# 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 Minh[1,3,*], Mai Văn Trịnh[2], Reiner Wassmann[3], Bjorn Ole Sander[3], Trần Đăng Hòa[4], Nguyễn Lê Trang[5], Nguyễn Mạnh Khải[6]

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

**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 ($CH_4$) 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 $CH_4$ 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 $CH_4$ emissions showed a fair agreement with observations although minor discrepancies existed across the sites and treatments; (2) temperature factor changes had considerable impact on $CH_4$ emissions; (3) soil properties affected significantly on $CH_4$ emissions; (4) varying management practices could substantially affect $CH_4$ flux from rice paddies. It was suggested that DNDC model is capable of capturing the seasonal patterns as well as the magnitudes of $CH_4$ emissions from the experimental site in Vu Gia-Thu Bồn River Basin.

*Keywords*: DNDC model, validation, Methane ($CH_4$), 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. ĐT: 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, CH4 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 $CO_2$, $N_2O$ 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 sensitice test, and then evaluate its applicability to simulate CH4 emissions of irigated 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, $N_2O$, $N_2$, $CO_2$, $CH_4$, 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 $N_2O$ 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].
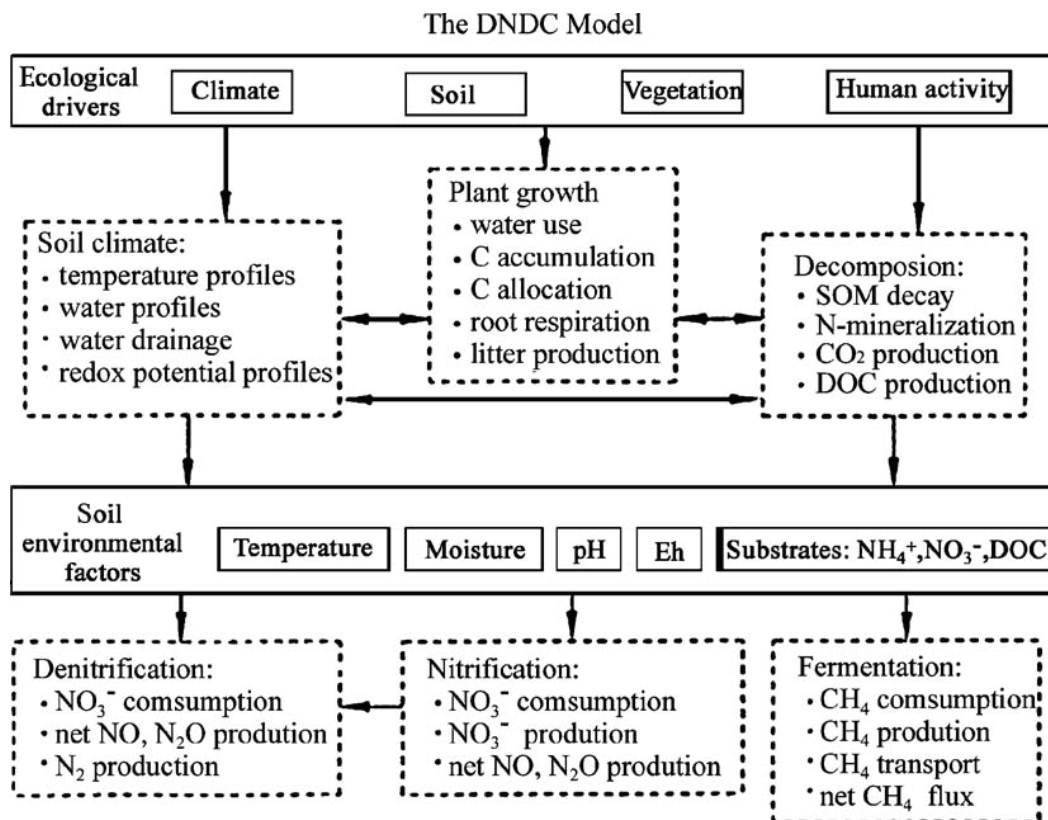


Figure1. The structure of the DNDC model [16].

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.

