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Field validation of DNDC model for simulating greenhouse gas emissions from rice soils of Kedah, Malaysia through DNDC Model

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Abstract

The laboratory and Denitrification and Decomposition (DNDC) model for assessment of greenhouse gas emission (GHG) and model validation was accurate for Kedah Malaysia as the farmers grow paddy in two seasons and apply nitrogen (N) at 280 kg N ha^{-1} $year^{-1}$ by splitting twice as well. In the first and second seasons, the crop received 1735.39 and 1507.15 kg C ha^{-1} with 44 and 41 C:N ratio observed from harvested straw. The simulated input of yearly C balance was 3242.5, 366.5 and 2508.6 kg C ha^{-1} $year^{-1}$ through rice straw, crop residues and roots, respectively which contributed 4674.9 kg C ha^{-1} $year^{-1}$ SOC with decline of -3.3 kg C ha^{-1} $year^{-1}$ CH_4 emission. The yearly DNDC simulation for CO_2 flux rate was 4675 kg C ha^{-1} and 932.8 kg ha^{-1} $year^{-1}$ recording -3 CH_4 flux. The Global Warming Potential (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. Bulk of all these gases had 471460 kg CO_2-eq ha^{-1} net GWP. The uncertainties for future forecast were measured through DNDC by N rates (20% less than recommended, recommended N, and 20, 40 and 60% more than recommended N) by fixing SOC rates viz. 0.02, 0.03, 0.04 and 0.05 for NH_3 volatilization. The unit increase in N rate as well as SOC correspondingly increased NH_3 volatilization, N_2O, NO and N_2 flux. It is concluded that GW is the main cause of GHG.

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Introduction

Rice production is arguably the most important economic activity on the planet. Almost half the people in the world eat rice at least once a day. Rice farms cover 11% of the world's arable area [International Rice Research Institute (IRRI, 2002). Asia dominates global rice agriculture. Total rice paddy area in Asia is 1.38 million km2, which accounts for 90% of global rice area (1.55 million km2) and 20% of total world cropland area for grain production (Food and Agriculture Organization (FAO), 2002). Rice production systems in Asia are in the midst of great changes (Wassmann *et al.* 2000). During the last 2 decades, the management for rice production in Asia converted from "traditional" to more energy dependent systems on a broad scale. For example, rice production in China, Indonesia, Malaysia, Thailand, Philippines, and Vietnam increased from approximately 210 to 310 Tg while the cropping area remained at a fairly stable level of 62–63 million ha from 1980 to 2000 (FAO 2002). The reduction of CH_4 and N_2O emissions from rice paddies has paid utmost attention in minimizing the rice production (Pandey *et al.* 2014). The ongoing agricultural activities are responsible for approximately 50% of global atmospheric inputs of CH_4 while agricultural soils are contributing as high as 75% of global N_2O emissions (Li *et al.* 2006). Methane is considered one of the most potent and dangerous greenhouse gas (Forster *et al.*, 2007) with as estimation of 9-19% and 15-26% entering in the atmosphere from the paddies. In continuation to that N_2O accounts also for more than 5% of global warming potential (IPPC 2007). Soils are among the planet's largest carbon (C) reservoirs, possessing great potential for expanded C sequestration providing a costeffective option to offset C emissions by buffering increased atmospheric CO_2 to prevent global warming (IPCC 2001; Sun *et al.* 2010). Global warming, caused by the increase in the concentration of greenhouse gases (GHGs) in the atmosphere, has emerged as one of the most prominent global environmental issues. These GHGs – carbon dioxide (CO_2), methane (CH_4) and nitrous-oxide (N_2O), trap the outgoing infrared radiation from the earth's surface and thus raise the temperature. The global mean annual temperatures at the end of the 20th century, as a result of GHG accumulation in the atmosphere, has increased by 0.4–0.76°C above that recorded at the end of the 19th century (IPCC 2007). Increasing application rates of fertilizer N has strong support to N_2O emissions to the atmosphere (Stehfest and Bouwman 2006). Moreover, the effect of changes in management practices like tillage, crop rotation, and type of N fertilization may lead to a new equilibrium towards emission of harmful gases contributing GHG. Furthermore, fluctuation in environmental temperature, soil properties (e.g., soil organic matter) water management practices (e.g. flooding and drought) are also crucial factors that affect the soil CH4, CO_2 and N_2O inventories and transport to the environment. All these inventories are very difficult to monitor, however, process based biogeochemical model like DNDC is an effective tool to estimate GHG emissions from agriculture systems. There is general consensus that the increasing concentration of greenhouse gases (e.g. CO_2, CH_4, N_2O,O_3) have led to changes in the earth's climate and a warming of the earth's surface. Furthermore, there is agreement that human activities such as fossil fuel combustion, land-use change and agricultural practices have contributed substantially to the rise in atmospheric greenhouse gas concentrations Global climate change is one of the most important issues of contemporary environmental safety. A scientific consensus is forming that the emissions of GHG, including carbon dioxide, nitrous oxide and methane, from anthropogenic activities may play a key role in elevating the global temperatures. In Malaysia, yet, no research has been conducted on GHG 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. CO2, CH4, N2O) have led to changes in the earth's climate and a warming of the earth's surface due to human activities. The objectives of this study was to investigate and forecast the agricultural practices involved in N_2O, CO_2 and CH_4 emissions from Kedah rice fields and to use of modeling approach to estimate changes in N_2O, CO_2 and CH_4 emissions from rice soils of Kedah, Malaysia.

Material and methods

Site Description

The soil and agriculture system studied for simulation were located in the Alor Setar (Kedah, the northern part of the West Coast of Malaysia); situated between 06°07'N, 100°22'E. This state covers a total area of 9,400 km² and consists mostly flat rice areas growing areas. This area produces about 75% of the total yield of rice in Malaysia due to favourable tropical climate with temperature between 21°C and 32°C throughout the year. The rainfall is throughout the year but, it is frequent in April and October. This area has agricultural rice lands where rice is grown in two seasons i.e. rice followed by rice.

