Simulation of Methane Emission from Rice Paddy Fields in Vu Gia-Thu Bồn River Basin of Vietnam Using the DNDC Model: Field Validation and Sensitivity Analysis

Ngô Đức Minh1,3,∗, Mai Văn Trịnh2, Reiner Wassmann3, Bjorn Ole Sander3, Trần Đăng Hòa4, Nguyễn Lê Trang5, Nguyễn Mạnh Khải6

1Soil and Fertilizers Research Institute, ĐỨc Thắng Ward, North Từ Liêm District, Hanoi, Vietnam
2Institute of Agricultural Environment, Phú Đô Ward, South Từ Liêm District, Hanoi, Vietnam
3International Rice Research Institute (IRRI), 4031 Los Banos, Laguna, Philippine
4Hue University of Agriculture and Forestry, 102 Phùng Hưng Street, Huế City, Vietnam
5Agriculture Genetic Institute, Phạm Văn Đồng Road, North Từ Liêm District, Hanoi, Vietnam
6Faculty of Environmental Sciences, VNU University of Science, 334 Nguyễn Trãi, Hanoi, Vietnam

Received 20 August 2014
Revised 19 September 2014; Accepted 26 March 2015

Abstract. Irrigated rice cultivation plays an important role in affecting atmospheric greenhouse gas concentrations. In recent years, extrapolation and simulation of impact of farming management on GHGs fluxes from field studies to a regional scale by models approach has been implementing. In this study, the DeNitrification & DeComposition (DNDC) model was validated to enhance its capacity of predicting methane (CH4) emissions from typical irrigated rice-based system in Vu Gia-Thu Bồn River Basin with two water management practices: Continuous Flooding and Alternate Wetting-Drying.2 rice field experiments were conducted at delta lowland (Duy Xuyen district) and midland (Dai Loc district), considered as typical regions along topography transect of study areas. The observed flux data in conjunction with the local climate, soil and management information were utilized to test a process based DNDC model, for its applicability for the rice-based system. The model was further refined to simulate emissions of CH4 under the conditions found in rice paddies of study area. The validated model was tested for its sensitivities to variations in natural conditions including weather and soil properties and management alternatives. The validation and sensitive test results indicated that (1) the modeled results of CH4 emissions showed a fair agreement with observations although minor discrepancies existed across the sites and treatments; (2) temperature factor changes had considerable impact on CH4 emissions; (3) soil properties affected significantly on CH4 emissions; (4) varying management practices could substantially affect CH4 flux from rice paddies. It was suggested that DNDC model is capable of capturing the seasonal patterns as well as the magnitudes of CH4 emissions from the experimental site in Vu Gia-Thu Bồn River Basin.

Keywords: DNDC model, validation, Methane (CH4), rice paddy, Vietnam.

1. Introduction

Rice is Vietnam’s main food product and accounting for about 50% of gross production of other food crops. Vietnam has now become a sustainable rice supplier, the world's fifth-largest rice producer and the second-largest rice exporter in the world [1]. Recognizing the importance of the role of rice production in the national economy and food security, environmental

∗ Corresponding author. DT: 84-913369778.
Email: khainm@yahoo.com
issues related to releasing the major greenhouse gas emission (GHG) has been paid great attention by Vietnam Government and became a part of The National Target Program to Respond to Climate Change. In 2012, total cultivated rice area is nearly 7.3 million hectares [2]. However, rice cultivation is the largest source of agricultural methane (CH\(_4\)) emission as 85% of annual cultivated rice areas in Vietnam is paddy field and then offer favourable conditions for CH\(_4\) emission [3]. Proportion of GHGs emission from rice cultivation in agriculture sector is accounting for 57.5% of agricultural GHGs or 26.1% of national GHGs [4]. According to estimation by IPCC method, CH\(_4\) emission from the rice fields in Vietnam is estimated to be 6.3 Tg yr\(^{-1}\) [4, 5].

