UNIVERSITI PUTRA MALAYSIA

ESTIMATION OF NITROUS OXIDE, CARBON DIOXIDE AND METHANE EMISSIONS FROM SELECTED RICE SOILS IN MALAYSIA USING DNDC MODEL

RABAIL GANDAHI

FP 2015 83

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By

RABAIL GANDAHI

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

January 2015

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DEDICATION

SPECIAL DEDICATION

TO MY LOVELY FAMILY

MY MOTHER, FATHER AND MY YOUNGER SISTER ANMOL AND MY BROTHERS, MEHTAB AND SHIRAZ

Thank you for the inspiration and encouragement in everything I do

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

ESTIMATION OF NITROUS OXIDE, CARBON DIOXIDE AND METHANE EMISSIONS FROM SELECTED RICE SOILS IN MALAYSIA USING DNDC MODEL

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January 2015

Chairman : Professor Mohd. Khanif Yusop, PhD

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Greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the main cause of global warming. In Malaysia, all these gases can be assessed through Denitrification and Decomposition (DNDC) model in various agricultural systems. Three soils and agriculture system studied for simulation were located in Kota Bharu (Kelantan) situated between 6°8′N 102°15′E, Alor Setar (Kedah) situated between 06°07'N,l 100°22'E and Selangor, Malaysia situated at 2°43′N 101°57′E. All the three sites have double cropping system in a year. The objectives of these studies were to examine and forecast the agricultural practices involved in N_2O, CO_2 and CH_4 emissions from various rice fields and to utilize the modeling approach to estimate changes in N_2O, CO_2 and CH_4 emissions from rice soils of Malaysia.

Through DNDC model, four interacting sub-models: thermal/hydraulic, crop growth, decomposition, and denitrification were simulated. (Rice cultivation is an important source of GHGs that cause global warming. Rice systems contribute over 25% of total global anthropogenic CH_4 emissions currently). The model efficiently treats nitrogen inputs from atmospheric deposition, fertilizer use and nitrogen fixation and represents soil inorganic turnover to enable calculation of gas emissions. The farmers of Kelantan, Kedah and Selangor apply 248, 280 and 300 kg N ha^{-1} year^{-1}, respectively. The model validation was found satisfactory and gave correct simulations when compared with other studies reported elsewhere. In Kelantan, simulated CO_2 flux rate was 4392 kg C ha^{-1}, 33.7 N_2O kg ha^{-1} year^{-1} with -2 CH_4 flux kg ha^{-1} year^{-1}. The Global Warming Potential (GWP) for CO_2 flux was 16105 kg CO_2-eq ha^{-1}, N_2O 16403 kg CO_2-eq ha^{-1}. However, CH_4 was found as sink (-66 kg CO_2-eq ha^{-1}). Bulk of all these gases had 32442 kg CO_2-eq ha^{-1} net GWP. In Kedah, the simulated CO_2 flux rate was 4675 kg C ha^{-1} and 15.2 kg N_2O ha^{-1} year^{-1} recording -3 CH_4 flux kg ha^{-1} year^{-1}. The GWP for CO_2 flux was 17141 kg CO_2-eq ha^{-1}, N_2O 454412 kg CO_2-eq ha^{-1}.