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 $CH_4$ 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 $CH_4$ 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 $CH_4$ and $N_2O$ 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 ($^o$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/cm$^3$. 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. The

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 (kg$CH_4$-C/ha/day) in 4 case studies

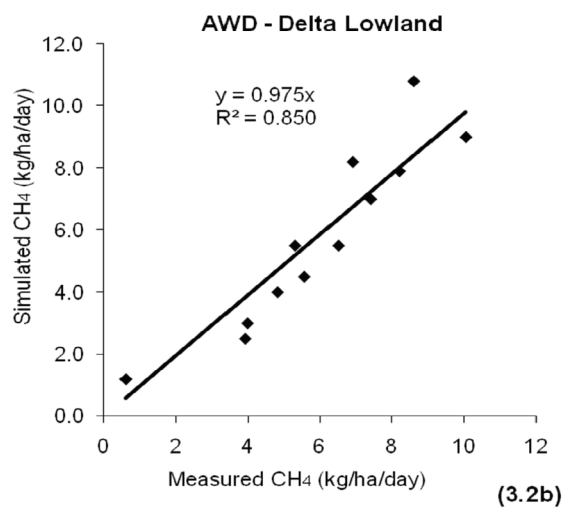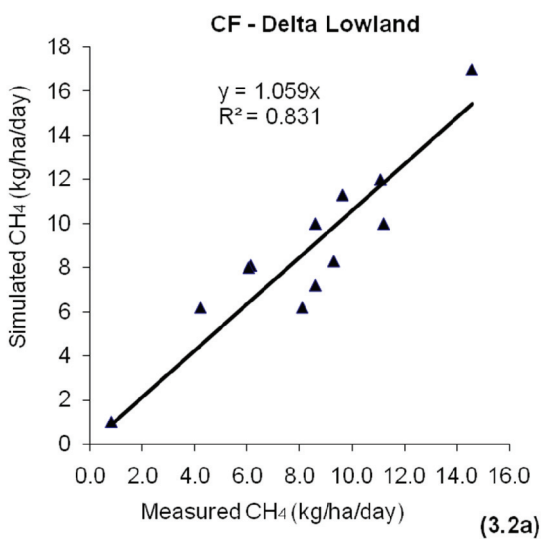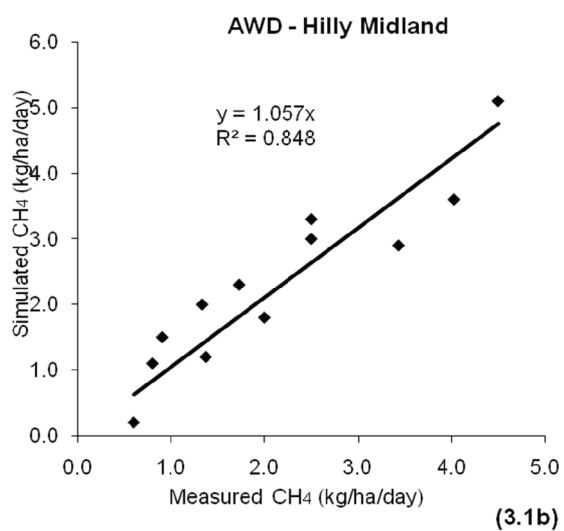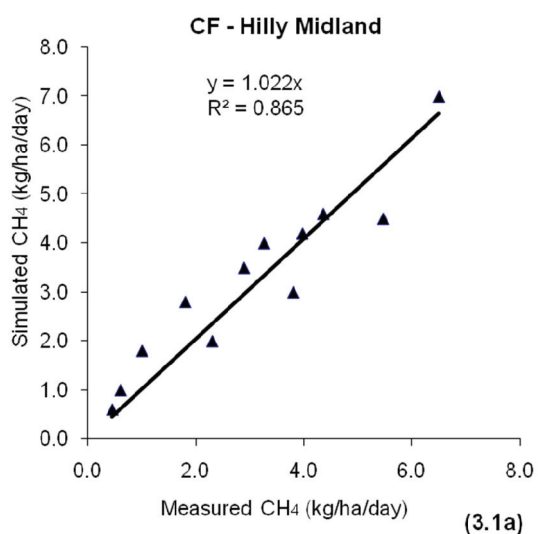| Treatments | Measurement number | $R^2$ | RMSE | EF | CD |
|---|---|---|---|---|---|
| CF-HM | 12 | 0.856 | 0.198 | 0.835 | 1.189 |
| CF-DL | 12 | 0.848 | 0.215 | 0.828 | 1.226 |
| AWD-HM | 12 | 0.831 | 0.206 | 0.809 | 1.068 |
| AWD-DL | 12 | 0.850 | 0.234 | 0.816 | 1.160 |