Fig. 1. Map showing locations of Sampling from Rice field of Kedah, Malaysia.

The DNDC Model Description (DNDC Rice)

The DeNitrification-DeComposition DNDC model was first adapted to simulate GHG emissions from rice paddy ecosystems by Li *et al.* (2004b). The revised model used the 'anaerobic balloon' concept to model soil biogeochemistry under the anaerobic conditions found in paddy rice-involved agro-ecosystems. To model rice (and other crop) development and growth, a generic crop model, Modules of an Annual Crop Simulator (MACROS), developed by Penning de Vries *et al.* (1989) was modified and integrated with DNDC. Pathak *et al.* (2005) and Babu *et al.* (2006) further refined the DNDC model developed by Li *et al.* (2004b) to simulate emissions of CO_2, CH_4, and N_2O under the conditions found in the rice paddies of India. Fumoto *et al.* (2008, 2010) published research using the DNDC adaptation which was by now labelled as DNDC-Rice. Fumoto *et al.* (2008, 2010) enhanced DNDC's capacity on modelling paddy biogeochemistry by refining the CO_2-induced and DOC-induced CH_4 productions. The enhancements carried out by Fumoto *et al.* (2008) allowed DNDC to improve its performance in predicting CH_4 emission from rice fields across a range of climatic, soil, and management scenarios. Fumoto *et al.* (2010) used the modified DNDC-Rice to assess the CH_4 mitigation potentials of alternative water regimes in rice fields in Japan. The (DNDC) is a computer simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems. The DNDC model is based on four sub-models.(i) thermal/hydraulic, (ii) crop growth, (iii) decomposition, and (iv) denitrification which assess GHG emissions in rice growing area. The model consisting of four interacting sub-models: thermal/hydraulic, crop growth, decomposition, and denitrification, to assess the impact of changes in management on GHG emissions in selected rice growing areas of Malaysia. A widely used process-based biogeochemical model, DNDC calculate soil fluxes of some N forms (NH_3 and N_2) that are difficult to estimate by field or laboratory measurements. The DNDC model estimates soil fluxes of all important N compounds including NO and N_2O.

Model sensitivity analyses

The laboratory soil analysis for total Soil Organic Carbon (SOC) was observed as 2% which was base to caliberate and sensitivity of the DNDC model. However, microbial activity index parameter was set to 1% as per recommendations of Li *et al.* (1997). During the calibration process all parameters related to soil organic matter and crop growth were put based on sample analysis in the laboratory. Crop straw, grain yield, temperature, rainfall, irrigation were fed in the model. For sensitivity simulations certain fluctuation (increase or decrease) in N and SOC rates (2, 3, 4 and 5%) for future forecast were fed in the model. However, remaining soil, crop and farmers practices remained same.

Climate, Crop and Land Management Information

Daily rainfall, maximum and minimum temperature data were collected from the nearby weather station. The weather files of three years data were prepared as described in the DNDC guide (version 9.2) including Julian days, daily minimum and maximum air temperature (°C) , and daily precipitation of three studied locations. Fertilizer inputs, farming management practices (tillage, manure amendments, irrigation, and flooding), land management practices (crop rotation, land preparation, water management, and harvesting dates) were collected from farmers of the rice area.

Soil analyses and Plant sampling

Soil organic matter (SOM) was determined using Walkley and Black method (1934), Organic C in soils using non-dispersive, infrared, digital-controlled instrument CR-412 Carbon Analyzer. Determination of total nitrogen was done following the methods of Bremner (1960). Inorganic N in soils was performed through methods of Bremner and Keeney (1960). Soil pH was measured at a ratio of 1:2.5 (soil: water) (Benton 2001). The EC was measured using electrical conductivity meter From each study location, a random sample from one square meter crop area (replicated thrice). The sample was worked out for the determination of fresh and dry matter yield, carbon %, and total Nitrogen. Plants fresh weight was recorded immediately after the sampling. Seeds were threshed manually. Plants were cut in to pieces, roots and shoots were separated and weighed after oven drying at 70oC for 90 hours. Roots were washed in tap water to remove adhering soil. Roots and shoots were ground in a Wiley mill to pass through a 20-mesh screen, and then stored for analyses. Rice grain samples were air-dried on concrete, threshed, and oven-dried at 70°C for 48 hrs. and then weighed. Soil total nitrogen in plant was analysed using the Kjeldahl digestion method (Bremner,1960). Organic carbon (% OC) in plant and grain samples was determined as described by Walkley and Black (1934). The C and N outputs from DNDC were converted to CO_2, CH_4 and N_2O. To convert the change in soil C to CO_2 the value was multiplied by 3.67, C was converted to CH_4 by multiplying by 1.33. Similarly N was converted to N_2O by multiplying by 1.57 (all on the basis of molecular weight). IPCC conversion factors were used to convert the GHG to CO_2 equivalent by multiplying CO_2 by 1, CH_4 by 25 and N_2O by 298 (IPCC 2007). The totals of all fluxes were summed and for determination of GWP.

Soil Physico-Chemical Properties of Kedah

Input data requirements for the sub-models in DNDC were as follows: Daily rainfall and daily maximum and minimum temperature data were acquired from the Malaysia Meteorological Department. The weather file was prepared as described in the DNDC guide (version 9.2) (Institute for the Study of Earth Oceans and Space 2009) Table.1 shows soil Physico-chemical properties of selected study rice soils.