During the past two decades, many empirical and physical models have been developed to predict GHG emissions from rice fields. In a number of empirical models, the regression relationships between GHG emission rate and rice biomass or yield were used to estimate GHG [6]. Although these empirical approaches were easy to use, the accuracy and precision of estimated results could not be ensured, and the variation in emissions at regional scale also couldn't be explained reasonably. It would be difficult to predict the gas fluxes with over-simplified equations across a wide range of soil conditions and management practices since many biogeochemical processes are involved in GHG production, oxidation and reduction. To meet the gaps, process-based biogeochemical models were developed to incorporate the comprehensive biogeochemical reactions and their environmental drivers. The major models that are able to simulate CH\(_4\) production include MEM, MERES, InforCrop, DNDC (DeNitrification & DeComposition)… etc. These models have been using in describing GHG production and oxidation process in paddies and estimating the GHGs emissions at regional or global scales [7-12]. Among these models, DNDC has been tested against observed CO\(_2\), N\(_2\)O or CH\(_4\) fluxes from rice paddy fields in some Asian countries, and continuously improved based on comments or suggestions from a wide range of researchers worldwide during the past about 20 years [11-13]. Calibration and validation of the model were performed for the US, China, Thailand, India, Japan ... with satisfactory results [10, 12, 14, 15]. These studies proved that DNDC is applicable for estimating CH\(_4\) emissions from rice paddies at regional scale. The objectives of the present study were to validate a process-based biogeochemistry model using field experiment data through a series of sensitivity test, and then evaluate its applicability to simulate CH\(_4\) emissions of irrigated rice field with different management practices and the typical rice-growing regions of South Central of Vietnam.

2. Materials and Methods

2.1. Description of the DNDC model

The Denitrification-Decomposition (DNDC) model is a generic model of C and N biogeochemistry in agricultural ecosystems [16]. The model simulates C and N cycling in agro-ecosystems in a daily or subdaily time step. The DNDC consists of two components including six interacting sub-models to reflect the two-level driving forces that control C and N dynamics. The first component is based on ecological and biophysical drivers (e.g. climate, soil, vegetation, and anthropogenic activity), consisting of soil climate, crop growth, and
decomposition sub-models. The soil climate sub-model simulates soil temperature, moisture, and Eh profiles by air temperature, precipitation, soil thermal and hydraulic properties, and oxygen status. The plant growth sub-model calculates daily water and N uptake by vegetation, root respiration, and plant growth and partitioning of biomass into grain, stalk, and roots. The decomposition sub-model simulates concentrations of substrates (e.g. dissolved organic carbon, NH$_4^+$, and NO$_3^-$) by integrating climate, soil properties, plant effect, and farming practices. These three submodels interact with each other to determine soil profiles of temperature, moisture, pH, redox potential (Eh), and substrate concentration in a daily time step. The second component, which consists of fermentation, denitrification, and nitrification submodels, predicts NO, N$_2$O, N$_2$, CO$_2$, CH$_4$, and NH$_3$ gaseous fluxes based on the soil environmental variables. The fermentation submodel calculates the production, oxidation, and transport of CH$_4$ under anaerobic conditions. The denitrification submodel calculates the production, consumption, and diffusion of N$_2$O and NO during rainfall, irrigation, or flooding events. The nitrification submodel calculates initially the ammonium pool (taking into account ammonium production and NH$_3$ volatilization) and then the conversion of ammonium to nitrate [8, 9].

![Diagram of the DNDC model](image)
Whereas SOM the soil organic matter, DOC the dissolved organic carbon.

For the measurement-model fused study, the field experiments provided the first hand of information about the GHGs emissions with relevant environmental conditions, and the field observations were utilized for the model validation first and then extrapolated through the sensitivity analysis as well as long-term predictions with the validated model.

2.2. Field site and measurement

Study site is located in Vu Gia-Thu Bon River Basin. This is the largest river basins and also the key economic and agricultural regions in the Central Coast region of Vietnam. Area of agricultural land is accounting for 220,040 ha, of which 61% is used for rice cultivation. Rice is considered as the most important food crop with 120,000 ha of cultivated area. Rice is the dominant staple crop and is mainly planted in the lowland areas [17].

The experiments were conducted in collaboration with Hue University of Agriculture and Forestry in 2 dry crops (2011 and 2012) in Duy Xuyen (delta lowland - DL) and Dai Loc (hilly midland - HM) districts of Quang Nam Province.

