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COMPARISON OF METHANE EMISSIONS MEASURED IN A PADDY RICE FIELD IN SOUTHEASTERN BRAZIL WITH THE DNDC MODEL-SIMULATED EMISSIONS

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ABSTRACT: Paddy rice cultivation is an important anthropogenic source of atmospheric methane (CH_4). Quantifying CH_4 emissions under specific crop conditions is essential to improve the accuracy of global greenhouse gas estimates. Computer modeling simulation may contribute to a better understanding of how different environmental factors affect seasonal CH_4 emissions, thereby supporting mitigation strategies. The objective of this study was to compare three-growing-season field measurements of CH_4 emissions from a paddy rice field, under pre-germinated system, in Pindamonhangaba, São Paulo State, Brazil, with estimates of emissions obtained from simulations using the DeNitrification–DeComposition (DNDC) model under the same conditions. Methane fluxes were measured weekly using the closed-chamber method, and model input parameters were derived from the site-specific conditions (soil, crop, management, and climate) for each season. Daily pattern of CH_4 fluxes and seasonal emissions were obtained by DNDC for the evaluated growing seasons. The mean seasonal CH_4 fluxes quantified in the field ranged from 231.72 ± 40.23 to 285.25 ± 51.66 kg C- CH_4 ha⁻¹, while those obtained using DNDC ranged from 210.53 to 267.39 kg C- CH_4 ha⁻¹. The model results fell within the variability of field quantifications, with one season slightly above the upper observational limit, demonstrating the good accuracy of this simulator to estimate seasonal methane emissions for the site. However, in spite of the simulated daily methane fluxes have showed a temporal trend similar to that observed in the field for all the growing seasons, the magnitude of the simulated emissions differed from some observed values.

Keywords: greenhouse gas, IAC 105, tropical region, DNDC, pre-germinated system

INTRODUCTION

Rice (*Oryza sativa* L.) is a major global staple food, providing calories for more than half of the world's population (MOHIDEM et al., 2022). Global rice production reached approximately 162 million hectares in 2019 and is projected to exceed 560 million tons by 2050 (SAMAL et al., 2022). Brazil accounts for about 1.5% (8,378,000 metric tons) of the global rice production, figuring in the #11 position for the global ranking (USDA, 2025), with 91% originating from irrigated systems (CONAB, 2025). However, paddy fields are considered one of the most important agricultural sources of methane (CH_4) (IPCC, 2013), also emitting nitrous oxide (N_2O) on a smaller scale. Sauniois et al. (2020) attributed a global annual emission of 30 [24–40] Tg CH_4 ·year⁻¹ to this crop, corresponding to approximately 8% of the total global anthropic sources, estimated at 380 Tg CH_4 in 2017.

Several studies have evaluated CH_4 emissions from irrigated rice in Brazil, focusing on the soil and water management (MOTERLE et al., 2013; ZSCHORNACK et al., 2016), cropping systems (BAYER et al., 2014), and specific rice cultivars (SILVA et al.; 2014; NUNES et al., 2022). Due to the great number of soil and plant management and environment factors possibly affecting the greenhouse gas (GHG) emissions, even in the same place, computer simulations based on mathematical-models may collaborate with a better understanding of the interference of local conditions on the dynamic of CH_4 emissions throughout the season, contributing to the mitigation process. Many computer features have been used to simulate CH_4 emissions from flooded rice (PATHAK et

al., 2005; PESSOA et al., 2010; GILHES-PY et al., 2014; LEITE et al., 2015; GASSMAN et al., 2022; SANTOSA et al., 2022; NIKOLAISEN et al., 2023; BĂRBULESCU, 2025). Among them, the most well-known process-based models, which take into account the dynamic of the crop growing season ecosystem in the biogeochemical cycles of C and of N, are: DeNitrification-DeComposition (DNDC) (LI et al., 1994; LI, 2000), CENTURY (LEITE & MENDONÇA, 2003), DAYCENT (PARTON et al., 1998; DEL GROSSO et al., 2001; DEL GROSSO et al., 2009), CH₄MOD (HUANG et al., 1998; HUANG et al., 2004), and Soil and Water Assessment Tool (SWAT-GHG) (WAGENA et al., 2017).