However, CH_4 was found as sink (-92 kg CO_2-eq ha^{-1}) and thus, bulk of all these gases had 471460 kg CO_2-eq ha^{-1} net GWP. In Selangor, CO_2 flux rate was 1489 kg C ha^{-1}, 152.1 N_2O kg ha^{-1} year^{-1} with -2 CH_4 flux. The GWP for CO_2 flux was 5460 kg CO_2-eq ha^{-1} and N_2O 74085 kg CO_2-eq ha^{-1}. However, CH_4 was found as sink (-66 kg CO_2-eq ha^{-1}). Bulk of all these gases had 79440 kg CO_2-eq ha^{-1} net GWP. The simulations for field uncertainties were tested with variable nitrogen rates at 20% less than recommended and 20, 40 and 60% more N than recommended along with soil organic carbon (SOC) rates at 4, 3, 2 and 1.93% kg C kg^{-1} in Kelantan, 2, 3, 4 and 5% SOC rates in Kedah and 2.31, 3, 4 and 5% in Selangor. In all the rice sites, the unit increase in N rate as well as SOC correspondingly increased N_2O flux by 10.06, 6.80, 6.51 and 1.16 kg N ha^{-1}. NO flux by 0.76, 3.25, 3.14 and 2.03 kg N ha^{-1} year^{-1}.N_2 flux 17.87, 18.21, 21.75 and 25.22 kg ha^{-1} year^{-1}. N_2O GWP flux rate by 3495.3, 1614.6, 6.3.0 and 499.4. In Kedah, the unit increase in N rate as well as SOC correspondingly increased N_2O flux by 0.25, 0.42, 2.51 and 0.96 kg N ha^{-1}, NO flux by 1.04, 1.17, 1.33, 1.51 kg N ha^{-1} year^{-1} and N_2 flux by 0.12, 0.83, 1.19 and 0.99 kg ha^{-1} year^{-1}. N_2O GWP flux rate by 30.6, 23033, 110302 and 154765. Similarly, in Selangor, the unit increase in N rate as well as SOC correspondingly increased N_2O flux by 2.86, 3.83, 7.61 and 1.95 kg N ha^{-1}. NO flux by 5.41, 5.0, 4.39 and 3.78 kg N ha^{-1} year^{-1}. N_2 flux by 5.22, 9.76, 18.46 and 30.44 kg ha^{-1} year^{-1}. N_2O GWP flux rate by 1385.3, 1865.3, 2701.5 and 3411.5. In conclusion, the DNDC model validations were accurate for Malaysian rice. The farmers of these three sites are applying more nitrogen fertilizer against the crop demand corresponding more yearly NH_3 volatilization loss and increased fluxes of N_2O, NO and N_2 in the environment and excess fertilizer leach down in the soil by polluting underground water. In Malaysian rice, the simulated CH_4 values were negative indicating it as sink. In these sites, the GWP is also increasing due to elevated CO_2, ongoing management practices especially cropping system, straw incorporation, irrigation/flooding and N fertilizer management as well as C storage potential of the soil which is increasing with the passage of time due to left over residues and soil flooding condition.

The DNDC, was modified to enhance its capacity of predicting GHG emissions from rice ecosystems. The major modifications focused on simulations of anaerobic biogeochemistry and rice growth as well as parameterization of rice management. The new model was tested for its sensitivities to management alternatives and variations in natural conditions including weather and soil properties. The test results indicated that (1) varying management practices could substantially affect CO_2, CH_4, or N_2O emissions from rice; (2) soil properties affected the impacts of management alternatives on GHG emissions; and (3) the most sensitive management practices or soil factors varied for different GHGs. For estimating GHG emissions under certain management conditions at regional scale, the spatial heterogeneity of soil properties (e.g., texture, SOC content, pH) are the major source of uncertainty.

bstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

ANGGARAN PELEPASAN NITRUS OKSIDA, KARBON DIOKSIDE DAN METANA DARI TANAH SAWAH DI MALAYSIA MODEL DNDC

Oleh

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Gas rumah hijau (GRH) iaitu karbon dioksida (CO_2), metana (CH_4) dan nitrus oksida (N_2O) adalah punca utama pemanasan global. Di Malaysia, semua gas ini boleh dinilai melalui proses dinitrifikasi dan penguraian (DNDC) dalam pelbagai sistem pertanian. Tiga jenis tanah dan sistem pertanian dikaji untuk simulasi dijalankan di Malaysia yang terletak di Kota Bharu (Kelantan) di antara 6 ° 8'N 102 ° 15'E, Alor Setar (Kedah) di antara 06 ° 07'N, 100 ° I 22'E dan Sabak Bernam (Selangor) antara 2 ° 43'N 101 ° 57'E. Ketiga-tiga lokasi ini mempunyai sistem penanaman dua kali setahun. Objektif kajian ini adalah untuk mengkaji dan meramal amalan pertanian yang terlibat dalam N_2O, CO_2 dan pengeluaran CH_4 dari pelbagai bidang beras dan menggunakan pendekatan model untuk menganggarkan perubahan dalam N_2O, CO_2 dan pengeluaran CH4 dari tanah padi Malaysia.

