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RESEARCH ARTICLE

POTENTIAL PRODUCTION OF CH_4 AND N_2O IN SOIL PROFILES FROM ORGANIC AND CONVENTIONAL RICE FIELDS

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ABSTRACT

The horizons in soil profile will determine the magnitude of greenhouse gas production due to the difference of total organic carbon and other chemical properties. This study aimed to determine the potential production of methane (CH_4) and nitrous oxide (N_2O) in each horizon of soil profile from organic and conventional rice fields. Soil samples which were taken from Imogiri Bantul D.I. Yogyakarta, were used to determine soil properties, the potential of CH_4, and N_2O productions. The correlation analysis was used to determine the relationship between production of CH_4 and N_2O with soil properties. The results showed that production of CH_4 and N_2O will be decreased with the increase of soil depth. Production of CH_4 and N_2O was higher in organic rice field than in conventional rice field. The total organic carbon (TOC) correlated positively with CH_4-production (*r=0.89, P<0.001, n=8*) and N_2O-production (*r=0.87, P<0.001, n=8*). The nitrogen content also correlated positively with CH_4-production (*r=0.87, P<0.001, n=8*) and N_2O-production (r=0.94, P<0.001, n=8). Mitigation of CH_4 and N_2O emissions should consider of C and N in the soil.

Keywords*:* CH_4, N_2O, profile, soil, emission

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INTRODUCTION

Rice fields are considered to be an important source of greenhouse gas emission especially CH_4 and N_2O (Mosier, Wassmann, Verchot, King, & Palm, 2004). Greenhouse gas emissions from rice fields are mainly influenced by the practices of rice cultivation (Smith et al., 2007). Drainage prevents the occurrence of strong anaerobic conditions in the soil and can reduce emissions of CH_4 (Cai et al., 1997; Zou, Huang, Jiang, Zheng, & Sass, 2005), but leads to nitrification-denitrification and significantly produces N_2O (Diba, Shimizu, & Hatano, 2011).

Organic carbon plays an important role in maintaining soil fertility, soil health and crop production (Thangarajan, Bolan, Tian, Naidu, & Kunhikrishnan, 2013). However, improper organic material or management used may encourage the increase of greenhouse gas emissions into the atmosphere. CH_4 is produced in flooded soils by methanogen (Le Mer & Roger, 2001), with organic matter as substrate (Hou et al., 2013; Zou et al., 2005).

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N_2O is produced by nitrification-denitrification from agricultural soil management (Lal, 2007).

Organic farming has been utilized to improve the environment and make agriculture sustainable (Sutanto, 2002). In the organic rice fields, like in Jayan, Kebonagung, Imogiri, Bantul, D.I. Yogyakarta, the farmer usually uses in various doses of organic fertilizer, about 5-10 tons ha^{-1} planting season^{-1}. In the conventional rice fields, the farmer usually uses chemical fertilizer urea and phonska; 100-150 and 250-300 kg ha^{-1} planting season^{-1}, respectively. Because of the use of organic fertilizer, CH_4 emission from organic rice field higher than conventional rice field (Aguilera, Guzmán, & Alonso, 2014; Qin, Liu, Guo, Liu, & Zou, 2010), N_2O emission too (Qin et al., 2010). Organic C is a substrate for methanogens to produce CH_4 (Hou et al., 2013; Zou et al., 2005), more available in organic rice fields. Organic C is a substrate for denitrification (Vilain, Garnier, Decuq, & Lugnot, 2014), so N_2O production higher from the organic rice field.

The production of greenhouse gases on each horizon in the soil profile will determine the amount of greenhouse gas emissions. This study aims to determine the potential of CH_4 and N_2O production in each horizon from the organic and conventional rice field. The results of the research can be used as consideration in mitigating CH_4 and N_2O emissions in the rice field, specifically the organic rice fields which produce more greenhouse gasses than conventional.