DNDC model simulations have already been performed for Brazilian seasonal GHG estimates, some of which took into account both the model calibration and validation for CH₄ emissions for different rice growing seasons (2002/2003, 2003/2004, 2004/2005, and 2005/2006), located in the same study area in the municipality of Pindamonhangaba, a tropical region of São Paulo State (SP), Brazil (PESSOA et al. 2010; LEITE et al. 2015). According to these results, the DNDC estimates for seasonal CH₄ fluxes were very close to the quantified field data, thus indicating sufficient accuracy to use this model to forecast trends in methane emissions for the area. However, new paddy rice cultivars have been made available in the region, which requires knowing how DNDC will perform its estimations for the CH₄ emission. The objective of this study was to compare three-year field measurement of CH₄ emissions from a paddy rice field, under pre-germinated system, in Pindamonhangaba, São Paulo State, Brazil, with estimates of emissions obtained from

simulations using the DeNitrification–DeComposition (DNDC) model under the same conditions.

MATERIAL AND METHODS

Site description and field management practices

A three-year experiment was carried out during the 2011, 2012, and 2013 paddy rice (*Oryza sativa*) growing seasons, in the municipality of Pindamonhangaba, SP, Brazil (22° 55'26" S, 45° 27'43" W), at 560 meters of altitude. The municipality is located in the Paraíba Valley, the main rice-producing region of the state of São Paulo (LIMA; VILLELA, 2016), which intensively uses the pre-germinated system, especially in the floodplains of municipalities such as Guaratinguetá and Pindamonhangaba. The climate is type Cwa (Köppen classification), with an average highest temperature above 22°C and average lowest temperature below 18°C, warm and moist in the summer and dry in the winter. The average annual precipitation is 1,334 mm. The soil is classified as Gleysol, with 31.6 % of sand, 28.0 % of silt, and 40.3 % of clay, a bulk density of 1.35 g.cm⁻³, total carbon of 11.8 %, and total N of 1.3 % (LIMA et al., 2019). Flooded rice has been cultivated in the area for approximately four decades with fallow in the winter.

The experimental design was a split plot design with three replications of approximately 300 m². The rice cultivar used was IAC 105, developed by the Campinas Agronomic Institute (Instituto Agronômico de Campinas - IAC) (IAC, 2005), linked to the São Paulo State Agribusiness Technology Agency (Agência Paulista de Tecnologia dos

Agronegócios -APTA) of São Paulo State, Brazil. This cultivar has an average growth cycle of 135 days and an average productivity estimated at 6.486 kg.ha⁻¹. Details of the crop and water management operations used for each growing season evaluated are present as follow.

2011 season

As described by Lima et al. (2019), the study area was previously flooded for the muddy soil preparation four days before sowing with a density of 140 kg of seeds per hectare. Sowing was performed manually on January 10th 2011 (5 days after flooding – DAF), with emergence observed on January 14th, 2011 (9 DAF). The water blade was maintained initially at 4 cm. Furtherly, an average of 15 cm was maintained throughout the season. The removal of the water blade was done just one day before the herbicide and fertilizer application. The herbicide Ricer was sprayed (200 mL.ha⁻¹) on January 12th, 2011 (7 DAF) and on January 24th, 2011 (19 DAF). The second spray also included 4 g.ha⁻¹ of the herbicide Ally. The first fertilization was carried out on February 23rd (49 DAF) and the second on March 16th (70 DAF). On the first date, 170 kg.ha⁻¹ of 20-00-20 (N-P-K) were applied, while on the second date, 210 kg.ha⁻¹ of 20-00-20 (N-P-K). Urea, simple superphosphate, and potassium chloride were used as the sources of N, P and K, respectively, on both occasions. Flowering occurred on April 8th (93 DAF), drainage on May 17th (132 DAF), and the harvest on May 23rd (138 DAF).