Melalui model DNDC, empat interaksi sub-model: haba/hidraulik, pertumbuhan tanaman, penguraian, dan proses dinitrifikasi telah disimulasikan. (Penanaman padi merupakan sumber penting (GHGs) yang menyebabkan pemanasan global. Sistem tanaman padi menyumbang lebih 25% daripada jumlah pengeluaran antropogenik global (CH_4) pada masa ini). Model ini berkesan merawat input nitrogen dari pemendapan atmosfera, penggunaan baja dan pengikatan nitrogen dan menterjemahkan melalui pengiraan pelepasan gas dari tanah bukan organik. Petani Kelantan, Kedah dan Selangor Malaysia menggunakan 248 kg N ha^{-1}, 280 kg N ha^{-1} dan 300 kg N ha^{-1} setahun masing-masing. Pengesahan model didapati memuaskan dan memberikan simulasi yang betul berbanding dengan kajian-kajian lain dilaporkan di sebelum ini. Di Kelantan, simulasi kadar fluks CO_2 adalah 4392 kg C ha^{-1}, 33.7 N_2O kg ha^{-1} setahun dengan -2 CH_4 fluks kg ha^{-1} setahun. Potensi Pemanasan Global (GWP) untuk fluks CO_2 adalah 16.105 kg CO_2-eq ha^{-1}, N_2O 16.403 kg CO_2-eq ha^{-1}. Walau bagaimanapun, CH_4 didapati sebagai penenggelam (-66 kg CO_2-eq ha^{-1}). Sebahagian besar daripada

semua gas-gas ini mempunyai 32.442 kg CO_2-eq ha^{-1} potensi pemanasan global bersih.