![Figure 2. Location map of Vu Gia-Thu Bon River Basin.](image-url)
The measured data from two field experiments were used for the calibration of the model. The experiments included treatments varying in N sources and water management in plots of 5 m long and 5 m wide. Fourteen-day-old rice seedlings were transplanted by hand at 20 cm (row to row) by 15 cm (hill to hill) spacing in 2011-2013. Emission of CH₄ was measured frequently from the plots following GHGs measurement for static chamber method [18, 19]. Total dry matter and grain yield were measured at maturity. Daily ambient air temperature and precipitation data were collected from the local meteorological station. The soils, water and air temperature within the chambers were also recorded during each of gas samplings. Soil moisture at approximately 5 cm depth inside the closed chamber was measured with the oven drying method.

The closed chamber technique is widely used for emission analysis from soils [20, 21]. The concentration of a gas increases inside a closed chamber over time depending on its flux rate. Gas samples from the inside of the chamber are taken manually with a syringe at 10-minute intervals over a time period of 30 minutes. The gas is stored in glass vials and analyzed with a gas chromatograph (GC). The GC uses a flame ionization detector (FID) to analyze the concentration of methane in a gas sample and an electron capture detector (ECD) to analyze the concentration of nitrous oxide. The flux rate in the field can be calculated from the concentration increase of the respective gas in the different samples [22]. The effect of the irrigation regimes for rice on CH₄ emissions will be assessed.

2.3. Data input

All data for the 2 districts were collected from field survey and/or literatures of the Land Use and Climate Change Interactions in Central Vietnam (LUCCI) project and Quang Nam Province. Then, the data were converted, edited to fit the formal requirements as input parameters for running the DNDC model, and used to simulate CH₄ and N₂O emissions for all cropping systems in each district. The data required for the DNDC model comprised soil properties, meteorological data, and farming management, as shown in detail in the section describing the DNDC.

Climate data (radiation, minimum and maximum temperature, rainfall, etc., in daily time steps) were obtained from the RBIS system of the LUCCI project. The climate data were converted to text format file, including 365 days, maximum and minimum temperature (°C), and rainfall.

Soil database of the case study were compiled between 2008 and 2010. The soils were classified to the soil subunit level according to the FAO classification system. The soil databases provide information on all main soil profiles and final reports. With the soil profile information, qualitative and quantitative analyses for chemical and physical properties of soil horizon data can be conducted. Soil properties used in this thesis included mean values of clay fraction, pH, bulk density, and organic carbon content of the surface horizon (topsoil) by soil subunits. The pH varies from extreme acidity of 4.5 to slightly acid of 6. The texture is quite heavy with sandy loam, with clay content ranging from 15% to 19%. Bulk density ranges from 1.15 to 1.40 g/cm³. The soil database also provided the minimum and maximum value of soil properties (clay content, soil organic carbon (SOC), pH, and bulk density.

Farm management practices were extracted from questionnaires through farm household survey (FHS) conducted in 2012-2013.
A common amount of urea fertilizer applied for irrigated lowland rice systems in Quang Nam ranged from 110 to 130 kg/ha and was divided into three applications (i.e. 45% at 1 day before transplanting and 35% at 25 days and 20% at 60 days after transplanting). Farmyard manure was applied at 6,000 kg/ha 1 day before transplanting for both spring rice and summer/winter rice. Paddy fields were plowed one time, 20 cm depth, with a moldboard plow before rice transplanting, except for upland rice plowed only 10 cm deep. Irrigation was simulated in two practices: (i) continuous flooding with end-season drainage (CF) and (ii) Alternate Wetting-Drying (AWD). In the case of CF, fields were continuously flooded from 10 to 15 days before transplanting until 15 days before harvesting. For AWD, fields were drained 30 days after transplanting, allowed to dry for 7 days, re-flooded for 30 days, drained, allowed to dry for 7 days, and re-flooded again until 15 days before harvest.