2012 Season

The area was previously flooded in order to prepare the muddy soil on January 25th, with the sowing on January 30th (6 DAF) with a density of 140 kg of seeds per

hectare. Emergence occurred on February 3rd (10 DAF). A water blade was maintained at an average of 12 cm. The plants were sprayed with Ricer (250 mL.ha⁻¹) and Basagran (2.0 L.ha⁻¹) on February 6th (13 DAF). Fertilizers were applied on February 29th (36 DAF) and on March 20th (56 DAF), in each case with 200 kg.ha⁻¹ of 20-05-20 (N-P-K). The fertilizers used were the same as the previous season. Flowering occurred on May 6th (103 DAF). The soil was drained on May 23rd (120 DAF) and the harvest occurred on June 16th (144 DAF).

2013 Season

The area was flooded on January 24th and the sowing carried out on January 28th (5 DAF) with a density of 140 kg of seeds per hectare. Seedling emergence occurred on February 3rd. (8 DAF). The water blade was maintained at an average of 13 cm. The plants were sprayed with the herbicides Ricer (250 mL.ha⁻¹) and Basagran (2.5 L.ha⁻¹) on both February 8th (16 DAF) and February 18th (26 DAF). Fertilization occurred first on February 15th (23 DAF) consisting of 250 kg.ha⁻¹ of 12-6-12 (N-P-K), and the second on March 6th (42 DAF) with 220 kg.ha⁻¹ of 20-05-20 (N-P-K). The fertilizers used were the same as for the previous growing seasons. Flowering occurred on May 6th (103 DAF), drainage on May 21st (118 DAF) and the harvest on June 12th (140 DAF). The study area remained fallow between the three crop seasons.

Gas sampling and flux measurements

Samples of CH₄ fluxes were collected once a week throughout the rice growing season using the closed static chamber method (IAEA et al., 1992; SASS et al.,

2002), on 22, 18 and 20 sampling dates during the 2011, 2012 and 2013 growing seasons, respectively. The samples were analyzed in a SHIMADZU model GC 2014 *Greenhouse* Gas Analyzer, equipped with one 6-way valve and two 4-way valves, a direct mode injector, a 1 cm³ stainless-steel loop, and five packed columns. Of these, two columns were Porapak N 80/100 mesh (2 mm internal diameter x 1.5 m length), two were Hayesep T 80/100 mesh, and one Shimalite Q 100/180 mesh (2 mm internal diameter x 0.7 m length), plus a methanator and a flame ionization detector (FID) operated at 150°C. The CH₄ fluxes were calculated from the linear increase in gas concentration inside the chamber during gas sampling using the Equation 1:

$$f = \frac{\Delta C}{\Delta t} \frac{PV}{RT} \frac{M}{A} \quad (\text{Eq. 1})$$

where f = the flux of C-CH₄ (g.m⁻².h⁻¹); $\Delta C/\Delta t$ = the change in gas concentration over the sampling time (Δt) (mol.h⁻¹); P = the mean atmospheric pressure in the chamber (assumed as 1 atm); V = the chamber volume (L); R = the universal gas constant (0.08205 L.atm mol⁻¹.K⁻¹); T = the temperature inside the chamber during sampling in Kelvin degrees (°K); M = the gas molecular mass (g mol⁻¹); and A = the chamber basal area (m²). The gas emission rate was converted to $\mu\text{mol C-CH}_4 \text{ m}^{-2}.\text{h}^{-1}$.

The emission flux generated during each measurement was integrated to produce an estimate of the seasonal methane flux in kg.ha⁻¹, representing the accumulated gas emission in the chambers.