Input Data to the DNDC Model

Soil physical properties such as soil texture, clay content, bulk density, field capacity, wilting point, saturated hydraulic conductivity, soil pH, porosity and initial soil organic carbon content were required for simulation. Information regarding soil texture, bulk density and pH were collected from the Malaysia Fertilizer Recommendation Guide. Initial SOC content was assumed to be 0.02 k C kg_{-1} soil. (Table 2). Also the land management practices several kinds of farm management practices, including crop rotation, land Preparation, water management, fertilizer application, and harvesting date was put in the model.

Results and discussion

DNDC Model Validation

The data obtained from farmer's field at Kedah was validated through laboratory analysis vs DNDC simulations. All the observed data and their model simulations were about the same. Hence model was correctly validating the underlying processes. Likewise, scientists working in China on GHG emission on rice fields used the DNDC model for many years to simulate agricultural practices and their impact on GHG emission. Zheng *et al.* (1997) simulated N_2O and CH_4 emissions from rice fields in Wuxian county of Tai-Lake region through DNDC model and found that DNDC was working correctly while incorporating data of soil characteristics, fertilization rate, fertilization type, crop and water management. Huang (2003) also reported DNDC as reliable model for monitoring N_2O and CH_4 emissions. In the present study, the DNDC modeled N_2O emission values from paddy soils is also fall near these values indication consistent results with those of previous researchers. Further, Zou *et al.* (2003; 2005) observed only 10% fluctuation between laboratory observations and model simulations for Suzhou and Wuxi regions of China. In the present study, it was noticed that if, soil physico-chemical data are correctly fed in the model, the validation also has correct direction. This is also true with the crop data and other management practices. In Malaysia, this is the first time to estimate the GHG emission from Paddies through DNDC model.

Table 1. Soil physico-chemical properties of Kedah, Malaysia**.**

Soil parameters	Values
Soil texture	Silty clay loam
Clay content (%)	39.46
Bulk density (g cm^{-3})	1.19
Field capacity (WFPS)	0.55
Wilting point(WFPS)	0.26
Saturated hydraulic conductivity (m hr^{-1})	0.198
Soil pH	5.76
Porosity (%)	0.551
Soil organic carbon (kg C kg^{-1})	0.03
NO_3^-N (mg N kg^{-1})	9.00
NH_4^+N (mg N kg^{-1})	0.90

Greenhouse Gas Emission from Kedah paddies

The DNDC simulations for Kedah, Malaysia recorded 4675 kg C ha^{-1} CO_2 flux rate. The soil CO2 flux was dependant on all the paddy management practices. The use of mould board plow in this area has greater CO_2 flux. Similarly, inclusion of crop residues in soil from previous crop possibly enhanced CO2 flux rate.The agricultural practices affect the production and emission of carbon dioxide (CO2) from paddy soils (Li *et al*., 2010). Fluxes of CO_2 are the result of complex interactions between climate and several biological, chemical and physical soil properties (Oorts *et al.* 2007). All together release CO_2 (Robertson 2000). On the other hand, Burton *et al.* (2004) indicated that N application reduced extracellular enzyme activities and fungal populations, resulting in a decrease in soil CO2 flux. The DNDC model simulated 15.1 kg ha-1 $year^{-1}$ emission of N2O for this area. The reports are available that N fertilization significantly increases N2O and NO soil fluxes to the atmosphere. In spite of the expansion of agricultural activities in tropical managed soils, there is little information about the loss of applied nitrogen as NO and N_2O from these areas (Marquina *et al.* 2013). The N fertilizer applications accounts for the majority of N_2O emissions. The methane flux rate in this area was -3 kg C ha^{-1} $year^{-1}$. The negative flux rate indicates that methane played a role of sink. The field management is helpful in reducing CH_4 flux rate. Li *et al.* (2004b) found that applying mid-season drainage to a rice paddy substantially decreased CH_4 emissions. Fertilization rate, fertilization type, crop and water management are the main factors involved N_2O and CH_4 emissions (Zheng *et al.*, 1997). Most of agriculture's contribution of CH_4 flux results from growing rice and from animal production, whereas row crop agriculture tends to contribute little and can sometimes act as a sink (Johnson *et al.* 2007).. Others have reported that high levels of variability in CH_4 flux (Chan and Parkin 200Ia).

Table 2. Input data to the DNDC model Kedah, Malaysia.

Planting practices	Season 1	Season 2
Planting date	April 01	October 01
Harvest date	July 23	January 24
C content in biomass ((kg C ha^{-1})	1666.77	1524.22
Biomass fraction of grain	0.32	0.38
Biomass fraction of leaf + stem	0.20	0.18
C:N ratio of grain	30	31
C:N ratio leaf + stem	44	41
Water demand (mm)	200	300
Tillage practices	Mouldboard plow	Mouldboard plow
Fertilization (urea kg ha^{-1})	304	304
Manure amendment (previous crop straw yield; kg C ha^{-1})	1735.39	1507.15
C content in straw (%)	36.5	32.4
C:N ratio in straw	44	41
Number of weeding	1	1
Irrigation (cm/day)	2	2
C cut amount as grain yield (kg ha^{-1})	1666.77	1524.22

Table 3. DNDC model field validation for observed and simulated crop traits of Kedah, Malaysia.

Variable	Observed	Simulated	Increase/decrease (%)
Season-1			
Grain yield (kg C ha^{-1})	1667	1672	+1
Leaf + stem (kg C ha^{-1})	1042	1045	+1
Root (kg C ha^{-1})	234.2	237.1	+1
N demand (kg ha^{-1})	120	118	-2
Season-2			
Grain yield (kg C ha^{-1})	1524	1538	+1
Leaf + stem (kg C ha^{-1})	722	728	-1
Root (kg C ha^{-1})	1765	1780	+1
N demand (kg ha^{-1})	107	110	+3

The fluxes of CH_4 are negative in this study. Dendooven *et al.* (2012) reported that water content affects gas diffusion in soil. As such, both oxidation of CH_4, dependent on the influx of CH_4 into the soil and O_2 availability, but also production of CH_4, dependent on limited O2 supply, will be controlled by soil water content. Fluxes of CH_4 were not significantly affected by tillage or crop residue management, but the soil was always a sink for CH_4. Elder and Lal (2008) also reported that both CH_4 uptake and emission were low when comparing moalboard/disking, no-till and bare treatments.