2.4. Integration of field data and model

The field data from experiment were integrated with DNDC through 2 phases:

At first, the field data was utilized for model validation, through which the applicability of DNDC for rice based system in site was tested. During the validation tests, the local daily climate data, soil properties and actual farming practices (e.g. tillage, fertilization, irrigation etc.) were utilized to compose input scenarios, which were used to run DNDC for the target ecosystem; and the modelled rice yields as well as the GHG fluxes were compared with the field observations. Statistical tools including the root mean square error (RMSE), the coefficient of model efficiency (EF) and the coefficient of model determination (CD) were adopted to assess the “goodness of fit” of model predictions.

After the tests, the validated DNDC was utilized for a sensitivity test. DNDC was run for the same site but with varied climate, soil and management conditions. The purpose of the sensitivity test was to identify the most sensitive factors that could most effectively mitigate the greenhouse gas emissions from the target ecosystem. Model sensitivity was evaluated for changes in some farming management (water regime, farm yard manure (FYM) application, straw incorporation) on rice yields and GHGs emissions using the baseline data (weather, soil, cultivar, location, and other inputs) of the experiment.

3. Results and discussions

3.1. Model validation

Validations were made for the DNDC model to improve its performance in simulating crop yield and CH$_4$ emissions for Vietnamese rice fields. Most of the crop physiological and phenological parameters set in the DNDC model were originally calibrated against data sets observed in the U.S, India, China or other temperate regions [10, 12-15]. Discrepancies appeared when the model was applied for the rice crops in Vietnam. Originally, the CH$_4$ fluxes simulated by the model were higher than the measured fluxes in some rice paddies in Vietnam.

Table 1 shows the statistical analysis for comparison between the modeled CH$_4$ fluxes with observations at the two irrigation regimes (CF and AWD) for 2 sites. Regression analysis demonstrated that the simulated emissions explained over 85% of the variation in observed emissions for all the 2 cases. The RMSE values for the four cases are 0.198, 0.215, 0.206 and 0.234 for CF-HM, CF-DL, AWD-HM and
AWD-DL, respectively. All EF coefficients are positive (>0.8), and CD coefficients are greater than 1. The results indicated that DNDC is capable of capturing the seasonal patterns as well as the magnitudes of CH$_4$ emissions from the experimental site in the VG-TB river basin. Therefore, the modeled results generally showed a fair agreement with observations although minor discrepancies exist across the sites and treatments.

Figure 3 indicated that the modeled CH$_4$ fluxes showed a strong correlation with observations. The field measured and simulated daily CH$_4$ emission rates showed similar seasonal patterns for both hilly midland (HM) and delta lowland (DL). Along with the change in water regime, both modeled and observed CH$_4$ fluxes increased in the CF scenario and decreased rapidly in AWD scenario. Hence, there was a significantly positive correlation between CH$_4$ emission and with two water management regimes. The modelled CH$_4$ fluxes were mostly located within the standard deviations of the measured CH$_4$ fluxes. The linear regression of all simulated and observed mean CO$_2$ emission rates resulted in R$^2$ values 0.865 & 0.848 and 0.831 & 0.850 for HM and DL, respectively. The simulations fairly captured the magnitudes and patterns of the observed CH$_4$ emissions for both HM and DL. The daily simulated data in Figure 3 indicated that the modeled background emissions of CH$_4$ were mostly from decomposition; and the episodic peak fluxes were dominated by fermentation. In comparison with observations, DNDC predicted more CH$_4$ flux peaks which were not observed in the field. The overall correlation between observed and simulated daily CH$_4$ fluxes was acceptable for both HM and DL (R$^2$>0.863 and 0.836, respectively). Given the inherently complex processes involved in the CH$_4$ production in the field, the modeled results were encouraging.

Figure 4 also shows the modeled CH$_4$ emission fluxes in comparison with daily observations. During the period of the crop growth, especially in the vegetative stage, the root respiration accounted about more than 50% of the total CH$_4$ emissions. A steadily increasing CH$_4$ flux under CF regime and a large decreasing CH$_4$ flux under AWD were in agreement with the results in previous studies [21, 23, 24].

Applying AWD for irrigated rice paddies often gives rise to a drop in seasonal CH$_4$ flux. Measured and simulated data in Table 2 indicated that CH$_4$ emissions were reduced by 30-33% and 40-42% in the AWD treatment compared with the CF treatment for HM and DL, respectively. Water management would exert an influence on the decomposition of crop residue applied, and therefore their contributions to CH$_4$ emissions.