Di Kedah, kadar CO_2 simulasi fluks adalah 4675 kg C ha^{-1} dan 15.2 kg ha^{-1} setahun direkod -3 CH_4 fluks kg ha^{-1} setahun. Yang (GWP) untuk fluks CO_2 adalah 17.141 kg CO_2-eq ha^{-1}, N_2O 454.412 kg CO_2-eq ha^{-1}. Walau bagaimanapun, CH_4 didapati meneggelamkan (-92 kg CO_2-eq ha^{-1}) dan dengan itu, sebahagian besar daripada semua gas-gas ini mempunyai 471.460 kg CO_2-eq ha^{-1} GWP bersih. In Selangor, CO_2 flux rate was 1489 kg C ha^{-1}, 152.1 N_2O kg ha^{-1} $year^{-1}$ with -2 CH_4 flux. Di Selangor, kadar fluks CO_2 adalah 1489 kg C ha^{-1}, 152.1 N_2O kg ha^{-1} setahun dengan -2 CH_4 fluks. Yang (PPG) untuk fluks CO_2 adalah 5460 kg CO_2-eq ha^{-1} dan N_2O 74085 kg CO_2-eq ha^{-1}. Walau bagaimanapun, CH_4 didapati menenggelamkan (-66 kg CO_2-eq ha^{-1}). Sebahagian besar daripada semua gas-gas ini mempunyai 79.440 kg CO_2-eq ha^{-1} GWP bersih. Simulasi untuk ketidaktentuan lapangan diuji dengan pelbagai kadar nitrogen iaitu pada 20% kurang daripada yang disyorkan, 20, 40 dan 60% lebih daripada yang disyorkan N bersama-sama dengan dan kadar organic karbon dalam tanah SOC pada 4, 3, 2 dan 1.93% kg C kg^{-1} di Kelantan, 2, 3, 4 dan 5% kadar SOC di Kedah dan 2.31, 3, 4 dan 5% di Sabak bernam. Di semua lokasi tanaman padi, peningkatan unit kadar N serta SOC menigkat seiring dengan pemeruapan N_2O fluks oleh 10.06, 6.80, 6.51 dan 1.16 kg N ha^{-1}. NO flux by 0.76, 3.25, 3.14 dan 2.03 kg N ha^{-1} setahun.N_2 fluks 17.87, 18.21, 21.75 dan 25.22 kg ha^{-1} setahun. Kadar PPG N_2O fluks terlepas adalah 3495, 3, 1614, 6, 499,4 dan 6.3.0. Di Kedah, kadar unit N serta SOC meningkatan selari dengan peningkatan kadar.N_2O fluks sebanyak 0.25, 0.42, 2.51 dan 0.96 kg N ha^{-1}, N_2O fluks oleh 1.04, 1.17, 1.33, 1.51 kg N ha^{-1} setahun dan N_2 fluks oleh 0.12, 0.83, 1.19 dan 0.99 kg ha^{-1} setahun. Kadar N_2O PPG flux ialah 30.6, 23033, 110302 dan 154765. Begitu juga di Selangor , peningkatan unit dalam kadar N serta SOC meningkat selari dengan pemeruapan N_2O fluks ialah 2.86, 3.83, 7.61 dan 1.95 kg N ha^{-1}. NO fluks ialah 5.41, 5.0, 4.39 dan 3.78 kg N ha^{-1} setahun. N_2 fluks ialah 5.22, 9.76, 18.46 dan 30.44 kg ha^{-1} $tahun^{-1}$.PPG N_2O fluks terlepas ialah 1385,3, 1865,3, 2701,5 dan 3411,5. Kesimpulannya, model DNDC adalah sesuai untuk sawah Malaysia. Petani di ketiga-tiga tapak kajian membaja nitrogen lebih daripada keperluan tanaman selari dengan pemeruapan NH_3 dan peningkatan fluks daripada N_2O, NO dan N_2 dalam persekitaran dan baja yang berlebihan dilarut lesap ke dalam tanah dengan mencemarkan air di bawah tanah. Di sawah Malaysia, nilai CH_4 simulasi adalah negatif yang menunjukkan ia sebagai terlarut. Di dalam kajian ini, (GWP) juga meningkat kerana CO_2 tinggi, amalan pengurusan tanaman terutamanya system penanaman, pengurusan jerami, pengairan/saliran dan pengurusan baja N serta simpanan C berpotensi untuk tanah yang semakin meningkat dari semasa ke semasa oleh sisa-sisa buangan dan selepas banjir. The DNDC, telah diubahsuai untuk meningkatkan keupayaan meramal pelepasan gas rumah hijau (GHG) daripada ekosistem padi. Pengubahsuaian utama tertumpu kepada simulasi anaerobik biogeokimia dan pertumbuhan padi mengikut parameter pengurusan tanaman padi. Model baru telah diuji untuk sensitiviti kepada pengurusan alternatif dan variasi dalam keadaan semula jadi termasuk cuaca dan tanah hartanah.

Keputusan ujian menunjukkan bahawa (1) amalan pengurusan yang berbeza-beza boleh memberi kesan yang ketara kepada pelepasan karbon dioksida (CO_2), metana (CH_4), atau nitrus oksida (N_2O) daripada sawah padi; (2) Kandungan tanah menberi kesan alternatif pengurusan ke atas pengeluaran GHG; dan (3) amalan pengurusan tanah atau yang paling sensitif faktor diubah untuk GHG yang berbeza. Untuk menganggarkan pelepasan GHG di bawah syarat-syarat pengurusan tertentu di skala serantau, kepelbagaian ruang harta tanah (contohnya, tekstur, kandungan SOC, pH) adalah sumber utama ketidakpastian.