Table 4. Soil N balance (kg N ha^{-1} year^{-1}) with the application of 240 N ha^{-1} year^{-1}

N input source	(kg N ha^{-1} year^{-1})
Left over straw N input	76.2
Crop sub N input	8.3
Crop root N input	24.7
N uptake (kg ha^{-1})	214.2
N_2O flux	15.2
NO flux	9.5
N_2 flux	72.3

Table 5. Soil C balance (kg C ha^{-1} year^{-1}) of Kedah, Malaysia.

N outputs	(kg C ha^{-1} year^{-1})
Straw C input	3242.5
Crop residues C input	366.5
Crop root C input	2508.6
Change in SOC	4674.9
CH_4 emission	-3.3

Global Warming Potential (GWP)

The GWP is an estimate of the degree of contribution to the global warming from a given amount of greenhouse gas In Kedah, the sum of all these gases recorded 471460 kg CO_2-eq ha^{-1} net GWP This shows that GWP increased by both elevated CO^2 and management practices especially N fertilizers and left over crop residues as well as inherent soil CO^2. Accurate estimation of GHG emissions from the rice fields in Malaysia is vitally important for evaluating global warming potential (GWP). Recently, scientists have applied modeling to estimate GHG emissions from cropping systems (Cao *et al.* 1996; Sozanska *et al.* 2002).

Table 6. Greenhouse gases in Kedah, Malaysia.

Variable	Kedah
CO_2 flux rate (kg C ha^{-1})	4675
N_2O flux rate (kg N ha^{-1})	15.2
CH_4 flux rate (kg C ha^{-1})	- 3
Global warming potential (GWP)	
CO_2 (kg CO_2 equivalent ha^{-1})	17141
N_2O (kg CO_2 equivalent ha^{-1})	454412
CH_4 (kg CO_2 equivalent ha^{-1})	- 92
Net GWP (kg CO_2 equivalent ha^{-1})	471460

In this regard, DeNitrification– DeComposition (DNDC) model developed by Li *et al.* is a process based model for gas emissions from agro-ecosystems (Li *et al.* 1992a,b) and has been widely used in many countries like China (Li *et al.* 2006), India (Pathak *et al.* 2005) and Europe (Neufeldt *et al.*, 2006). Flooded rice systems emit both CH^4 and N^2O. Elevated CH^4 emissions in rice systems can lead to a high GWP relative to other crops, thus strategies to reduce GHG emissions, particularly CH^4, are needed. Altering water, residue (carbon) and fertilizer management practices are commonly suggested as options for mitigating GHG emissions in rice systems. Soil management practices are known to affect emissions of GHG, such as CO^2, CH^4 and N^2O, all contribute to global warming (Omonode *et al.* 2007) must be worked out to correct the GHG emission. In comparison with the baseline results, Wang *et al.* (2011) reported that larger amounts of N fertilizer use and manure amendment increases net GWP. In general, increasing residue return rate would be a more effective measure than other scenarios for reducing net GWP emission. Results reported by various researchers showed that low inorganic fertilizer N rates (averaging 79 kg N ha⁻¹) increased CH_4 emissions by 18% relative to when no N fertilizer was applied, while high N rates (average of 249 kg N ha^{-1}) decreased CH_4 emissions by 15%. Replacing urea with ammonium sulfate at the same N rate significantly reduced CH_4 emissions by 40%, but may increase N2O emissions. Overall, the fertilizer-induced emission factor for all inorganic N sources was 0.22% (Linquist *et al.* 2012).

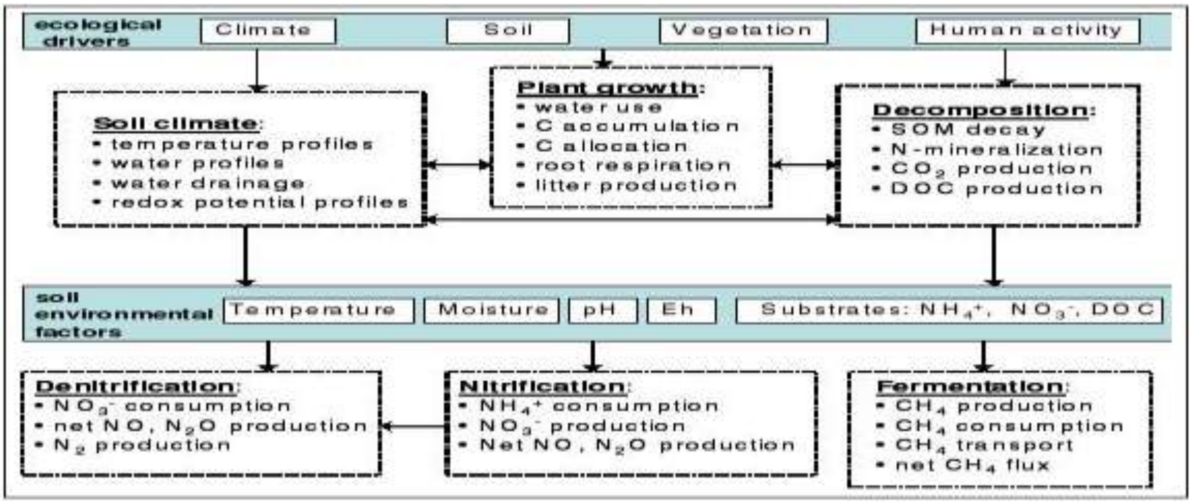

Fig. 2. Schematic diagram of DNDC model structure.