Seasonal CH₄ simulations using DNDC Model⁴

The Denitrification-Decomposition Model (DNDC) version 8.9 (University of New Hampshire, ISEOS, 2006) was used to simulate CH₄ emissions for each scenario. This model version was selected since it was already validated for seasonal CH₄ estimations based on previous growing seasons in the same study area, in Pindamonhanga, SP (PESSOA et al., 2010; LEITE et al., 2015). The DNDC input data required information concerning the site, soil properties, and cultivation practices conducted in each growing season, such as the geographical position (latitude), daily climate file, land use, soil texture/structure, organic C content (SOC), microbial activity index, cultivar, planting and harvest dates, N-fertilization dates (and amounts), flooding date, practices, among others. The soil properties and predominant cultivation practices considered for each season by the model, were obtained from the previous field experiments (**Table 1**) or automatically generated as default by DNDC, such as those considered from the soil input data.

Due to the unavailability of the Gleysol type among the 12 soil type options in the DNDC, the Clay Loam category was used, since it provided texture data closest to the above mentioned type.

It is also noteworthy that due to the lack of local information on the soil microbial activity index, this parameter was assumed to be 0.65 based on information concerning tropical soil conditions (CHÁVEZ et al., 2011; DENARDIN et al., 2020).

Climate data for the 2011 and 2012 growing seasons were made available in the Microsoft Excel format by APTA/Regio-

Seasons	Soil Properties (texture, pH, bulk density, floodwater layer, and SOC at surface)	Sowing and Harvest dates	Fertilization dates and amounts (kg N ha ⁻¹)	Flooding and Drainage dates	Flood water pH; and water leaking rate
2011	Clay loam (0.41); pH: 6.3; 1.39g.cm ⁻³ ; 15cm; 0.02 kg C.kg ⁻¹	Jan. 10 th ; Mai 23 rd	Feb 23 rd /34 kg Mar 16 th /42 kg Total: 76 kg N ha ⁻¹	Jan 6 th / May 17 th	6.39; 10.0 mm day ⁻¹
2012	Clay loam (0.41); pH: 6.3; 1.39g.cm ⁻³ ; 15cm; 0.02 kg C.kg ⁻¹	Jan., 30 th ; Jun, 16 th	Feb 29 th /40 kg N Mar 20 th /40 kg N Total: 80 kg N ha ⁻¹	Jan 25 th / May 23 rd	6.39; 10.0 mm day ⁻¹
2013	Clay loam (0.41); pH: 6.4; 1.39g.cm ⁻³ ; 13cm; 0.02 kg C.kg ⁻¹	Jan 28 th ; Jun 12 th	Feb 15 th / 30 kg N Mar 6 th / 44 kg N Total: 74 kg N ha ⁻¹	Jan 24 th / May 21 st	6.55; 10.0 mm day ⁻¹

Table 1. Soil and crop management input data in the DNDC model for each growing season simulated.

nal Pole for Technological Development of Agribusinesses in the Paraíba Valley (Apta Regional Pindamonhangaba). In turn, climatic data for the 2013 growing season were obtained from the Agrometeorological Information Integrated Center (“Centro Integrado de Informações Agrometeorológicas” (CIIAGRO)) of the Center for Eco-physiology and Biophysics - Agricultural Climatology of the IAC (“Centro de Eco-fisiologia e Biofísica” – “Climatologia Agrícola” do IAC). The daily weather data were formatted separately for each season (2011, 2012, and 2013) in a text data file (.TXT). Each file contained daily records on: the day (in Julian format), the maximum and minimum temperatures (°C), and the rainfall (cm). The average daily climatic data observed from flooding to harvest, considered in each DNDC growing season scenario, are shown in **Table 2**.

