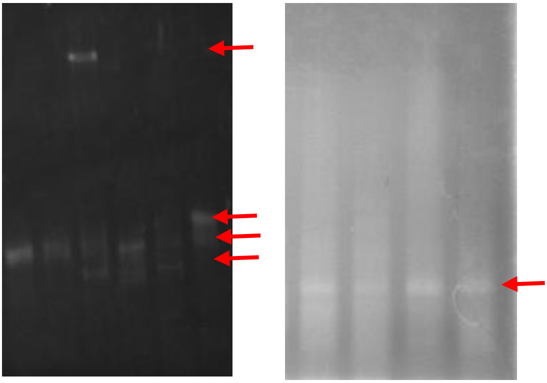


Picture 3. RNA bands of nitrifying bacteria. Lanes (left to right): KW, BB and P. Arrows pointed out DNA bands

TO189F/CTO654R18 357F-GC/520R

The diversity denitrifying bacteria using PCR has been carried out in Chiba University for all samples (eight samples). The eight samples were firstly run on agarose gel following an amplification using primer F-flu-Cu/R3-Cu to estimate the length of the DNA. We then check the bends with a marker (http://www.nippongene.com/pages/products/electrophoresis/marker/onestep/onestep_ladder.html#Lad0100) and found that the lengths of our DNA ranged from 100 to 1,500 bp. Denaturing gradient gel electrophoresis was finally employed to asses the diversity of denitrifying bacteria as shown in Picture 4. Picture 4 showed that the DNA bends were one, two or three (average two bands).

In addition to nitrifying and denitfying microorganisms, we also assessed the diversity of methanotrphs since Hadi et al (2007) has indicated the potential of methanotrophs in minimizing CH4 emissions from peat soil. We found that the diversities of methanotrophs were similar in four samples tested (KW, BB, P, K; Picture 5). This results suggest that any of the samples ws representative for the sites studied if the methanotrophs to be considered.



Picture 4. Diversity of denitrifying (left) and nitrifying bacteria (right). Lanes (from right to left): AH_3, AH_2, AH_1, GH, K, P, KW, BB. Refer Table 1 for the site description. Arrows pointed out DNA bands

CHAPTER V. MITIGATION OPTIONS

Applying Different Soil Ameliorant

Eighteen oil palm trees with similar age and performance in Landasan Ulin Utara villages, Banjarbaru city were selected. Treatment applied were as follow:

1. Without biochar (referred as control/A treatment hereafter);
2. 1.75 ton/ha biochar made from wood (considered as B treatment hereafter);
3. 1.75 ton/ha biochar made from oil palm empty fruit bunch (considered as C treatment hereafter);
4. B + C (considered as D treatment hereafter);
5. 3.5 ton/ha biochar made from wood (considered as D treatment hereafter)
6. 3.5 ton/ha biochar made from oil palm empty fruit bunch (considered as F treatment hereafter).

Oil palm plants were covered from the top by chamber at 1, 16, and 41 days after biochar/fertilizer application. Air samples were taken at 2, 5, and 12 mins after chamber closure at respective days of observation and be used for N2O determinations using a gas chromatography. N2O fluxes were calculated in the similar ways as previous experiment. The annual CO2 emissions were calculated by integrating the fluxes with the duration of experiment (Yagi, 1997).

There were no significant effect statistically of type and dose of biochar on emissions of N_2O from peatlands cultivated to oil palm (Table 8).

Table 8. N_2O emissions as affected by different type and dose of biochar applications.

Treatment**	mg $N/m^2/jam^1$			Annual
	1 DAT	15 DAT	41 DAT	Kg N/ha
A	-13.735	5.731	7.685	0.275
B	8.331	-9.186	-36.280	-0.343
C	-6.862	5.449	31.439	1.055
D	14.368	-1.746	-25.143	-0.612
E	27.001	36.828	13.289	2.401
F	-1.418	5.238	0.513	0.244

Note: DAT= days after treatment; **see text for the abbreviations.

Thought no statistical different among the treatments, oil palm field receiving biochar made from wood (treatments B and D) treatment resulted in negative N_2O fluxes. This indicated that some amounts of N_2O have been fixed by soil. Similar results have been obtained in Ando soil and reported by Inubushi et al. (1998). Most of the N2O fixations in those two treatments observed at 41 days after biochar application (Table 1).