DNDC model field validation for observed and simulated crop patterns at Kedah during 2012

In Kedah, The model simulated values for grain yield (kg C ha^{-1}) for season^{-1} and 2 were the same as that the observed values. Similar results were also found for left over plant biomass (leaf + stem and roots) in both seasons. Farmers of Kedah applied N at 140 kg ha^{-1} per growing season. The DNDC simulated N demand of 118 and 110 kg N ha^{-1} for 1st and 2nd seasons against farmer's application of N at 140 kg ha^{-1} in each season (Table 3). DNDC model field validation for observed and simulated crop traits for study location.

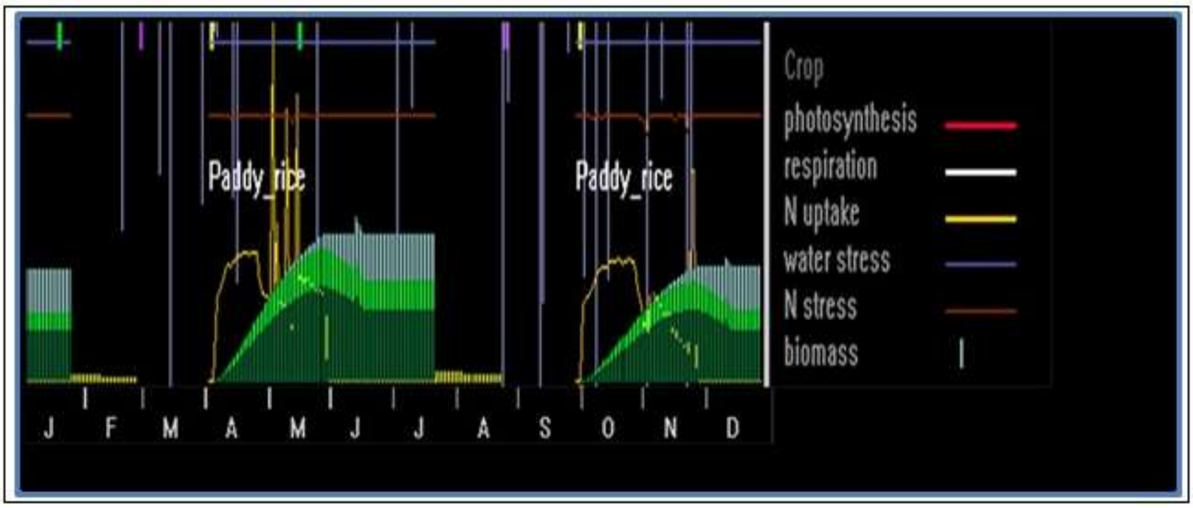

Fig. 3. DNDC Simulation for crop traits in Kedah, Malaysia.

Yearly Soil N Balance (kg N ha^{-1} year^{-1}) in Kedah

Data presented in Table 4 revealed that in Kedah, the yearly nitrogen at 280 kg N ha^{-1} also exhibited huge loss of N from the soil. The simulated results for yearly soil N balance showed that left over straw contributed 76.2 kg N ha^{-1} year^{-1}, crop sub N input 8.3 kg N ha^{-1} year^{-1} and roots contributed 24.7 kg N ha-1 year-1. Both crops had 215.2 kg ha-1 year-1 N uptake. Regarding N_2O flux, it was 15.2 kg ha^{-1} year^{-1} with, 9.5 NO flux and 72.3 N_2 flux kg ha^{-1} year^{-1}.4.2.2 Yearly Soil N Balance of Kedah.

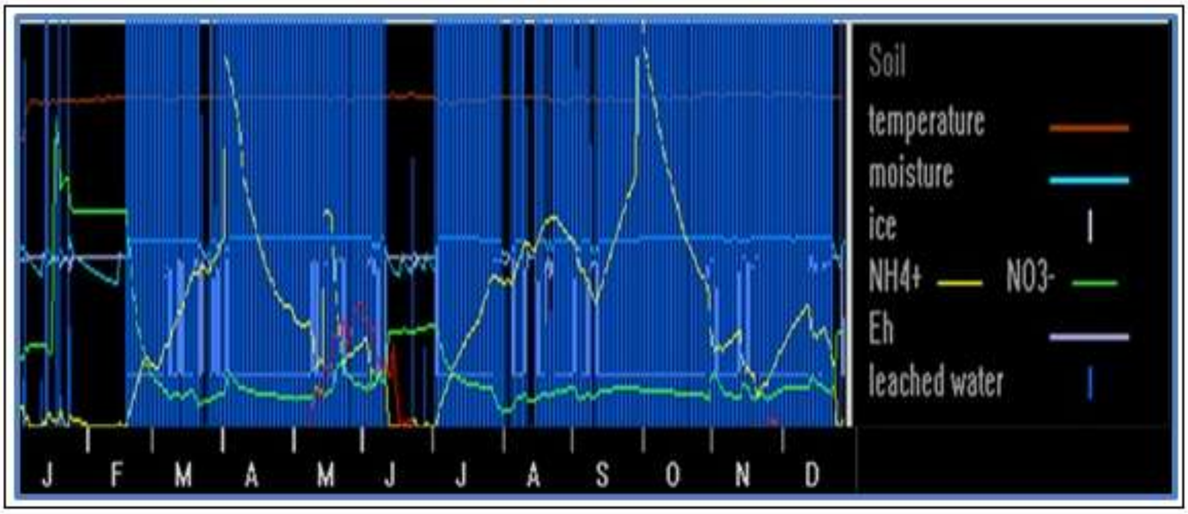

Fig. 4. DNDC Simulation for soil traits in Kedah Malaysia**.**

Yearly Soil C Balance (kg C ha^{-1} year^{-1} C) in Kedah

In Kedah(Table 5), the harvested straw, crop residues and left over roots in the soil played important role in soil C accumulation by recording 3242.5, 366.5 and 2508.6 kg C ha^{-1} year^{-1} C balance, respectively with changed in yearly SOC of 4674.9 kg C ha^{-1} and decline in CH_4 emission (-3.3 kg C ha^{-1} year^{-1}).