Figure 3. Correlation between simulated vs. measured CH4 emission from rice fields
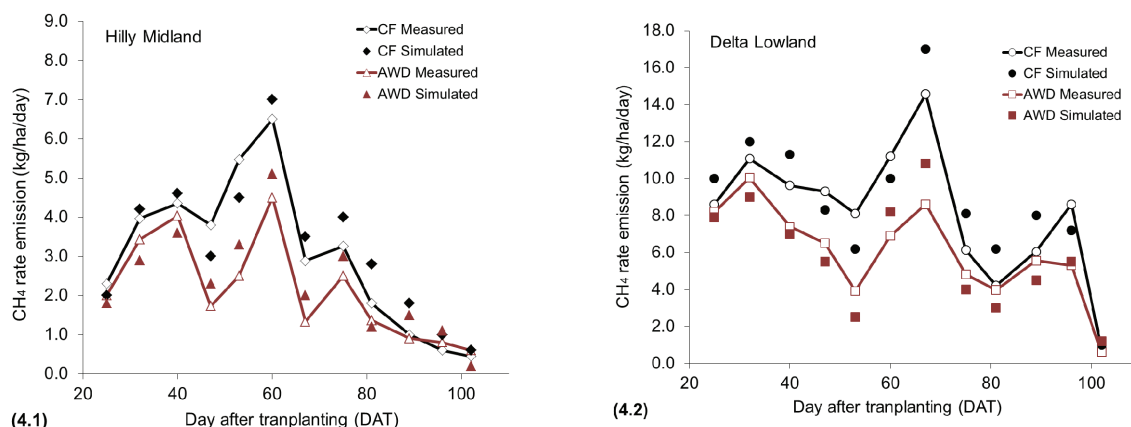with different water management regime/scenario.

Figure 4. Comparison of simulated and measured CH$_4$ daily emissions from rice fields with different management water regime/scenario.

Table 2. Measured and simulated CH$_4$ emission rate (kg/ha/season)

| Treatment | Hilly Midland | | Delta Lowland | |
|---|---|---|---|---|
| | Measured | Simulated | Measured | Simulated |
| CF | 197.9[a] | 220.5[a] | 598.7[A] | 647.2[A] |
| AWD | 131.4[b] | 153.6[b] | 347.6[B] | 384.2[B] |
| % Decrease | -33.6 | -30.3 | -41.9 | -40.6 |

(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 CH$_4$ 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 CH$_4$ were less than 16% for both study sites and water management regime. The discrepancy on the CH$_4$ emissions could be related to the interpolation approach converting the observed daily CH$_4$ fluxes to a seasonal total. 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 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 CH$_4$ 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

| No | Input parameter | Unit | Baseline value | Range of value for sensitive test | | | |
|----|-----------------|------|----------------|-------------|---|---|---|
| I | Weather data | | | | | | |
| | Annual mean temperature | ºC | 26.8 | -2 | -1 | 1 | 2 |
| | Total annual precipitation | mm | 2893 | -20% | -10% | +10% | +20% |
| II | Soil | | | | | | |
| | Soil texture (soil type) | | Silt loam | Loamy sand | Sandy loam | Loam | Sandy clay loam |
| | Bulk density of top soil | g/cm$^3$ | 2.5 | 1.5 | 2.0 | 3.0 | 3.5 |
| | pH of top soil | | 5.5 | 4.5 | 5 | 6 | 6.5 |
| | SOC | % | 1.1 | 0.1 | 0.6 | 1.6 | 2.1 |
| III | Management alternatives | | | | | | |
| | Total fertilizer N input | kg/ha | 120 | 60 | 90 | 150 | 180 |
| | Number of water drainages | | 0 | | 1 | 2 | 3 |
| | FYM amendment | kg/ha | 0 | - | 2000 | 4000 | 6000 |
| | Residue incorporation | % | 20 | 40 | 60 | 80 | 100 |