The characteristics of the IAC 105 cultivar with respect to its biomass production in terms of grain, leaf+stem, and root (in kg dry matter.ha⁻¹), as required by the

DNDC, were incorporated into the model input using the “Crop Creator” tool. These characteristics were based on information provided by Apta Regional Pindamonhangaba (personal communication from the developers of the cultivar IAC 105) and from the literature (IAC, 2005). The rice plant growth model adopted in the DNDC simulations was the empirical plant growth submodel. According to the model guide, this option relies on a generalized crop growth curves and parameters (degree-days, accumulated temperature, N uptake, water stress, among others) inherent both to model version 8.9 and to the input data (provided by the user) for the cultivar to estimate the plant biomass during the whole period simulated.

RESULTS AND DISCUSSION

The CH₄ fluxes observed and simulated using DNDC throughout each paddy rice crop seasons were obtained (**Figure 1**).

Season / (Duration)	Tmax mean (°C)	Tmin mean (°C)	Rainfall Total (mm)
2011 (137 days)	29.5±3.4	18.9±2.8	768.73
2012 (144 days)	28.4±3.7	17.3±3.0	563.3
2013 (140 days)	27.8±3.4	17.2±3.6	534.4

Table 2. Mean values and accumulated totals of the daily climatic variables for the 2011, 2012, and 2013 seasons, from flooding to harvest, considered in each DNDC simulation.

Obs.: Tmax: Maximum temperature; Tmin: Minimum temperature. Data source of daily climatic data: Apta Regional Pindamonhangaba (for 2011 and 2012); and CIIAGRO (for 2013).