Greenhouse Gas Emission from Selected Rice Soils of Malaysia

CO_2 flux rate

The DNDC simulations for CO_2 flux rate in Kedah were: 4675 kg C ha^{-1} CO_2 respectively. The soil C storage generally increased through elevated atmospheric CO_2 primarily because of increased biomass production (Table 4.5).The soil CO_2 flux was also dependant on all the rice management practices. Further, inclusion of crop residues in the soil from previous crop possibly enhanced CO_2 flux rate.

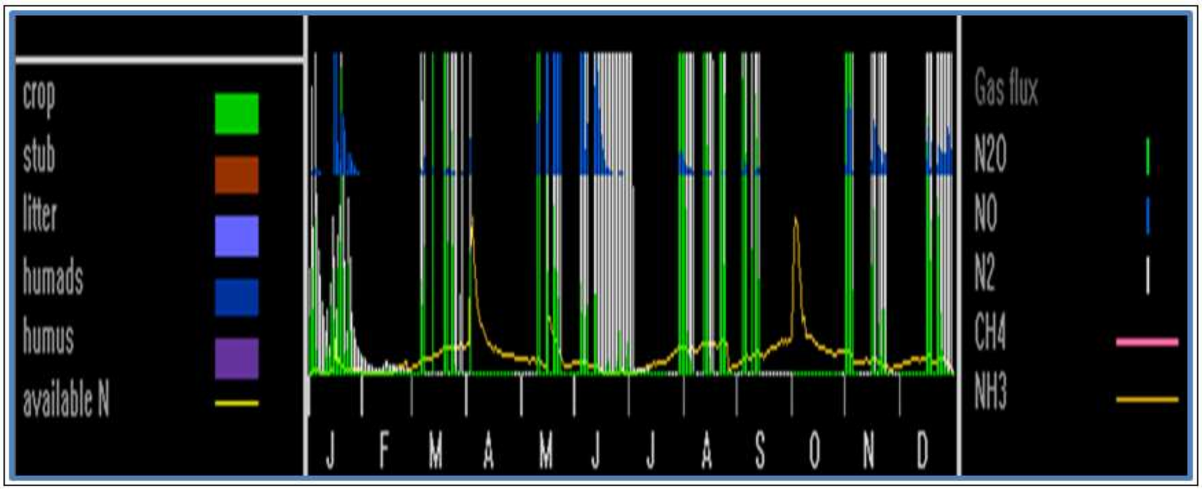

Fig. 5. Greenhouse Gas fluxes in Kedah Malaysia.

N_2O Emissions

The simulated results showed 15.2 N_2O kg ha^{-1} year^{-1} in Kedah Nitrous oxide emission. The N_2O emission is also dependent on excess N application in the studied areas against the crop demand.

CH_4 flux rate

In Kedah the DNDC model simulated methane flux was negative (-3 C ha^{-1} year$^{-1)}$ indicating CH_4 as sink.

Global Warming Potential (GWP)

The global warming potential (GWP) is an estimate of the degree of contribution to the global warming from a given amount of greenhouse gas. In Kedah, the sum of all these gases recorded 471460 kg CO_2-eq ha^{-1} net GWP (Table 6). In this study rice area, CH_4 had negative values serving as sink. This shows that GWP increased by both elevated CO_2 and management practices especially N fertilizers and left over crop residues as well as inherent soil CO_2.

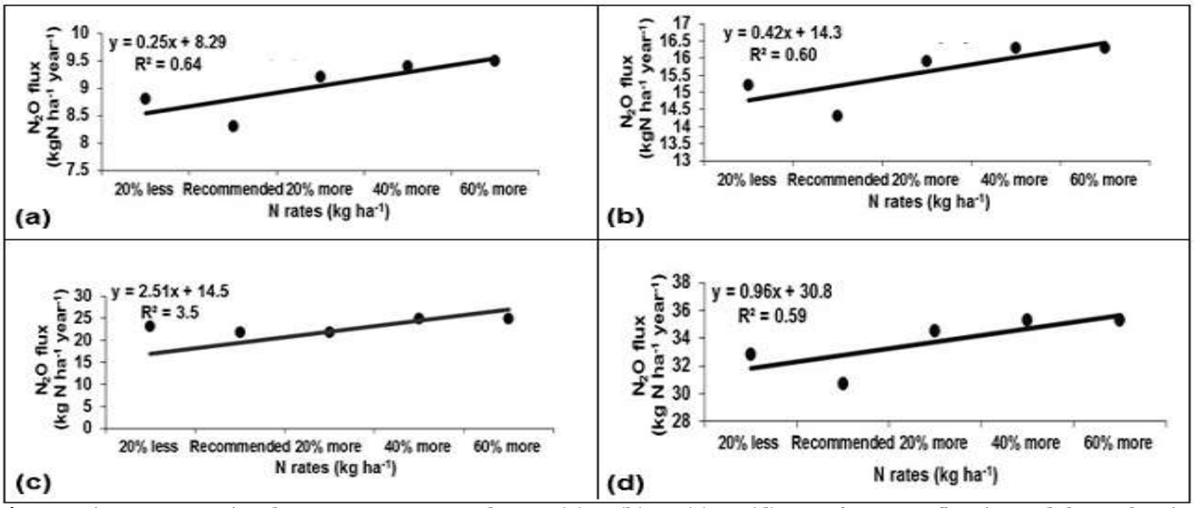

Fig. 6. Linear regression between N rates and SOC (a) 2 (b) 3, (c) 4, (d) 5 % for N_2O flux in Kedah, Malaysia.