MATERIALS AND METHOD

Soil profile

The soil profile where was taken from organic and conventional rice fields was done in Jayan, Kebonagung, Imogiri, Bantul, D.I. Yogyakarta. Organic rice fields are usually given organic fertilizer with the doses 5-10 tons ha^{-1} planting season^{-1}. Conventional rice fields are usually given chemical fertilizer phonska 250-300 kg ha^{-1} planting season^{-1} and urea 100-150 kg ha^{-1} planting season^{-1}. Soil profile location of organic rice field at 7°56’01,22” N, 110°22’18,86” E and conventional rice field at 7°55’57,09” N, 110°22’17,05” E. Altitude 60 meter from sea level. The soil profile description was based on Soil Survey Staff (2014). The dimension of soil profile 1.5-meter width, 2.0-meter length, and 1.2-meter depth. Soil classified as Inceptisol. The soil samples were taken from each horizon then dried and sieved with 0.5 and 2 mm diameter-sieves.

Soil properties

Soil samples each horizon were analyzed which referred to Eviati & Sulaeman (2009), including C-organic (Walkley and Black method), N-total (Kjeldahl method), C humic acid-fulvate (extraction of sodium pyrophosphate + NaOH, H_2SO_4) and NO_3^- soil (percolation, brucine method).

Production of CH_4 and N_2O

20 grams of soil samples with 0.5 mm diameter was dissolved in 40 ml of distilled water then incubated at 28 °C. Gas samples were taken with 5 ml syringe for laboratory analysis. Production of CH_4 and N_2O was analyzed by gas chromatography, for CH_4 with flame ionization detector (FID) and N_2O with electron capture detector (ECD). The potential production of CH_4 and N_2O was adopted using formula from Susilawati H.L. (2007), as follows:

$$\mathrm{CH_4 - N_2O\ Production} = (C24 - C0)\ x\ \frac{Vhs}{WS}\ x\ \frac{MW}{Vm}\ x\ \frac{Tsc}{(Tsc + T)}$$

where:

C0 = CH_4 – N_2O concentration at hour 0 (ppm)

C24 = CH_4 – N_2O concentration at hour 24 (ppm)

Vhs = volume of headspace (ml)

WS = weight of soil sample (g)
MW = weight of molecule $CH_4 – N_2O$ (g)
Vm = volume of CH_4–N_2O at standard conditions (273.2 K)
Tsc = temperature standard conditions (273.2 K)
T = air temperature of incubation (°C)

Statistical analysis

The correlation analysis was used to determine the relationship between potential production of CH_4 and N_2O with soil properties (Steel & Torie, 1978).

RESULT AND DISCUSSIONS

Potential production of CH_4 dan N_2O

The soil profile from organic and conventional rice fields had four horizons (Apg, Bw1, Bw2, and Bw3). Table 1 shows the horizon, soil properties, CH_4-PP, and N_2O-PP. CH_4-PP and N_2O-PP in the organic rice field are higher than conventional ones. The production of CH_4 and N_2O will decrease with the increase of soil depth. CH_4-PP and N_2O-PP were associated with soil organic matter (TOC, HA, FA). Soil organic matter in organic rice field is higher than conventional, in topsoil is higher than subsoil.

Figure 1 and 2 shows that the CH_4 flux both in organic and conventional rice field has a similar pattern. The CH_4 flux increased and reached maximum on incubation at 15^{th} day and after that subsequently decrease. The CH_4 flux in organic rice field was relatively higher than in conventional ones.

The surface soil (Apg) produced CH_4 higher than subsoil layer on incubation at 15^{th} day. The higher total organic carbon (TOC) provides the more substrate for CH_4 formation. This result was in line with the study done by Brzezińska, Nosalewicz, Pasztelan, & Włodarczyk (2012) and Mujiyo, Sunarminto, Hanudin, Widada, & Syamsiyah (2017) regarding the measurement of CH_4 production in logged condition. The soil with higher C-organic has more available substrates so it has higher and longer flux.

The flux pattern of N_2O differs between surface soil layer and subsoil layer (Figure 3 and 4). In the surface soil (Apg), the maximum N_2O flux was reached on incubation of 15^{th} day. On the other hand, the N_2O flux in subsoil layers tends to decrease.