Twelve oil palm trees with similar age and performance in Jajangkit village, Barito Kuala district were selected. All trees were given a recommended dose of NPK fertilizer by band application along the canopy projection on ground. Three trees each were given either biochar or iron slag at the rate of one ton per ha. The remaining three trees were given coal acid mine drainage (ADM) water at the rate of L per ha. Chambers similar to those used in previous experiment were constructed to beneath the soil and to cover the canopies of the selected plants.

The N2O flux was calculated from temporal increase of the gas concentration inside the chamber during the first 12-minute closure of the chamber (as recommended by previous experiment) (Yagi, 1997).

The gas emissions as affected by different soil ameliorants are shown in Figure 4 which showed that the averaged N_2O emission was lower in rice-husk charcoal treatment (0.56 mg $N/m^2/h$) as compared to control treatment (4.01), though they were not significant at 5% significant level. This may suggest that biochar can be developed further in order to minimize greenhouse gas emissions from oil palm field. Chicken manure is another candidate of soil ameliorant for this purpose.

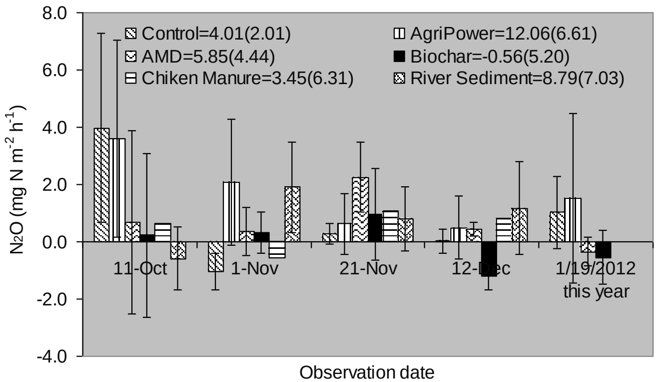


Figure 9. Temporal changes in N_2O emissions as affected by soil ameliorant.

At least, incorporation of biochar into peat soil could off-set the C released by oil palm field—if any. Assuming that the C content of biochar ranged from 64-74% (Elsaprike et al., 2018), additional 1.12 – 2.78 ton C/ha has returned and retained in peat soil due to biochar application.

Life Cycle Analyses

Life cycle assessment (LCA) can be defined as how different activities in the various stages of the life cycle contribute to the cumulative greenhouse emissions for products and services we consume. The purpose of LCA at present study is to compare the greenhouse gas emissions from conventional oil palm cultivation and the one receiving bio-char (i.e., our finding). The production of full fruit branch is broken up into three main individual processes and activities, i.e., (1) land clearing, (2) planting (including basal fertilizations and or application of soil ameliorant), (3) maintenance (including weeding, fertilizer application) and (4) harvesting. The gas emissions during the preparation of bio-char was also quantified and were considered as component of life cycle analysis.

Observation and interview were carried out to obtain data on machinery, fuel, agrochemicals, human labor and other data activities which have significant contributions to the overall greenhouse emissions. For example, global warming impact of fertilizer was adopted from Kim and Dale (2003). Since the land clearing and harvesting processes were similar for the two treatments, the data collection was focused in the planting and maintenance processes. Data sources used for this step was acquired from primary data and published local studies and overseas data.

Activities during the above-ground biomass study are shown in Pictures 4 and 5 (Appendices 2). An incinerator designed for producing bio-char is shown in Picture 6 of Appendix 2. The CO_2, CH_4 and N_2O emissions during the bio-char production are shown in Table 3. The weight of biochar was about half of the rice husk.

Table 9. CO_2, CH_4 and N_2O emissions during the bio-char production

Gases/Replicates	CO_2 (ppm)	CH_4 (ppm)	N_2O (ppb)
Burning 1 hour	443.81	3.94	390.6
Burning 2 hour	447.02	2.59	363.2
Burning 3 hour	444.33	3.66	341.6
Average	445.05	3.40	365.1

Table 3 showed that the burning of rice husk released CO_2 CH_4 and N_2O, but the amounts were not much greater that those in clean air (CO_2 = 350 ppm, CH_4 = 1.7 ppm and N_2O = 350 ppb). This will be additional advantage of charring processes in

Intercropping of oil palm with rice

To warrant the availability of rice husk as raw material for bio-char also to compare the carbon sequestration, an intercropping paddy in between annual oil palm (referred as IRIAN system hereafter) was introduced. For this, fifteen oil palm fields sizing 9.3 m x 9.3 m each was selected near by PT. Palmina Utama plantation in South Kalimantan. Five fields were intercropped with paddy and the rice hush is incorporated to the oil palm plant, another five fields were intercropped without rice husk application, while the rest of the field will not be intercropped and considered as control treatment.