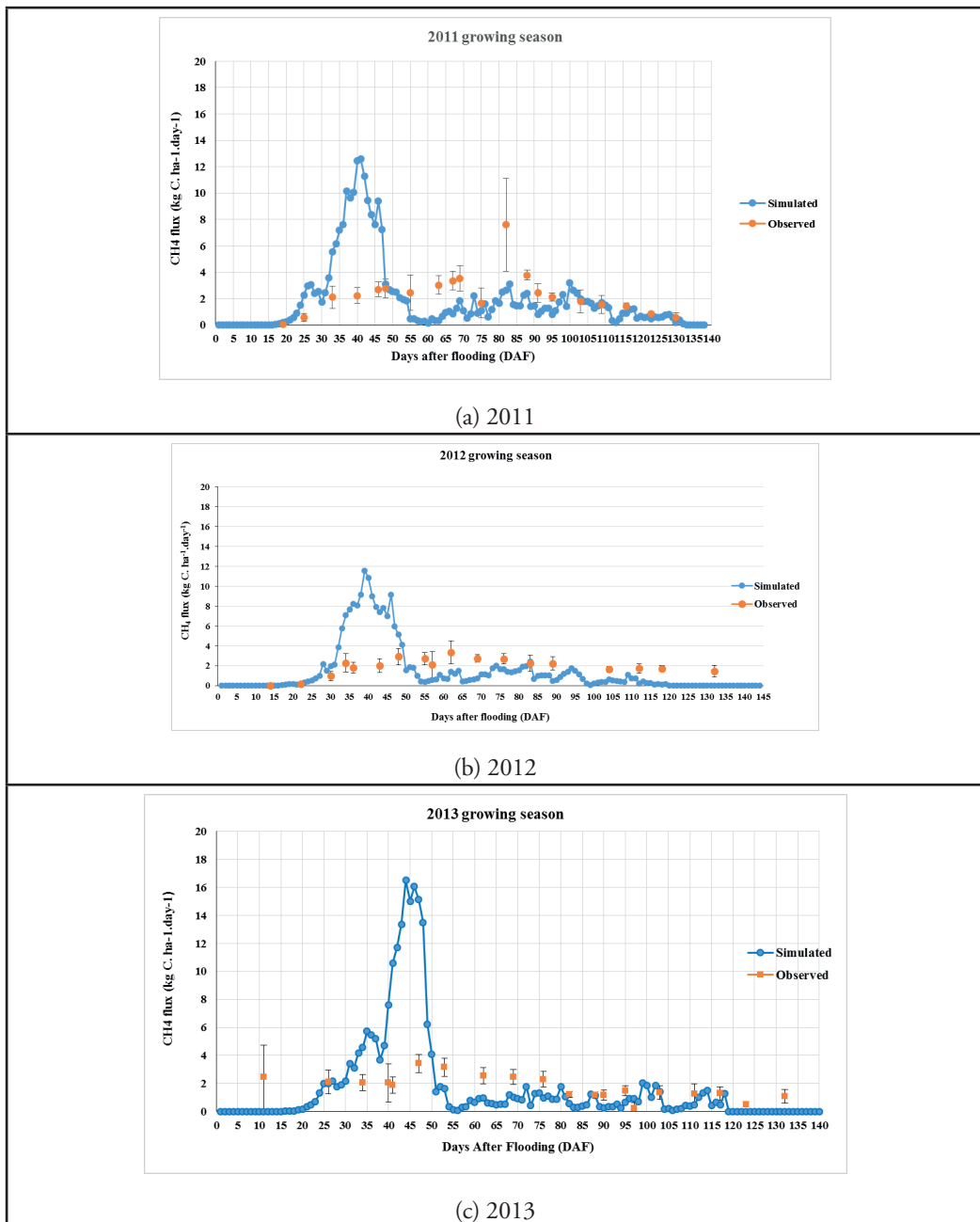


Figure 1. CH₄ fluxes from IAC 105 observed and simulated for Pindamonhangaba, SP, during the paddy rice crop seasons of (a) 2011; (b) 2012; and (c) 2013. [Obs. Bars represent standard deviation]

CH₄ fluxes measured

Throughout the 2011 growing season, CH₄ flux rises were observed as the plant grew, reaching the highest rate in the reproductive phase (**Figure 1a**), more specifically at the booting stage. This trend aligns with the physiological expansion of the tillers and intensification of aerenchyma development, which enhances plant-mediated CH₄ transport (JIA et al.; 2001; KIM et al., 2018). It has been well established that 60–90% of the total CH₄ emissions in rice systems occur via aerenchyma transport (AULAKH et al., 2000), and peaks during tillering have frequently been documented (AHMAD et al., 2009; ODA; HUU, 2019). In this season, precipitation was greater (768.73 mm) in comparison to the following seasons (563.3 and 534.4 mm in 2012 and 2013, respectively). The average maximum temperature was also higher in the 2011 season than in the subsequent seasons, being $29.5 \pm 3.4^\circ\text{C}$, as also the average minimum temperature of $18.9 \pm 2.8^\circ\text{C}$, which condition could favor methanogenesis.

The CH₄ fluxes presented similar patterns throughout the 2012 and 2013 growing seasons (Figures 1b and 1c), except at the beginning of the 2013 season, where the higher values probably due to the recent straw incorporation into the soil just before flooding. Both seasons were characterized by the late sowing. Throughout the 2012 season, an increase in the CH₄ emission rates also occurred during rice tillering, with higher fluxes being observed 49 DAF (**Figure 1b**). The highest CH₄ fluxes were observed close to panicle differentiation (62 DAF). Over the course of the reproductive phase, photosynthesis is the most important source of CH₄ production, probably due to the increased exudation of photosynthates from the root and the root decomposition (WATANABE et al., 1999). The same result was observed in other experiments

(WATANABE et al., 1997; SAHA et al., 2017; WANG et al., 2017).

A relevant fact that occurred during the 2012 season was the failure of the crop to reach anthesis due to low temperatures [minimum temperatures varying from 8.9 to 14.8°C (on average of $12.7 \pm 1.8^\circ\text{C}$)] between 1st and 11th May (98 - 108 DAF), a range with the risk to induce sterility (critical threshold of 15–17°C).

During the 2013 season, increased CH₄ emissions were observed at the beginning of the vegetative phase (**Figure 1c**). This early season peak appear in soils with high organic matter (GAIHRE et al., 2011) which in our study probably is associated with the presence of organic residues from the previous season. The following largest fluxes were observed 49 DAF, during rice tillering. Flowering occurred 103 DAF, with little influence on the CH₄ fluxes. The slight increase observed at the end of this season, at 134 DAF, could be explained by the rainfall that occurred after soil drainage.