The likely response of CH$_4$ 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 2ºC. The modeled results (Figure 5) indicated that the precipitation changes were negligible impact on CH$_4$ emissions while the higher temperature elevated CH$_4$ 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 CH$_4$ fluxes due to its effects on the soil anaerobic status: the clay loam soil was more likely to produce more CH$_4$ 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 CH$_4$ 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 CH$_4$. In comparison with SOC and soil texture, other natural factors such as temperature, bulk density, pH had relatively

moderate effects on CH$_4$ 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.
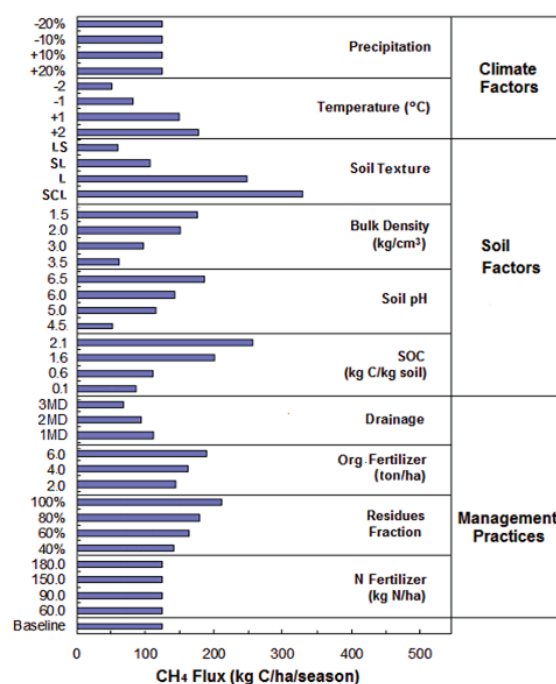


Figure 5. Sensitivity tests of environmental factors and alternative management practices driving CH$_4$ emissions from rice paddies.

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

## Reference

[1] International Rice Research Institute. In http://irri.org/our-work/locations/vietnam

[2] General Statistics Office Of Vietnam. Statistical data on Agriculture, Forestry and Fishery. Available in http://www.gso.gov.vn/default_en.aspx?tabid=469&idmid=3

[3] Institute for Agricultural Environment. Climate change impacts and adaptation strategies in agriculture. Vietnam Study on the Adaptation to Climate Change: Agriculture. Study report of Project P114750, 2009.

[4] World Bank. Potential climate change mitigation opportunities in the agriculture and forestry sector in Vietnam. Background Paper 58102. Carbon Finance Assist Program – Vietnam. Nov-2010.

[5]   US-EPA. Emissions and Projections of Non-CO2 Greenhouse Gases for Developing Countries: 1990-2020. Office of Air and Radiation, USEPA, Washington, D.C.

[6]   Anastasi C, Dowding M, Simpson VJ. Future $CH_4$ emission from rice production. J. Geophys. Res. 97 (1992):7521-7525,.

[7]   Cao M, Dent JB, Heal O W. Modelling methane emissions from rice paddies. Global Biogeochem. Cycles 9 (1995):183-195.

[8]   Li C, Frolking S, Harriss RC. Modeling carbon biogeochemistry in agricultural soils. Global Biogeochem. Cycles 8 (1994):237-254.

[9]   Li C. Modeling trace gas emissions from agricultural ecosystems. Nutr. Cycl. Agroecosyst. 58 (200):259-276.

[10]  Li, C., Mosier, A., Wassmann, R., Cai, Z., Zheng, X., Huang, Y., Tsuruta, H., Boonjawat, J., and Lantin, R.: Modeling greenhouse gas emissions from rice-based production systems: Sensitivity and upscaling, Global Biogeochemical Cycles, 18 (2004), 1–19.

[11]  Cai Z, Sawamoto T, Li C, Kang G, Boonjawat J, Mosier A, Wassmann R, Tsuruta H. Field validation of the DNDC model for greenhouse gas emissions in East Asian cropping systems. Global Biogeochem. Cycles 17(4):1107. doi:10.1029/2003GB002046, 2003.

[12]  Pathak H, Li CS, Wassmann R. Greenhouse gas emissions from Indian rice fields: calibration and upscaling using the DNDC model. Biogeosciences. 2005; 2:113–123

[13]  Zhang L, Yu D, Shi X, Weindorf D, Zhao L, et al. Quantifing methane emissions from rice fields in the Taihu Lake region, China by coupling a detailed soil database with biogeochemical model. Biogeosciences. 2009; 6:739–749

[14]  Babu YJ, Li CS, Frolking S, Nayak DR, Adhya TK. Field validation of DNDC model for methane and nitrous oxide emissions from rice-based production systems of India. Nutr Cycl Agroecosys. 2006;74:157–174

[15]  Matthews RB, Wassmann R, Arah J. Using a crop/soil simulation model and GIS techniques to assess methane emsissions from rice fields in Asia, I. Model development. Nutr Cycl Agroecosys. 2000;58:141–159

[16]  Institute for the Study of Earth, Oceans and Space - University of New Hampshire. User's Guide for the DNDC Model, April 15, 2007

[17]  LUCCi –Land Use and Climate Change Interactions in Central Vietnam. Available in http://www.lucci-vietnam.info/project-region/natural-environment

[18]  IPCC (Intergovernmental Panel on Climate Change). IPCC guidelines for national greenhouse gas inventories. Vol. 4. Hayama (Japan): Institute for Global Environmental Strategies (IGES), 2006.