Table 1. Statistical analysis for comparison of the simulated and observed CH$_4$ fluxes (kgCH$_4$-C/ha/day) in 4 case studies

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Measurement number</th>
<th>R$^2$</th>
<th>RMSE</th>
<th>EF</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF-HM</td>
<td>12</td>
<td>0.856</td>
<td>0.198</td>
<td>0.835</td>
<td>1.189</td>
</tr>
<tr>
<td>CF-DL</td>
<td>12</td>
<td>0.848</td>
<td>0.215</td>
<td>0.828</td>
<td>1.226</td>
</tr>
<tr>
<td>AWD-HM</td>
<td>12</td>
<td>0.831</td>
<td>0.206</td>
<td>0.809</td>
<td>1.068</td>
</tr>
<tr>
<td>AWD-DL</td>
<td>12</td>
<td>0.850</td>
<td>0.234</td>
<td>0.816</td>
<td>1.160</td>
</tr>
</tbody>
</table>
Figure 3. Correlation between simulated vs. measured CH4 emission from rice fields with different water management regime/scenario.
Figure 4. Comparison of simulated and measured CH₄ daily emissions from rice fields with different management water regime/scenario.

![Graphs comparing simulated and measured CH₄ emissions](image)

Table 2. Measured and simulated CH₄ emission rate (kg/ha/season)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Hilly Midland</th>
<th>Delta Lowland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured</td>
<td>Simulated</td>
</tr>
<tr>
<td>CF</td>
<td>197.9  a</td>
<td>220.5  a</td>
</tr>
<tr>
<td>AWD</td>
<td>131.4  b</td>
<td>153.6  b</td>
</tr>
<tr>
<td>% Decrease</td>
<td>-33.6</td>
<td>-30.3</td>
</tr>
</tbody>
</table>

(Note: a & b; A & B: the significant difference between two means by T-test analysis at α=0.05)

As can be seen in Table 2, total measured seasonal emissions of CH₄ during the dry season were 197.9 & 598.7 and 131.4 & 347.6 kg/ha/season for the CF plot and the AWD plot, respectively, while the simulated emissions were 220.5 & 647.2 and 153.6 & 384.2 kg/ha/season respectively. The discrepancies between simulated and observed seasonal fluxes of CH₄ were less than 16% for both study sites and water management regime. The discrepancy on the CH₄ emissions could be related to the interpolation approach converting the observed daily CH₄ fluxes to a seasonal total. The results indicated that DNDC is capable of capturing the seasonal patterns as well as the magnitudes of CH₄ emissions from the experimental site in Quang Nam province.

3.2. Model sensitivity analysis

Sensitivity tests were conducted to check the general behaviour of the DNDC model for the specific rice-based system. Though a great amount of observations on GHGs emissions from croplands have been reported worldwide, few of field measurements have tested impacts of variations of a complete set of the driver on GHGs emissions. A sensitivity test was conducted with DNDC to find out the most sensitive factors for CH₄ emissions from rice field in Quang Nam.

The baseline scenario was set based on the actual climate, soil and management conditions in the dry rice crop season in Quang Nam. The sensitivity test was conducted by varying a single input parameter in a observed range (climate variables (temperature or precipitation), soil properties (soil organic carbon (SOC) content, clay fraction, pH and bulk density), or agricultural management practices (water regime, residue management and N-fertilizer application rate) within province scope while keeping all other input parameters constant as baseline scenario. All the parameters of baseline and alternative for sensitivity analysis are listed in Table 3.
Table 3. Values of driver parameters varied for sensitivity tests