Gas sample was taken using chamber covering the oil palm plant as done during the second year. In addition to that, gas samples will also be taken in between the oil palm plants. Plant biomass analysis was carry our using method described by Agus (2011) at the beginning and the end of the experiment in order to estimate the carbon sequestration benefit of intercropping cultivation system.

From series of workshops, a comparison between conventional oil palm cultivation and the introduced model has been agreed (Table 4). Table 4 showed that the intercropping rice in between oil palm was thought to increase the cycle of biomass through rice plant biomass, in addition to those from grass/understory and oil palm fruit and its complementariness.

Table 10. Comparison of life cycle between conventional pal oil cultivation and IRIAN system

Cycle	**Conventional oil palm cultivation**	**Intercropping rice in between oil palm**
Oil palm transplanting	O	O
Open burning/Charring	O	O
Rice growing seasons	-	O
Understory's growth	O	O
Fruit production	O	O

Note: O=do; -=nil

Table 5 showed greenhouse gas emissions at conventional oil palm cultivation and those with insertion of rice with or without biochar. Table 11 indicated that the insertion of rice in between oil palm (IRIAN system) eliminated the greenhouse gas emissions from the field to the atmosphere, meanly due to the CO_2 uptake by rice. This also confirmed by the fact that the above ground biomass was more in IRIAN system as compared to conventional oil palm by farmer. In one year cycle, the global warming potential of conventional oil palm cultivation, introduced IRIAN plus biochar and IRIAN without biochar were 1,852, -3,749 and -2,384 kg $CO_{2\ equ}$/ha, respectively.

The incorporation of rice husk-charcoal tended to also improve the bulk density of soil (Table 12). Activities during the establishment of intercropping rice with oil palm were shown in Picture 6-8.

Table 11. Summary of life cycle gas emissions from conventional and introduced oil palm cultivation systems

		Farmer practice	**IRIAN+ Biochar**	**IRIAN- Biochar**
N_2O	Emission (ug $N/m^2/h$)	17.99	30.92	0.28
	GWP (g CO_2 equ/m^2/y)	73306.04	125988.37	1137.15
CH_4	Emission (mg $C/m^2/h$)	0.01	0.01	-0.04
	GWP (g CO_2 equ/m^2/y)	10156.67	9414.86	-28446.45
CO_2	Emission (mg $C/m^2/h$)	3.17	-31.04	-7.58
	GWP (g CO_2 equ/m^2/y)	101663.43	-510271.18	-211126.31
Total	GWP (kg CO_2 equ/ha/y)	1851.26	-3748.68	-2384.36

Table 12. Changes in soil bulk density in conventional farmer practice and introduced IRIAN system

No	**Treatments**	**0-30 cm**	**30-60 cm**	**60-90 cm**	**Average 0-90 cm**
1	IRIAN without biochar	0.2720	0.2652	0.2721	0.2698
2	IRIAN with biocher	0.2857	0.2653	0.2789	0.2766
3	Conventional	0.2653	0.2619	0.2687	0.2653

Improvement of Beneficial Microbes

The third step of the study will comprise of field and laboratory works. Laboratory works focus in cultivating greenhouse gases' microbes beneficial for agricultural crops. Nitrifying and denitrifying bacteria obtained during the second year's work were grown on appropriate media following separation of DNA from gel. Separation was done by Takara's suprec-PCR technique (MBio Co, Japan). Propagation of isolates was carried out and the growth of the isolate was observed regularly (Setyaningsih et al., 2010). Formulation was done by repeated-spraying the microbial isolates to charcoal and air-drying. The formula was considered as enriched bio-char.

Table 2 showed the population growth of microbes after three month of inoculation, indicating that population of some microbes (colony 1 carried by cow dung or rice husk charcoal; colony 2 carried by oil palm empty fruit bunch charcoal, and colony 3 carried by cow dung) can achieved the application standard according to Indonesian Government Regulation No. 70/2011 (10^7 cell g^{-1}). This suggests that certain colony with appropriate carrier can be developed for bio-fertilizer, although the affectivity of the microbes in creating favorable soil conditions for plant growth needs further research.