Greenhouse gases in selected study location

Field uncertainties at study location

Field uncertainties may happen due to application of inadequate or higher N fertilizer rates. This is also true with SOC content of the soil. Thus, different rates of N and SOC content were simulated through DNDC model to predict and forecast the outcomes of GHG emission and data for other field remained the same at all study location.

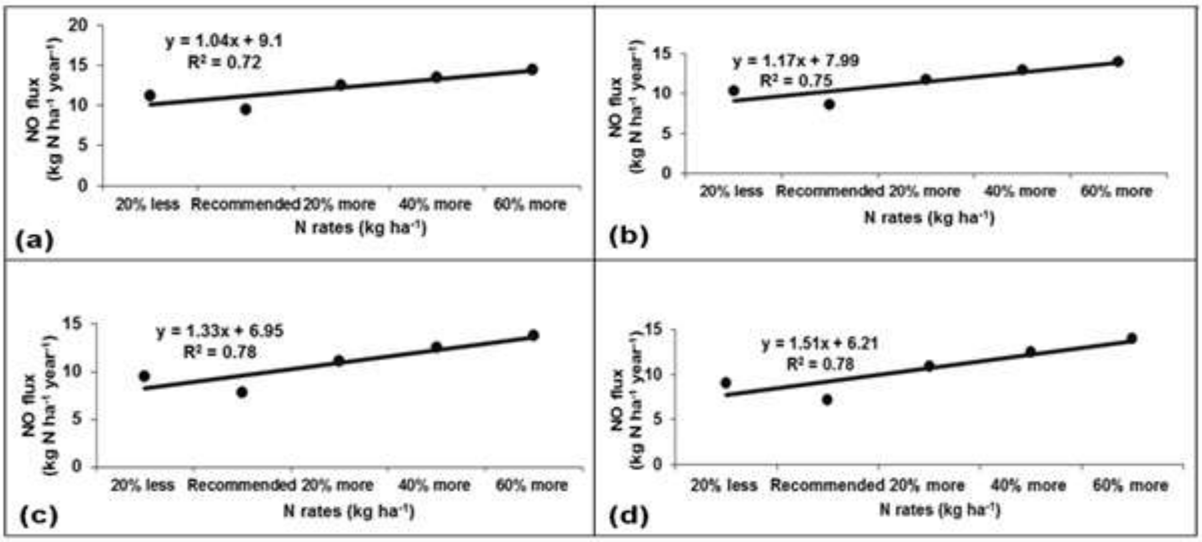

Fig. 7. Linear regression between N rates and SOC (a) 2 (b), 3 (c), 4 (d) 5 % for NO flux rate.

Uncertainties in N_2O flux

In Kedah, the unit change in SOC i.e. 0.02, 0.03, 0.04 and 0.05 kg C kg^{-1} correspondingly increased N_2O flux by 0.25, 0.42, 2.51 and 0.96 kg N ha^{-1}, respectively(Fig. 5). The coefficient of determination in all SOC contents across N rates ranged between 56 to 74 which showed strong positive relationship between N fertilizer and SOC. However, very low values of coefficient of determination (0.02) was observed at 0.02 SOC level. Figure 5.linear regression between N rates and SOC (a) 2 (b) 3, (c) 4, (d) 5 % for N_2O flux in Kedah, Malaysia.

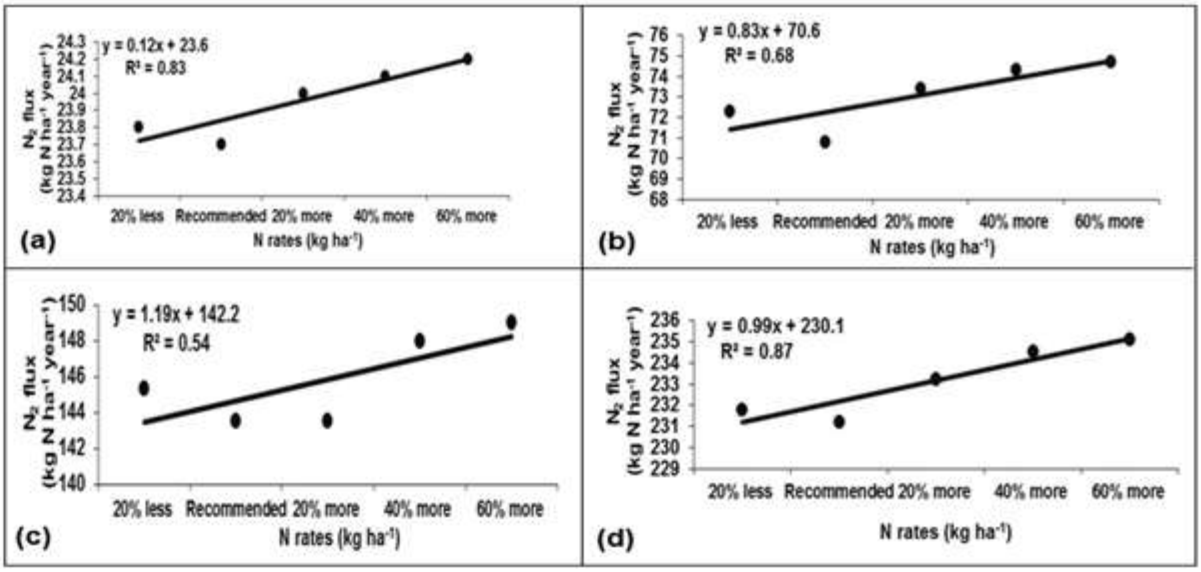

Fig. 8. Linear regression between N rates and SOC (a) 2 (b), 3 (c), 4 (d) 5 % for N_2 flux rate in Kedah, Malaysia.