<table>
<thead>
<tr>
<th>No</th>
<th>Input parameter</th>
<th>Unit</th>
<th>Baseline value</th>
<th>Range of value for sensitive test</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Weather data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual mean temperature °C</td>
<td>26.8</td>
<td>-2 -1 1 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total annual precipitation mm</td>
<td>2893</td>
<td>-20% -10% +10% +20%</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Soil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil texture (soil type)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silt loam</td>
<td>2.5</td>
<td>1.5 2.0 3.0 3.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loamy sand</td>
<td>5.5</td>
<td>4.5 5 6 6.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandy loam</td>
<td>1.1</td>
<td>0.1 0.6 1.6 2.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandy clay loam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulk density of top soil g/cm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total fertilizer N input kg/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of water drainages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FYM amendment kg/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Residue incorporation %</td>
<td>20</td>
<td>20 40 60 80 100</td>
<td></td>
</tr>
</tbody>
</table>

The likely response of CH₄ emission to changes in climate was investigated by running DNDC using alternative climate scenarios. Precipitation was either increased or decreased by 10% and 20% of the baseline value (2893 mm year⁻¹); and temperature was varied by 1 or 2°C. The modeled results (Figure 5) indicated that the precipitation changes were negligible impact on CH₄ emissions while the higher temperature elevated CH₄ emissions due to the accelerated SOM decomposition and fermentation process. The results are in agreement with previous studies reported by other researchers [19-26].

Four soil properties (soil texture, bulk density pH and SOC content) were investigated in the sensitivity test. The soil texture showed the greatest impact on CH₄ fluxes due to its effects on the soil anaerobic status: the clay loam soil was more likely to produce more CH₄ than the sandy soil. SOC content was the second most sensitive factor due its effects on the soil DOC availability as well as the methanogen population. An increase in the initial SOC from baseline 1% to 2% elevated SOC decomposition rate, and hence led to more CH₄ emitted. Conversely, a decrease in the initial SOC content from 1% to 0.25% converted the soil from a source to a sink of atmospheric CH₄. In comparison with SOC and soil texture, other natural factors such as temperature, bulk density, pH had relatively moderate effects on CH₄ emissions for the tested site. These trends in this study were similar to those reported in earlier studies [10, 23, 24]. The sensitivity test provided crucial information for simulations as we learnt which input parameters could most sensitively affect the modeled results and hence should be paid with the greatest considerations.

Figure 5. Sensitivity tests of environmental factors and alternative management practices driving CH₄ emissions from rice paddies.
Among the tested farming management practices in rice paddy, water management regime, FYM application and straw incorporation rate are three major anthropogenic activities that showed notable impacts on the seasonal net CH$_4$ emissions. Figure 3 shows that the CH$_4$ emission was reduced by 35% when the number of the midseason drainage (MD) increased from 1 to 3 times. Many studies also revealed that midseason drainage can significantly reduce CH$_4$ emissions from the soil [21, 24]. Adding FYM significantly elevated CH$_4$ emission. Increase in organic fertilizer application rate from 2 to 6 tons FYM per ha increased CH$_4$ emission rate from 15-32% comparing with baseline survey. In the test, crop straw incorporation also show strong effect on CH$_4$ emission: Rate of CH$_4$ emissions increased to 12%, 25%, 37% and 46% in rice-rice systems under the 0.4, 0.6, 0.8 and 1 scenarios of fraction of rice residue incorporated in the field (40%, 60%, 80% and 100% straw residues left after harvest). The variation in N fertilizer application rate probably do not effect on CH$_4$ emission either.

4. Conclusion

In this study we report the test of the DNDC model for paddy rice in South Central Coast of Vietnam. This initial study compared simulations of CH$_4$ emissions with observation. There was a strong correlation between simulated and measured daily and seasonal CH$_4$ fluxes, particularly for the closed chamber measurement site. The statistical analysis for comparison of the simulated and observed CH4 fluxes demonstrated the “goodness of fit” of model prediction as all EF coefficients are positive (>0.8), CD coefficients are greater than 1 in all case study sites. The sensitive test results indicated that the environmental factor changes and varying management practices could substantially affect CH$_4$ flux from rice paddies. There were some minor discrepancies between observed and simulated CH$_4$ fluxes because of the diverse soil and climate conditions and the socioeconomic status of the farmers indicating that DNDC could not capture all the processes occurring in the field.

The analysis suggested that the model can be applied for capturing the seasonal patterns as well as the magnitudes of CH$_4$ emissions from the experimental site in Vu Gia-Thu Bon River Basin. With continuous modification and calibration, the DNDC model can also become powerful and very useful tool for estimation of GHGs emissions at regional and national scale.