The average seasonal CH₄ emissions measured *in situ* during the 2011, 2012, and 2013 seasons were, respectively, $285.25 \pm 51.66 \text{ kg C ha}^{-1}$, $241.17 \pm 23.87 \text{ kg C ha}^{-1}$ and $231.72 \pm 40.23 \text{ kg C ha}^{-1}$ (**Figure 2**).

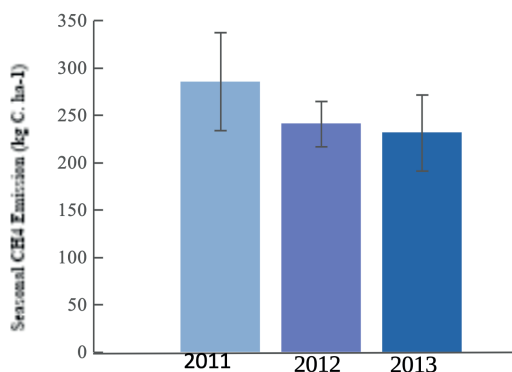


Figure 2. Average seasonal CH₄ fluxes (in kg C ha⁻¹) determined from the field measurements during the 2011, 2012, and 2013 seasons.

The average CH₄ emissions across the three seasons (245.34 kg C-CH₄ ha⁻¹) fall within the global range reported by Yan et al. (2009) (2.7 to 1,059 kg C ha⁻¹), and exceed the mean value of 180 kg CH₄.ha⁻¹ reported by Akiyama et al. (2005) for continuously flooded paddies with no organic amendments. Methane emission factors (EF) of 2.11 kg C-CH₄ ha⁻¹ day⁻¹, 1.79 kg C-CH₄ ha⁻¹ day⁻¹ and 1.72 kg C-CH₄ ha⁻¹ day⁻¹ were estimated for the 2011, 2012, and 2013 seasons, respectively. Considering the three seasons, the average of EF obtained for IAC 105 (1.87 kg CH₄ ha⁻¹day⁻¹) was consistent with the IPCC (2019) range of the 1.10 – 2.40 kg CH₄ ha⁻¹ day⁻¹ (average: 1.62 kg CH₄ ha⁻¹day⁻¹).

CH₄ emissions estimated by the DNDC model

The daily pattern of CH₄ fluxes simulated by DNDC from flooding to harvest throughout each growing season evaluated (2011, 2012, and 2012) was obtained (**Figure 1**). The seasonal CH₄ emissions simulated by DNDC for each growing season are shown as following, alongside the values measured (**Table 3**).

Season	Field CH ₄ (kg C ha ⁻¹)	DNDC CH ₄ (kg C ha ⁻¹)	Accuracy (%)
2011	285.25 ± 51.66	267.39	94.08
2012	241.17 ± 23.87	210.53	87.30
2013	231.72 ± 40.23	238.59	102.96

Table 3. Seasonal CH₄ emissions quantified by field measurements and estimated by DNDC, for three paddy rice growing seasons, using the pre-germinated system.