The relationship between the potential production of CH_4 and N_2O and soil properties

The potential production of CH_4 correlated positively with the total of organic carbon (TOC) (*$r=0.89$, $P<0.001$, $n=8$*), humic acid (HA) (*$r=0.71$, $P<0.005$, $n=8$*), fulvic acid (FA) (*$r=0.92$, $P<0.001$, $n=8$*), total nitrogen (TN) (*$r=0.87$, $P<0.001$, $n=8$*) and the ratio of total organic carbon-total nitrogen (TOC/TN) (*$r=0.65$, $P<0.005$, $n=8$*). Thus production of CH_4 is affected by soil organic matter. Study result of Aguilera et al. (2014) showed that the increase of CH_4 emissions in the organic rice system was associated with the addition of straw and manure to the soil. Application of rice straw will increase C-organic in soil which becomes a substrate for methanogenic bacteria (bacteria which produces CH_4) (Hou et al., 2013; Sass, Fisher, Hareombe, & Turner, 1991; Yagi & Minami, 1990), and consequences in increasing the production of CH_4 (Mujiyo, Sunarminto, Hanudin, Widada, & Syamsiyah, 2016; Swerts, Merckx, & Vlassak, 1996).

The C-organic in the upper horizon is higher than the lower horizon, as well as the production of CH_4 (Brzezińska et al., 2012; Mujiyo et al., 2017). The increase of C-organic is related to improve soil fertility and quality (Turmuktini et al., 2012) which will be maintained agricultural sustainability (Syamsiyah, Sunarminto, & Mujiyo, 2016). However, the increase in organic C also enhances methane formation so that appropriate management of organic matter is needed.

Table 1. Horizon, selected soil properties, CH_4-PP and N_2O-PP

Profile	Horizon	Depth (cm)	Epipedon Endopedon Classification	TOC	HA	FA	TN	NO_3^-	CH_4-PP	N_2O-PP
				%				$mg.kg^{-1}$	$mg.kg\ soil^{-1}.day^{-1}$	
Organic	I(Apg)	0 – 24/26	Umbric	2.24	0.019	0.041	0.13	6.07	79.53	1.34
	II(Bw1)	24/26 – 38/48	Cambic	1.08	0.017	0.023	0.10	8.73	60.31	1.12
	III(Bw2)	38/48 – 70/80	Typic	0.98	0.016	0.016	0.08	8.17	56.03	0.94
	IV(Bw3)	70/80 - 120	Humaquept	0.58	0.014	0.016	0.06	6.44	41.03	0.74
Conventional	I(Apg)	0 – 23/25	Umbric	1.18	0.021	0.025	0.12	7.27	59.36	1.15
	II(Bw1)	23/25 – 47/54	Cambic	1.03	0.016	0.016	0.09	10.33	43.63	1.06
	III(Bw2)	47/54 - 63/72	Typic	1.02	0.016	0.016	0.08	9.71	42.46	0.92
	IV(Bw3)	63/72 – 120	Humaquept	0.72	0.010	0.015	0.07	9.41	37.40	0.68

TOC = total organic carbon ; *TN* = total nitrogen ; *HA* = humic acid ; *FA* = fulfic acid ;
CH_4-PP = production potential of CH_4 ; *N_2O-PP* = production potential of N_2O