Table 13. Population of microbes after three months of incorporation with carriers

No	**Carrier type/ isolate no**	**Observed colony**	**Weight correction factor**	**∑ microbes (CFU/g)**	**Remark**
1	KEL 2 TJ KOLONI 2	36	1.22656	4415585.76	
2	KEL 3 TJ KOLONI 1	29	1.22656	3556999.64	
3	KEL 3 TJ KOLONI 2	25	1.22656	3066379.00	
4	KEL 3 TJ KOLONI 3	60	1.22656	7359309.60	
5	KEL 1 TJ KOLONI 2	10	1.22656	1226551.60	
6	KEL 1 TJ KOLONI 3	8	1.22656	981241.28	
7	KEL 3 TJ KOLONI 3	26	1.22656	3189034.16	
8	KEL 3 TJ KOLONI 1	32	1.22656	3924965.12	
9	KEL 1 TJ KOLONI 1	26	1.22656	3189034.16	
10	KEL 3 KS KOLONI 3	30	3.78768	11363040.00	
11	KEL 3 KS KOLONI 1	23	3.78768	8711664.00	About $1x\ 10^7$ cell/g
12	KEL 3 KS KOLONI 1	24	3.78768	9090432.00	
13	KEL 1 TS KOLONI 2	60	1.20611	7236660.00	
14	KEL 3 TS KOLONI 3	15	1.20611	1809165.00	
15	KEL 1 TS KOLONI 1	31	1.20611	3738941.00	
16	KEL 3 TS KOLONI 2	51	1.20611	6151161.00	About $1x\ 10^7$ cell/g
17	KEL 2 TS KOLONI 1	24	1.20611	2894664.00	
18	KEL 2 TS KOLONI 3	40	1.20611	4824440.00	
19	KEL 3 TS KOLONI 1	29	1.20611	3497719.00	

20	KEL 1 TS KOLONI 3	32	1.20611	3859552.00	
21	KEL 2 TS KOLONI 2	33	1.20611	3980163.00	
22	KEL 4 TK KOLONI 2	42	1.19170	5005135.80	
23	KEL 1 TK KOLONI 1	50	1.19170	5958495.00	About $1x\ 10^7$ cell/g
24	KEL 1 TK KOLONI 3	41	1.19170	4885965.90	
25	KEL 3 TK KOLONI 3	5	1.19170	595849.50	
26	KEL 2 TK KOLONI 1	21	1.19170	2502567.90	
27	KEL 3 TK KOLONI 2	29	1.19170	3455927.10	
28	KEL 3 TK KOLONI 1	22	1.19170	2621737.80	
29	KEL 2 TK KOLONI 3	44	1.19170	5243475.60	
30	KEL 2 TK KOLONI 2	16	1.19170	1906718.40	

Note of carries types: KS= cow dung; TS=rice husk charcoal; TJ=rice straw charcoal; TK= oil palm empty bunch charcoal. Highlighted isolates are above or near the standard value for soil bio-ameliorant according to Indonesia Government Regulation No 70/2011.

Dissemination of Research Results

The main findings of the author research were (1) soil ameliorants which are enriched with microbial isolate, (2) type and dose of soil ameliorants which can be useful to mitigate GHG emissions from oil palm on peatlands, and (3) people view on GHG issues. To make a research findings are more meaningful, dissemination activities following the research are a must. Dissemination can be in the form of journal articles, conference, and workshop.

One paper has been published International Journal of Tropical Soil Volume 17 No 2 (page 105-114); another paper has been accepted by Malaysian Journal of Soil Science to be published in November 2012 (Volume 16). The team presented a paper at an International Seminar and Workshop which was held in Banjarmasin, 26-27 November, 2012.

Three workshops have been organized in fiscal year 2012. The first workshop was on the Future of Peatlands at Farmers Perspectives. A questionnaire was collected from each farmer during the workshop. The second workshop was to disseminate the results to stakeholders (academia, researcher, corporate and farmers). Japanese counterpart came and delivered a presentation at the workshop along with the Team Leader of the researchers. Extensional work has also done to encourage farmers and corporate to apply bio-char in order to minimize N_2O emissions from oil palm fields (Pictures 5).

	
	Ficture 5. Documentation of workshop (left top), conference (left under), and field visit (right top).

CHAPTER VI. EPILOGE

At the 15th Conference of Parties of United Nation Forum on Climate Change, President Susilo Bambang Yudoyono has committed to reduced 26% of greenhouse gas emissions by Indonesian own budget and 41% if other countries give aids. To achieve the target, the Government of Indonesia has allocated funding to invent, search and implement technologies relevant to reductions of greenhouse gas emissions from contributing sectors. Some IDR 44 trillions is to be spent for peat soil (Las, 2010). This shows a strong intention of Indonesian government to combat global warning and it sequential climate change.