ACKNOWLEDGEMENTS

"In the Name of Allah, the Most Gracious and Most Merciful". Peace and blessings of Allah be upon Prophet Muhammad. Praised be to Allah SWT, with His grace I am able to complete this thesis.

Special appreciation and gratitude are extended to my conscientious and caring advisors, Professor Dr. Mohd Khanif Yusop, Professor Dr. Mohamed Hanafi Musa, and Associate Prof. Dr. Radziah Othman. The author would like to acknowledge Universiti Putra Malaysia and the Ministry of the Higher Education, Malaysia for the Special Graduate Research Allowance Scheme Fund for Efficacy of Efficiency Enhanced Fertilizer (EEF) of One Baja Urea on Crop Production (Project ID-5525200).

I am grateful to Dr. Fateh Chand Oad for his special attention and guidance, regarding report writing and data processing. Sincere thanks and appreciation are also extended to Ms Umi Kalthum Bt Asmaon and Mr. Ab Aziz Abdullah for their valuable help and guidelines on soil and plant analysis and all the persons who helped to make these studies successful.

I would like to express my deepest apperception to my Mother for her love and prayers. My deep gratitude is extended to my Father Dr. Allah Wadhyo Gandahi for his patience encouragement and support. His constructive ways of life, patience and advice inspired me for a greater achievement in life. Finally, I would like to thank to my younger sister Anmol and my brothers, Mehtab and Shiraz for their encouragement and moral support throughout this educational journey.

I certify that a Thesis Examination Committee has met on 28 January 2015 to conduct the final examination of Rabail Gandahi on her thesis entitled "Estimation of Nitrous Oxide, Carbon dioxide and Methane Emissions from Selected Rice Soils in Malaysia using Dndc Model" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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CO_2	Carbon dioxide
CH_4	Methane
DNDC	DeNitrification and Decomposition
DOC	Dissolved Organic Carbon
FAO	Food and Agriculture Organization
GWP	Global warmig potential
GHG	Greenhouse Gas
GHGE	Greenhouse gas emissions
GDAT	Growth Duration after Transplanting
GDP	Gross Domestic Product
GAIN	Global Adaptation Index
IPCC	Intergovernmental Panel on Climate Change
ISSS	International Soil Science Society
LAI	Leaf Area Index
NO_2	Nitrous oxide
NH_3	Ammonia
N_2	Nitrogen Gas
NO	Nitric Oxide
NH_4	Ammonium
NO_3^-	Nitrate
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
TDD	Thermal Degree Days
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1

INTRODUCTION

Greenhouse gas (GHG) absorbs infrared light in the atmosphere, thereby trap heat and cause a warming of the earth's surface. In terms of their global warming potential, the three important GHG are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Agriculture releases to the atmosphere significant amounts of these three gases (Paustian et al., 2004). Agricultural activities have a massive impact on the climate. Carbon dioxide, CH_4 and N_2O contributing 60, 15 and 5%, respectively, towards enhanced global warming. Concentrations of these gases are increasing at 0.4, 3.0 and 0.22% year^{-1}, respectively (Battle et al., 1996). Apart from causing global warming N_2O is also responsible for the destruction of the stratospheric ozone (Rodhe, 1990). Quantification of GHG emission from soil is needed for global modeling studies in the context of ecosystem modification and climate change (Li et al., 1997). They also have considerable indirect effects arising from changes in land use (Bellarby et al., 2008). Concentrations of atmospheric GHGs, such as N_2O, CO_2, and CH_4 which can alter the earth's climate have risen dramatically during the past century. Soil N_2O emissions often indicate an inefficient use of nitrogen (N) in agricultural soils. Although amounts of N lost as N_2O from agricultural systems may be small relative to fertilizer inputs and crop outputs, N_2O emissions may be symptoms of N losses more difficult to detect, such as N_2 and water soluble nitrate (NO_3^-). Furthermore, N_2O emissions have adverse effects on the atmosphere, because they enhance radiative forcing and catalyze ozone destruction in the stratosphere (Bouwman et al., 2002). Carbon dioxide is released largely from microbial decay or burning of plant litter and soil organic matter (Janzen, 2004). Methane is produced when organic materials decompose in oxygen-deprived conditions, notably from fermentative digestion by ruminant livestock, from stored manures, and from rice grown under flooded conditions (Mosier et al. 1998). Nitrous oxide is generated by the microbial transformation of nitrogen in soils and manures, and is often enhanced where available N exceeds plant requirements, especially under wet conditions (Oenema et al., 2005) Agricultural GHG fluxes are complex and heterogeneous, but the active management of agricultural systems offers possibilities for mitigation. Many of these mitigation opportunities use current technologies and can be implemented immediately.