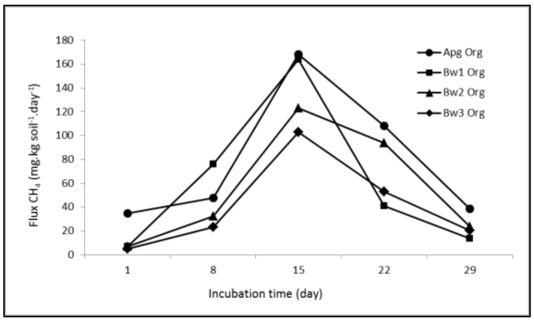

Figure 1. Flux CH_4 in soil profile from organic rice fields

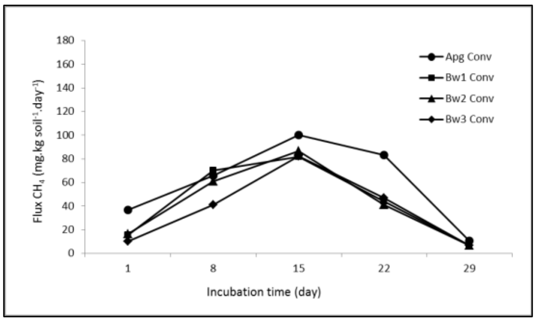

Figure 2. Flux CH_4 in soil profile from conventional rice fields

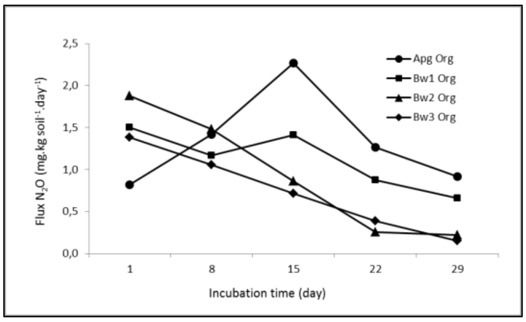

Figure 3. Flux N_2O in soil profile from organic rice fields

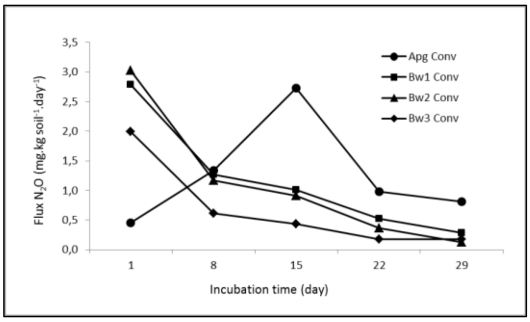

Figure 4. Flux N_2O in soil profile from conventional rice field

Potential production of N_2O correlated positively with total organic carbon (TOC) (*r=0.87, P<0.001, n=8*), humic acid (HA) (*r=0.85, P<0.001, n=8*), fulvic acid (FA) (*r=0.82, P<0.001, n=8*) and total nitrogen (TN) (*r=0.94, P<0.001, n=8*). This result was supported by finding of Qiu, Q., L. Wu, Z. Ouyang (2016) who stated that addition of N-organic fertilizer causes higher N_2O emissions than the application of single N-inorganic fertilizer or together with N-organic fertilizers. According to Huang, *et al*. (2004) application of organic matter produced higher N_2O emissions than urea. Pelster et al., 2012) specifically mentioned that application of organic matter in sandy loam soil will lead higher N_2O emissions than calcium ammonium nitrate fertilizer, but not in silty clay soil.

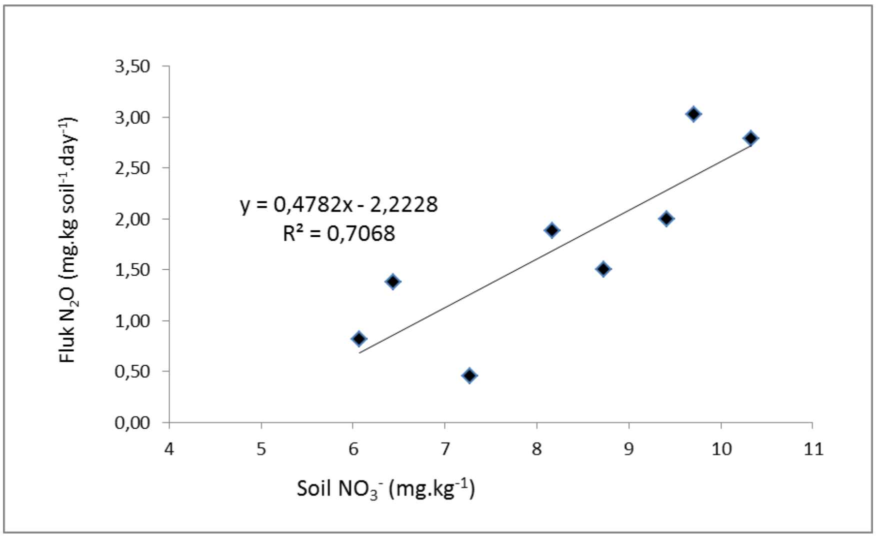

Figure 5. Relationship between NO_3^- soil and N_2O flux on first day of incubation

Organic rice field provides organic C higher than conventional rice field. In the microbial nitrification-denitrification process, bacteria use organic C as a denitrification substrate to produce N_2O (Vilain et al., 2014; Wagner-Riddle et al., 2007). While C-organic availability is suspected lead the higher mechanism of N_2O-PP in the organic rice field.

Potential production of N_2O will decrease with the increase of soil depth. This result is also supported by Vilain, Garnier, Roose-Amsaled, & Laville (2012) who stated that the production of N_2O in surface (upper) soil is higher than in the ground below.