All sectors, including peat, should contribute to achieve this national target. Researches done so far by the team showed that the potentials of water management application in paddy field and nitrification inhibitor application in corn field in reducing GHG emissions were 37% and 97%, respectively, which are above the country wide target (i.e., 26%). However, the potentials of these technologies in peat soil cultivated to oil palm are poorly understood. The wide use of a technology will also determine the significance of the technology to nation wide strategy. This needs assessment of people preference to the technology and technical, social and economical constraint in adopting the technology.

Addition of fresh organic matter is known to increase gas emissions from peat soils, though the fresh organic matter is needed to stimulate the decomposition in soil and subsequent release of plant nutrients. The use microbes ought to now be promising technique to enhance the nutrient release from organic matter while keeping the gas emissions low. Additionally, the people/farmers attitude is believed to contribute to the success or failure of new technology application (Hadi, 2007). It is, therefore, important to encourage beneficial characteristics of people and microbes for the success development of oil palm on peat in Borneo island.

The oil palm in Indonesian part of Borneo's peat soil is relatively new as compared to that of Malaysian part of Borneo's peat soil. The experience of Malaysia in developing oil palm on peat may be useful as lessen learn for Indonesia, though the microbial aspect of Malaysian peat needs to be elucidated more (Uyo, 2007) . To achieve the objective of the study, research, experiment and knowledge exchange should be carried out within and between Malaysia and or Indonesia. Three years duration is needed to find the technology, understand the people and assess the technology.

Previous years researches have designed technology packages in reducing greenhouse gas emissions from peat soil cultivated to oil palm in South Kalimantan province (i.e., the use of rice-husk charcoal). This indicated that the use of rice-husk charcoal can be extended to and practiced by corporate and/or farmer. Therefore, the focus of the current year works was in dissemination of the second year results to academia, corporate and farmers, in addition to the introduction of intercropping of rice-oil palm system and life cycle analysis.

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Reducing Greenhouse Gas Emissions
From Peatlands Cultivated to Oil Palm

"Reducing greenhouse gas emissions from peatlands cultivated to oil palm" by Prof. Abdul Hadi, Ph.D.; Prof. Luthfi, Ph.D.(Lambung Mangkurat University); Prof. Dr. Dedi Nursyamsi (Ministry of Agriculture of Indonesia), and Prof. Dr. Kazuyuki Inubushi (Chiba University). This book consists five chapters. The first chapter is Introduction chapter.

This chapter explains the definitions of peat soil, the species of greenhouse gas (GHG), and prior studies related to GHGs' issues. This chapter also updates the status of oil palm market and development in Borneo Island, as well as the global.

Introduction chapter is followed by a chapter about People View in GHG Issues (Chapter 2). This chapter was mainly composed from the primer and secondary data. The primary data was obtained through interview, while the secondary data was mainly statistics published by Statistics Center Agency. Some students of Lambung Mangkurat and Chiba Universities participated in the interview. Farmers in South Kalimantan had also involved as respondent.

Chapter 3 is on The Soil Profile and Modes of GHG Emissions. The background of this chapter was the fact that there are few reports on the profile and the modes of GHG emissions from peat soil, especially those cultivated to oil palm (Elaeis guenensis Jarq.). The emissions of CO2 and CH4 increased in the first 12 minutes of chamber closure bur decreased onward. The N2O emissions increased consistently with time. The authors realized that report on microbial aspect of tropical peat soil, especially those studied by molecular techniques was very limited. This was inspired the authors to elucidate the soil molecular profile. The results of the study is presented in Chapter 4.

Mitigation options has been tested and the results are presented in Chapter 5. Great efforts have been done to test the use of soil ameliorant in suppressing GHG emissions from oil palm fields to atmosphere. Agronomic technique (i.e., the insertion of rice in between oil palm) has been tested and is reported in this chapter. The authors introduced the insertion of rice in between
oil palm as IRIAN system. Formulation of microbes with charcoal as carriers was designed.

Last chapter (chapter 6) of this book presents the conclusions and recommendations. The insertion of rice in between oil palm (IRIAN system) eliminated the greenhouse gas emissions from the field to the atmosphere, meanly due to the CO2 uptake by rice. Averaged N2O emission was lower in rice-husk charcoal treatment (0.56 mg N/m2/h) as compared to control treatment (4.01). As recommendation the author suggest that biochar can be developed further in order to minimize greenhouse gas emissions from oil palm field.

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