The N loss from agriculture through emissions is insignificant in terms of agronomy however, the emissions of N_2O has an enormous environmental impact. The N_2O is a GHG, as well as CO_2, CH_4, halogenated fluorocarbon, and per fluorocarbon and sulfur hexafluoride. Investigations of the Inter governmental Panel Climate Change (IPCC) have shown that the atmospheric concentration of GHGs, like CO_2, CH_4 and N_2O have increased by 31, 151 and 17%, respectively within less than 150 years (IPCC, 2001). The atmospheric concentration of N_2O has increased from 270 ppb at the pre-industrial time to 314 ppb (IPCC, 2001), thus it causes between 5–6% of the global warming.

Today, there is no doubt that the change in atmospheric composition is mainly caused by human activities (Houghton, 1997). The increase in N_2O and other trace gases emissions is attributed to the increased N input in the biosphere (IFA and FAO, 2001). It is widely known that the intense N fertilization in agriculture led to increased N leaching and to increased N emissions (Haag and Kaupenjohann, 2001). The Kyoto protocol is set the stage to reduce the emissions of GHGs worldwide. The N_2O and NO are both environmentally significant trace gases produced in soils by the processes of nitrification and denitrification (Bremner and Robertson et al., 1997).

The production of rice in Asia has increased markedly with the introduction and widespread adoption of modern crop production technologies, such as early maturing and N responsive semi-dwarf cultivars; high use of inorganic fertilizers, especially N fertilizers, and pesticides; and the expansion of irrigation facilities. The chemical environment of reduced soil and the extremely limited O_2 supply in the soil-floodwater system has a large influence on the soil nutrient dynamics of irrigated rice systems. Global and regional estimates of GHG emission from rice fields vary greatly with the assumptions made on the importance of different factors affecting the emissions. Only a few studies (Bachelet and Neue, 1993) have attempted to calculate detailed regional GHG emissions. Emissions from rice production and burning of biomass were heavily concentrated in the group of developing countries, with 97 and 92% of world totals, respectively. While CH_4 emissions from rice occurred mostly in South and East Asia, where it is a dominant food source, those from biomass burning originated in Sub-Saharan Africa and Latin America and the Caribbean (74% of total). Manure management was the only source for which emissions where higher in the group of developed regions than in developing regions (US-EPA, 2006a).

Crop growth simulation models provide a means to quantify the effects of climate, soil and management on crop growth and biogeochemical processes in soil. Several models have been developed in recent years to predict GHG emissions from agricultural fields. Early models used regression relationships between rates of emissions and either the crop biomass (Kern et al., 1997) or grain yield . These relationships were based on the assumption that higher the biomass production of the crop, the more substrate would be available for CH4 production, either from increased crop residues or from higher rates of rhizo-deposition. Lu et al. (2000) developed a model for CH_4 production derived from incubation studies. They developed Methane Emission in Rice Ecosystems model for simulating CH_4 emissions from rice fields. The model was based on CERES-Rice model but did not cover N_2O or CO_2 emissions. Other models, however, include the entire set of GHG, for example, CENTURY (Parton, 1996), and Info Crop (Aggarwal et al., 2004) but are not yet at a stage where their predictive ability is satisfactory. Moreover, the models have hardly been used in tropical regions.