[19]  Sapkota, T.B., Rai, M., Singh, L.K., Gathala, M.K., Jat, M.L., Sutaliya, J.M., Bijarniya, D., Jat, M.K., Jat, R.K., Parihar, C.M., Kapoor, P., Jat, H.S., Dadarwal, R.S., Sharma, P.C. and Sharma, D.K. Greenhouse Gas Measurement from Smallholder Production Systems: Guidelines for Static Chamber Method. International Maize and Wheat Improvement Center (CIMMYT) and Indian Council of Agricultural Research (ICAR), New Delhi, India. 2014.

[20]  Adhya TK, Rath AK, Gupta PK, Rao PR, Das SN, Parida KM, Parasher DC, Sethunathan N. Methane emission from flooded rice fields under irrigated conditions. Biol. Fert. Soils 18 (1994): 245-248.

[21]  Sass RL, Fisher FM, Harcombe PA, Tumer FT. Methane production and emission in a Texas rice field. Global Biogeochem. Cycles 4 (1990):47-68.

[22]  Parashar DC, Gupta PK, Rai J, Sharma RC, Singh N. Effect of soil temperature on methane emission from paddy field. Chemosphere 26 (1993):247-250.

[23]  Wassmann R, Lantin RS, Neue HU, Buendia LV, Corton TM, Lu Y. Characterization of methane emissions from rice fields in Asia. III. Mitigation options and future research needs. Nutr. Cycl. Agroecosyst. 58 (2000):23-36.

[24]  Yagi K, Tsuruta H, Kanda K, Minami K. Effect of water management on methane emission from Japanese rice paddy field: automated methane monitoring. Global Biogeochem. Cycles 10 (1996):255-267.

[25]  Lu WF, Chen W, Duan BW, Guo WM, Lu Y, Lantin RS, Wassmann R, Neue HU. Methane emission and mitigation options in irrigated rice fields in southeast China. Nutr. Cycl. Agroecosyst. 58 (2000):65-73.

[26]  Corton TM. Methane emission from irrigated and intensively managed rice fields in Central Luzon (Phillipines). Nutr. Cycl. Agroecosyst. 58:37-53, 2000.

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

Ngô Đức Minh[1,3], Mai Văn Trịnh[2], Reiner Wassmann[3], Bjorn Ole Sander[3],
Trần Đăng Hòa[4], Nguyễn Lê Trang[5], Nguyễn Mạnh Khải[6]

[1]*Viện Thổ nhưỡng Nông hóa, phường Đức Thắng, Bắc Từ Liêm, Hà Nội, Việt Nam*
[2]*Viện Môi trường Nông nghiệp, phường Phú Đô, Nam Từ Liêm, Hà Nội, Việt Nam*
[3]*Viện Nghiên cứu lúa quốc tế, 4031 Los Banos, Laguna, Philippine*
[4]*Đại học Nông lâm Huế 102 đường Phùng Hưng, TP Huế, Việt Nam*
[5]*Viện Di truyền Nông nghiệp, Km2, đường Phạm Văn Đồng, Bắc Từ Liêm, Hà Nội, Việt Nam*
[6]*Khoa Môi trường, Trường Đại học Khoa học Tự nhiên, ĐHQGHN, 334 Nguyễn Trãi, Hà Nội, Việt Nam*

**Tóm tắt:** Sản xuất nông nghiệp hiện 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 biện 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 hóa) được kiểm định và hiệu chỉnh nhằm đánh giá khả năng ứng dụng trong tính toán phát thải metan trong các chế độ tưới khác nhau (ngập nước thường xuyên và khô ướt xen kẽ) tại hai khu vực canh tác lúa nước điển 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, biện pháp canh tác đã được sử dụng để kiệm 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 phân 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 biện pháp canh tác (chế độ tưới, bón phân hữu cơ…) cũng có ảnh hưởng đáng kể phát thải metan. Thứ tự mức độ ảnh hưởng của các yếu tố khá thống nhất giữa hai khu vực nghiên cứu.

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