The content of soil nitrate plays an important role for N_2O flux pattern in the surface soil and the soil below. Nitrates are intermediate products, which can be reduced to produce N_2O. The presence of nitrate will accelerate the formation of N_2O and the higher N_2O flux will occur. However, the maximum N_2O flux will not last long and soon decreased due to limited nitrate supply. There was a positive correlation between soil nitrate content and N_2O flux on day one (r=84, P<0,001, n=8) (Figure 5). These results were also supported by the studies from Burton, Zebarth, Gillam, & MacLeod (2008) and Engel, Liang, Wallander, & Bembenek (2010) who stated that the nitrate content level was positively correlated with the level of N_2O emission.

CONCLUSION

The potential production of CH_4 and N_2O in soil is higher in the organic rice field than in the conventional rice field. The high production of CH_4 and N_2O is affected by the presence of organic matters and nitrogen in the soil. Potential production of CH_4 and N_2O in -what soil type- correlated positively with total organic carbon (TOC) and available nitrogen content. The presence of soil nitrate determines the N_2O flux pattern. The existence of C and N in the soil will be considered as mitigation action.

REFERENCES

Aguilera, E., Guzmán, G., & Alonso, A. (2014). Greenhouse gas emissions from conventional and organic cropping systems in Spain. I. Herbaceous crops. *Agron. Sustain. Dev.*, *35*, 713–724.

Brzezińska, M., Nosalewicz, M., Pasztelan, M., & Włodarczyk, T. (2012). Methane production and consumption in loess soil at different slope position. *The Scientific World Journal.*, 1–8.

Burton, D. L., Zebarth, B. J., Gillam, K. M., & MacLeod, J. A. (2008). Effect of split application of fertilizer nitrogen on N2O emissions from potatoes. *Canadian Journal of Soil Science.*, *88*, 229–239.

Cai, Z., Xing, G., Yan, X., Xu, H., Tsuruta, H., Yagi, K., & Minami, K. (1997). Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilisers and water management. *Plant and Soil.*, *196*, 7–14.

Diba, F., Shimizu, M., & Hatano, R. (2011). Effects of soil aggregate size , moisture content and fertilizer management on nitrous oxide production in a volcanic ash soil Effects of soil aggregate size , moisture content and fertilizer management on nitrous oxide pr. *Soil Science and Plant Nutrition.*, *0768*(December), 733—747. https://doi.org/10.1080/00380768.2011.604767

Engel, R. D., Liang, L., Wallander, R., & Bembenek, A. (2010). Influence of urea fertilizer placement on nitrous oxide production from a silt loam soil. *J. Environ. Qual.*, *39*, 115–125.

Eviati, & Sulaeman. (2009). Petunjuk teknis analisis tanah, tanaman, air dan pupuk. *Balai Penelitian Tanah. Bogor.*

Hou, F., Li, G., Wang, S., Jin, X., Yang, Y., Chen, X., … Ding, Y. (2013). Methane emissions from rice fields under continuous straw return in the middle-lower reaches of the Yangtze River. *Journal of Environmental Sciences.*, *25*, 1874–1881.

Huang, Y., Zou, J., Zhen, X., Wanga, Y., & Xu, X. (2004). Nitrous oxide emissions as influenced by amendment of plant residues with different C:N ratios. *Soil Biology and Biochemistry.*, *36*, 973–981.

Lal, R. (2007). Carbon management in agricultural soils. *Mitigation and Adaptation Strategies for Global Change.*, *12*, 303–322.

Le Mer, J., & Roger, P. (2001). Production, oxidation, emission and consumption of methane by soils : A Review. *Eur. J. Soil Biol.*, *37*, 25–50.

Mosier, A. R., Wassmann, R., Verchot, L., King, J., & Palm, C. (2004). Methane and nitrogen oxide fluxes in tropical agricultural soils : Sources, sinks and mechanisms. *Environment, Development and Sustainability.*, *6*, 11–49.

Mujiyo, Sunarminto, B. H., Hanudin, E., Widada, J., & Syamsiyah, J. (2016). Methane emission on organic rice experiment using azolla. *International Journal of Applied Environmental Sciences.*, *11*, 295–308.

Mujiyo, Sunarminto, B. H., Hanudin, E., Widada, J., & Syamsiyah, J. (2017). Methane production potential of soil profile in organic paddy field. *Soil and Water Resources.*, *4*, 212–219.