Problem statement

In Malaysia, yet, no research has been conducted on greenhouse gas emissions from agricultural lands as influenced by climate, soil characteristics and management practices to clarify the magnitude and controlling factors of emissions coming from our agricultural systems, and in the development of region-specific emission coefficients. The increasing concentration of greenhouse gases (e.g. CO_2, CH_4, N_2O) have led to changes in the earth's climate and a warming of the earth's surface due to human activities.

It has long been known that rice soil is an important emitter of methane which may vary due to environmental and agronomic conditions (e.g. climate, soil types and farming practices). In rice soils, CH_4 is produced by methanogens through anaerobic decomposition of organic matter, and part of the CH_4 is oxidized by methanotrophic bacteria in aerobic regions of the soil (i.e. the surface soil layer and the rice rhizosphere). The modern agricultural practices are strongly linked to GHG emission. These practises have raised average temperatures, patterns of precipitation, water logging, soil acidity, soil fertility, water quality, flooding incidences, high concentrations of tropospheric ozone, risk of pests, diseases, weeds, emergence of poisonous residues in the food chain and shift of optimal production zones towards specific crops and farming practices. It is vital need to study Malaysian agricultural activities and entire suite of greenhouse gases (CO_2, CH_4, and N_2O) needs to be properly monitored, estimated and interpreted through DNDC model and outcomes could be set for future planning.

DeNitrification-DeComposition is a computer simulation model of C and N biogeochemistry in agro-ecosystems. The model can be used for predicting emissions of trace gases including N_2O, NO, N_2, NH_3, CH_4 and CO_2. The DNDC model has been widely used over the last 10 years by many researchers (Cai et al., 2003; Li et al., 1997, 2000, 2004). Simulated results showed that DNDC was able to simulate the basic patterns of NO, N_2O, CH_4 and NH_3 fluxes simultaneously (Li, 2000). This feature could be valuable in assessing the net effect of the changing climate or alternative agricultural management on either the atmosphere or agriculture. Recently the DNDC model has been modified for predicting GHG emissions from rice rice ecosystems (Li et al., 2004). The modified model was tested for its sensitivities to management alternatives and variations in natural conditions including weather and soil properties. When estimating GHG emissions under specific management conditions at regional scale, the spatial heterogeneity of soil properties (e.g., texture, SOC content, pH) are the major sources of uncertainty. The modified DNDC model was used for estimating emissions of CO_2, CH_4, and N_2O from all of the rice paddies in China with two different water management practices, i.e., continuous flooding and midseason drainage that were the dominant practices before 1980 and in 2000, respectively (Li et al., 2004).

DNDC consists of two components. The first component entails three sub-models and converts primary drivers (i.e., climate, soil, vegetation and anthropogenic activity) to soil environmental factors (i.e., temperature, moisture, pH, Eh and substrate concentration gradient). The second component consists of nitrification, denitrification and fermentation sub-models; and simulates production/consumption of N_2O, NO, N_2, NH_3 and CH_4 driven by the modeled soil environmental conditions. With the bio-geochemical reactions embedded in the model framework, DNDC can predict the turnover of soil organic matter and the consequent trace gas emissions and nitrate leaching losses.

In Malaysia, a limited data analysis GHG's emissions from agricultural lands as influenced by climate, soil characteristics and management practices to clarify the magnitude and controlling factors of emissions coming from our agricultural systems, and in the development of region-specific emission coefficients.
The objectives of the present study were

1. To evaluate the use of DNDC model to estimate greenhouse gas (N_2O,CO_2 and CH_4) emission from Malaysian rice fields

2. To assess the greenhouse gas emission from different rice (Kedah, Kelantan and Selangor) growing areas in Malaysia using DNDC model.
3. To investigate the responses of greenhouse gas emissions and global warming potential of rice fields to different management practices.

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