Acknowledgments

The first author is thankful to the International Rice Research Institute (IRRI) for providing a fellowship and facilities to carry out the work. Funding for this study was supported by IRRI and the LUCCI project.

Reference


Kiểm định và hiệu chỉnh mô hình DNDC trong tính toán phát thải khí metan (CH₄) từ canh tác lúa tại lưu vực sông Vu Gia-Thu Bồn, Việt Nam

Ngô Đức Minh¹,², Mai Văn Trinh², Reiner Wassmann³, Bjorn Ole Sander⁴, Trần Đăng Hòa⁴, Nguyễn Lê Trang⁵, Nguyễn Mạnh Khải⁶

¹Viện Thơ nhỏ Nông hòa, phường Đức Thắng, Bắc Từ Liêm, Hà Nội, Việt Nam
²Viện Môi trường Nông nghiệp, phường Phú Đô, Nam Từ Liêm, Hà Nội, Việt Nam
³Viện Nghiên cứu lúa quốc tế, 4031 Los Banos, Laguna, Philippine
⁴Đại học Nông lâm lũy 102 đường Phùng Hưng, TP Huế, Việt Nam
⁵Viện Di truyền Nông nghiệp, Km2, đường Phạm Văn Đông, Bắc Từ Liêm, Hà Nội, Việt Nam
⁶Khoa Môi trường, Trường Đại học Khoa học Tài nguyên, ĐHQGHN, 334 Nguyễn Trãi, Hà Nội, Việt Nam

Tóm tắt: Sản xuất nông nghiệp hiện đang đóng góp 14% tổng lượng khí thải nhà kính ra môi trường, trong đó phát thải từ canh tác lúa nước chiếm gần 60% tổng lượng phát thải từ nông nghiệp. Trong những năm gần đây, ứng dụng mô hình hóa nhằm tính toán, đánh giá tác động của các yếu tố tự nhiên (đất đai, thời tiết...) và biến pháp canh tác đến sự phát thải khí nhà kính đã dần trở lên phổ biến trên thế giới. Tuy nhiên, việc áp dụng mô hình trong tính toán phát thải khí nhà kính chưa được áp dụng nhiều. Trong nghiên cứu này, mô hình DNDC (mô hình sinh địa hoa) được kiểm định và hiệu chỉnh nhằm đánh giá khả năng ứng dụng trong tính toán phát thải metan trong các chế độ trồng khác nhau (ngập nước thường xuyên và khô ướt xen kẽ) tại hai khu vực canh tác lúa nước diện hình ở lưu vực sông Vu Gia-Thu Bồn (vùng đồng bằng và vùng trung du). Số liệu đo đạc từ thí nghiệm đồng ruộng và dữ liệu về khí hậu, biến pháp canh tác đã được sử dụng để kiểm nghiệm và hiệu chỉnh mô hình DNDC thích hợp với điều kiện của khu vực nghiên cứu. Các kết quả kiểm định cho thấy: Mô hình DNDC thích hợp cho tính toán phát thải metan tại vùng nghiên cứu với hệ số tương quan giữa kết quả mô hình và phần tích trên 83%, đại lượng mức độ phù hợp của mô hình xấp xỉ 0,90. Ngoài ra, kết quả phân tích sau hiệu chỉnh chỉ ra được mức độ ảnh hưởng cụ thể và chính xác của từng yếu tố đến kết quả ước lượng metan: (1) yếu tố nhiệt độ có ảnh hưởng rất lớn đến lượng khí thải CH₄; (2) tính chất của đất (hàm lượng OC, thành phần cơ giới, pH) ảnh hưởng lớn nhất đến phát thải CH₄; (3) Các biến pháp canh tác (chế độ vườn, bón phân hữu cơ...) cũng có ảnh hưởng đáng kể phát thải metan. Thử tự mức độ ảnh hưởng của các yếu tố khá thông nhất giữa hai khu vực nghiên cứu.

Từ khóa: Mô hình, DNDC, kiểm định, Metan (CH₄), lúa, Việt Nam.