Uncertainties in NO flux

In Kedah, the linear regression showed increasing trend in NO flux with a unit increase in SOC content i.e. 0.02, 0.03, 0.04 and 0.05 kg C kg^{-1} by recording NO flux of 1.04, 1.17, 1.33, 1.51 kg N ha^{-1} year^{-1}, respectively. The observed coefficient of determination in all SOC contents across N rates ranged between 0.72 to 0.78 indicating strong association between N and SOC content for NO flux (Fig. 6). Linear regression between N rates and SOC (a) 2 (b), 3 (c), 4 (d) 5 % for NO flux rate.

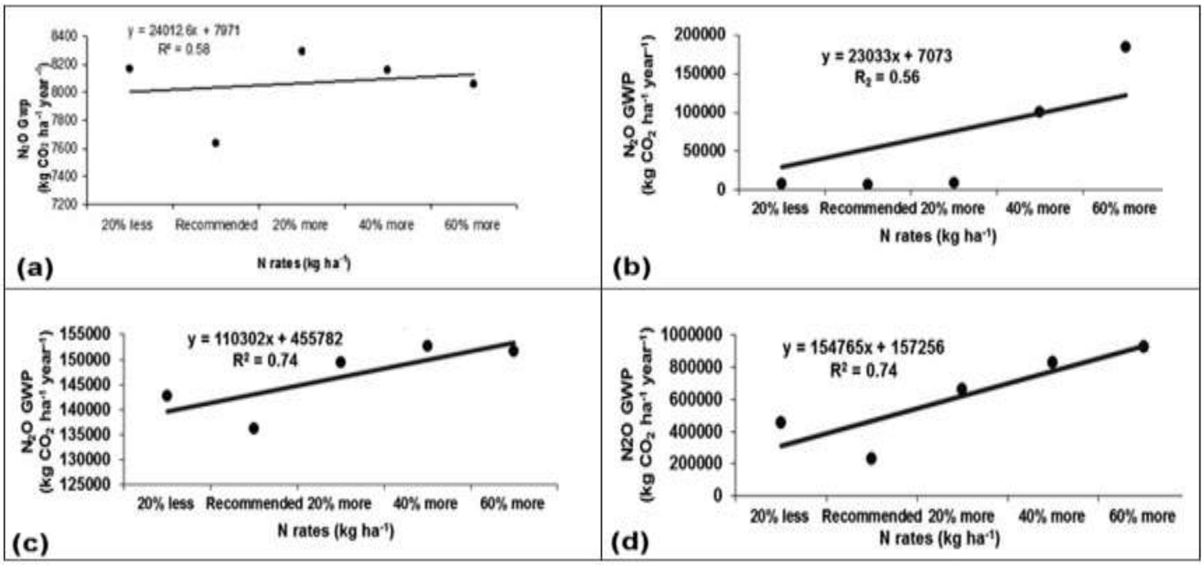

Fig. 9. Linear regression between N rates and SOC (a) 2 (b), 3 (c), 4 (d) 5% for N_2O GWP flux rate in Kedah, Malaysia.

Uncertainties in N_2 flux

The field uncertainties regarding N_2 flux in Kedah, the linear regression had positive relationship between N rates and SOC showing increasing trend in N_2 flux rate. Across N rates, a unit increase in SOC content (0.02, 0.03, 0.04 and 0.05 kg C kg^{-1}) correspondingly recorded N_2 flux by 0.12, 0.83, 1.19 and 0.99 kg ha^{-1} $year^{-1}$, respectively. The strong correlation (74 to 79 %) between N and SOC was also observed (Figure 7).

Uncertainties in N_2O GWP flux

In Kedah site, linear regression between N and SOC rates also showed positive relationship with increasing trend in N_2O GWP flux rate. A unit increase in SOC rate correspondingly increased N_2O GWP flux rate by 24012, 23033, 110302 and 154765 kg C kg^{-1} $Year^{-1}$. The coefficient of determination ranged between 0.56 to 0.74. However, very low (0.03) in 0.02 SOC (Figure 8).

Conclusions

This study assessed the applicability of the DNDC (version 9.2) model as a tool to investigate the GHG emission for approximation of annual NO, N_2O, CH_4 fluxes of some Malaysian rice. The DNDC model is process-based modeling which refers to biochemical (Hydrolysis, Nitrification, Denitrification, etc.) by simulating varying conditions within soil and crop environment. This model captures impact of soils on C and N cycling and GHG emissions, and thus simultaneously assess impact of management practices on crop yields and GHG emissions. The model emission fluxes were dependant on tillage, fertilizations, harvested straw, irrigation, crop rotation, soil reclamation and micro meteorology. In an agriculture system it is difficult to estimate the accurate GHG emission. However, DNDC made easy to estimate and validate the data. In Kelantan Malaysia, the CO_2 flux rate was increasing due to Soc, deposition of residues, elevated C and tillage practices. The N_2O emissions was greater due to current N rates, cropping system (rice-rice), flooding in the field due to annual rainfall and canal water. The clay content in soil and use of mould board plow followed by tractor operated soil peddler was also enough contributing soil N_2O flux. Methane flux was negative indicating the soil as sink. The net global warming potential was favored by both elevated CO_2 and management practices especially N fertilizers and left over crop residues as well as soil CO_2 flux. Simulation for uncertainties simulation showed that a unit increase in N rate as well as SOC correspondingly increased Nitrous oxide of fluxes (NO, N_2, GWP). Model validation showed that the simulation values and laboratory analysed values were very close indicating the model efficiency for Malaysian paddies. In Kedah farmers apply N at 140 kg ha^{-1} per season against simulated N demand of 118 and 110 kg N ha^{-1} for 1st and 2nd seasons respectively. The N_2O flux loss was 15.2 kg ha^{-1} $year^{-1}$ with, 9.5 NO flux and 72.3 N_2 flux kg ha-1 $year^{-1}$. The field uncertainties appeared due to fluctuating rates of N fertilizers and SOC. The unit increase in N rate as well as SOC correspondingly increased NO flux, and N_2O flux rate in all the rice tracts.

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