The performance of DNDC model was not completely satisfactory. DNDC proved to be capable of representing the same magnitude of the daily-emitted fluxes observed in the field. Nevertheless, although the simulated methane fluxes showed a temporal trend similar to that observed in the field for all the growing seasons, the magnitude of the simulated emissions differed from some observed values (**Figure 1**). However, good estimations for seasonal methane emissions were found (**Table 3**). It is believed that the values observed for the daily CH₄ emission trend obtained could be due to the input data provided for IAC 105 cultivar. These data required detailed information on diverse parameters of the cultivar, such as growth, development, water demand, and of C and N available on different parts of the plant, among others not usually available in literature. Therefore, the input data considered took into account literature and the expertise of a plant breeder researcher consulted, who provided estimated data for several input parameters not available in the literature. The results obtained by the model for seasonal emissions fell within the variability of field quantifications, with one season slightly above the upper observational limit, demonstrating the good accuracy of this model to estimate seasonal methane emissions for the studied area. The seasonal CH₄ emissions estimated for the 2011 season using DNDC resulted in 94.08% of accuracy, when compared with the mean value obtained from the field measurements (**Table 3**). Therefore, DNDC underestimated the mean value quantified in the field by about 6%. Moreover, the seasonal CH₄ emission estimated by the model is within the range of variation of the standard error of the mean (SEM) obtained for the field measurements. For the 2012 season, the model reached 87.30% of accuracy, or underestimated the result measured by 12.70% (**Table 3**). Considering the SEM

obtained, DNDC estimate was close to the lower limit of the variation range (217.30 kg C ha⁻¹), and remained in the same order of magnitude as the mean value quantified in the field. For the 2013 season, DNDC overestimated the field measurement seasonal average by only 2.96% (**Table 3**). Therefore, DNDC estimate was close to the mean value obtained from field measurements.

The results of our study show that the seasonal methane emissions simulated by DNDC are in good agreement with the measured data, reinforcing the suitability of this model to estimate such emissions considering the different characteristics of each growing seasons, as already highlighted in literature for the same area (PESSOA et al., 2010; LEITE et al., 2015). The results also corroborate the studies carried out by Pathak, Li and Wassmann (2005) and Babu et al. (2006) in India under conditions of continuous water management. Babu et al. (2006) also found that the most discrepancies between simulated and observed seasonal fluxes were less than 20% of the field estimate and observed the same performance for daily methane emissions obtained by DNDC, achieving a good fit for only one of the five regions evaluated in India. However, they also found good estimations for seasonal methane emissions for all regions.

The differences observed in the emissions pattern, when considering the different growing seasons evaluated, may be related to the management practices, which, as reported by Li et al. (2004), can substantially affect gas emissions from rice fields. It is also important to consider that DNDC model does not consider the occasional withdrawals of the water blade, which occurred in field when fertilizers and herbicides were applied.

The importance of the soil microbial activity index in methane emission estimates should also be emphasized. Few studies available in literature justify the values adopted for this index. Babu et al. (2005), for instance, during the model calibration adjusted the microbial activity index from 1.0 and Li et al. (1992) to 0.2, in order to match the seasonal CH₄ emissions observed in field experiments conducted in India. In the present study, a value of 0.65 was adopted based on available literature for tropical conditions, and the results obtained with the DNDC model showed good agreement with the quantified seasonal CH₄ emissions.

Another important aspect to report is that the DNDC model was developed considering the transplantation system and not the pre-germinated system. For this reason, the simulation carried out in the present work considered the period from soil flooding until harvest.

Further studies evaluating the sensitivity of the DNDC model to variations in the microbial activity index, as well as to soil texture parameters (such as clay, bulk density, pH), water depths, temperatures, and rainfall variability, among others, may provide further insights into the model behavior under different environmental conditions. The estimates obtained by the DNDC model also may be improved, as detailed data on the cultivar's parameters becomes available in literature.

CONCLUSIONS

The DNDC model closely reflected the measured seasonal CH₄ emissions from paddy rice in Pindamonhangaba, SP, Brazil for the 2011, 2012, and 2013 growing seasons, under pre-germinated systems using

the cultivar IAC 105, achieving high accuracy (87.30-102.96%). However, in spite of the simulated daily methane fluxes showed a temporal trend similar to that observed in the field for all the growing seasons, the magnitude of the simulated emissions differed from some observed values.

The present study reinforces the applicability of DNDC model for estimating seasonal methane emissions from pre-germinated paddy rice systems in a tropical region of São Paulo State, Brazil taking into account the different characteristics of the growing seasons.

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