Pelster, D. E., Chantigny, M. H., Rochett, P., Angers, D. A., Rieux, C., & Vanasse, A. (2012). Nitrous oxide emissions respond differently to mineral and organic nitrogen sources in contrasting soil types. *Journal of Environtal Quality.*, *41*, 427–435.

Qin, Y. M., Liu, S. W., Guo, Y. Q., Liu, Q. H., & Zou, J. W. (2010). Methane and nitrous oxide emissions from organic and conventional rice cropping systems in Southeast China. *Biology and Fertility of Soils.*, *46*, 825–834.

Qiu, Q., L. Wu, Z. Ouyang, B. L. and Y. X. (2016). Effect of different forms of plant-derived organic matter on nitrous oxide emissions. *Environmental Science : Processes and Impacts.*, *18(7)*, 854–862.

Sass, R. L., Fisher, F. M., Hareombe, P. A., & Turner, F. T. (1991). Mitigation of methane emissions from rice fields : Effects of incorporated rice straw. *Global Biochemical Cycles.*, *5*, 275–288.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., … Sirotenko, O. (2007). Agriculture. In : Metz, B., O.R. Davidson, P.R. Bosch, R. Dave and L.A. Meyer (eds) Climate Change 2007 : Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In *Cambridge University Press.*

Soil Survey Staff. (2014). Keys to soil taxonomy, 12th ed. In *USDA-Natural Resources Conservation Service, Washington, DC.*

Steel, R. G. ., & Torie, J. H. (1978). Principles and procedures of statistics : Biometrical Approach. *Mac Graw Hill Inc. Book Co. Tokyo.*

Susilawati H.L. (2007). Pengukuran potensi produksi gas CH4, CO2, dan N2O dengan teknik inkubasi tanah. *Balingtan. Departemen Pertanian. Pati.*

Sutanto, R. (2002). Pertanian organik : Menuju pertanian alternatif dan berkelanjutan. *Penerbit Kanisius. Yogyakarta.*

Swerts, M., Merckx, R., & Vlassak, K. (1996). Influence of carbon availability on the production of NO, N20, N2 and CO2 by soil cores during anaerobic incubation. *Plant and Soil.*, *181*, 145–151.

Syamsiyah, J., Sunarminto, B. H., & Mujiyo. (2016). Change in chemical properties of organic paddy field with azolla application. *SAINS TANAH – Journal of Soil Science and Agroclimatology.*, *13*, 68–73.

Thangarajan, R., Bolan, N. S., Tian, G., Naidu, R., & Kunhikrishnan, A. (2013). Role of organic amendment application on greenhouse gas emission from soil. *Sci. Total Environ.*, *465*, 72–96.

Turmuktini, T., Kantikowati, E., Natalie, B., Setiawati, M., Yuwariah, Y., Joy, B., & Simarmata, T. (2012). Restoring the Health of Paddy Soil by Using Straw compost and Biofertilizers to Increase Fertilizer efficiency and Rice Production with Sobari (System of Organic Based aerobic Rice Intensification) Technology. *Asian J. of Agric. and Rural Dev.*, *2*, 519–526.

Vilain, G., Garnier, J., Decuq, C., & Lugnot, M. (2014). Nitrous oxide production from soil experiments : denitrification prevails over nitrification. *Nutr. Cycl. Agroecosyst.*, *98*, 169–186.

Vilain, G., Garnier, J., Roose-Amsaled, C., & Laville, P. (2012). Potential of denitrification and nitrous oxide production from agricultural soil profiles (Seine Basin, France). *Nutr. Cycl. Agroecosyst.*, *92*, 35–50.

Wagner-Riddle, C., Furon, A., McLaughlin, N. L., Lee, I., Barbeau, J., Jayasundara, S., … Warland, J. (2007). Intensive measurement of nitrous oxide emissions from a corn–soybean–wheat rotation under two contrasting management systems over 5 years. *Global Change Biology.*, *13*, 1722–1736.

Yagi, K., & Minami, K. (1990). Effect of organic matter application of methane emission from some Japanese paddy fields. *Soil Science and Plant Nutrition.*, *36*, 599–610.

Zou, J., Huang, Y., Jiang, J., Zheng, X., & Sass, R. L. (2005). A 3-year field measurement of methane and nitrous oxide emissions from rice paddies in China: Effects of water regime, crop residue, and fertilizer application. *Global Biogeochemical Cycles.*, *19*.