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N_2O Emission from Managed Soil Under Different Crops in Rainfed Area, Central Java

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ABSTRACT

N_2O emission from agriculture has been assumed to increase by 30-35% until 2030. This gas has a major contribute to the emission from agriculture. N_2O emission from managed soils is the 2^{nd} contributor to green house gas (GHG) emission from agriculture in Indonesia. Rainfed area requested high management input. This research aimed to examine N_2O emission from different crops in the rainfed area and its affecting factors, also to identify things that need to be considered in conducting N_2O measurement from managed soil. Research conducted in Pati and Blora District, Central Java Province. Four (4) different experimental sites with 4 different crops were chosen. Those were mung bean, rubber plantation and sugarcane which located within Pati District, and maize crop which located in Blora District. No treatment was applied. Gas samples were taken following the day after fertilizing. Daily N_2O fluxes from managed soil in tropical land of Indonesia determine by several factors, which are: days after fertilizing, fertilizer type and dosage, previous land use, growth phase of crops, sampling point and soil characteristic. The peak time was mostly influenced by crop type. Maize has the highest N_2O daily fluxes with the range of 311.9 - 9651.6 ugN_2O $m^{-2}day^{-1}$ and rubber plantation has the lowest with the range of 16.1 - 2270.7 ugN_2O $m^{-2}day^{-1}$. Measurement of N_2O from managed soil to determine annual emissions should be done at all crop types, soil types, considering crops growth phase and also high sampling frequency to prevent an over or under estimation.

Keywords: Crop type, managed soil, N_2O, rainfed

ABSTRAK

Emisi N_2O dari lahan pertanian diasumsikan akan terus meningkat sebesar 30-35% hingga tahun 2030. Emisi N_2O dari tanah yang dikelola adalah penyumbang terbesar kedua emisi gas rumah kaca dari pertanian di Indonesia. Gas ini berkontribusi besar terhadap emisi dari pertanian karena praktik budidaya terutama dari pemupukan. N_2O dihasilkan dari proses kompleks yang dipengaruhi oleh berbagai kondisi, karena itu variabilitas data sangat tinggi. Daerah tadah hujan memerlukan input yang tinggi dari pupuk sintetis. Penelitian ini bertujuan untuk mempelajari emisi N_2O dari tanaman yang berbeda dan faktor-faktor yang mempengaruhinya, juga untuk mengidentifikasi hal-hal yang perlu diperhatikan dalam melakukan pengukuran N_2O dari tanah yang dikelola. Penelitian dilakukan di Kabupaten Pati dan Blora, Provinsi Jawa Tengah. Empat (4) lahan untuk penelitian dengan 4 tanaman yang berbeda telah dipilih. Pertanamn kacang hijau, perkebunan karet dan tebu yang terletak di Kabupaten Pati, dan tanaman jagung yang terletak di Kabupaten Blora.Tidak ada perlakuan yang diterapkan dalam penelitian ini. Sampel gas diambil mengikuti hari setelah pemupukan. Fluks N_2O harian dari tanah yang dikelola di daerah tropis Indonesia ditentukan oleh beberapa faktor, yaitu: hari setelah pemupukan, jenis pupuk dan dosis, penggunaan lahan sebelumnya, fase pertumbuhan tanaman, titik sampling serta karakteristik tanah. Waktu puncak sebagian besar dipengaruhi oleh jenis tanaman. Jagung memiliki fluks harian N_2O tertinggi dengan kisaran 311,9-9651,6 ug N_2O m^{-2} $hari^{-1}$ dan perkebunan karet memiliki fluks harian terendah dengan kisaran 16,1-2270,7 ug N_2O m^{-2} $hari^{-1}$. Pengukuran N_2O dari berbagai penggunaan lahan dengan tanaman tertentu untuk menentukan emisi tahunan sebaiknya dilakukan harian atau mingguan selama periode tumbuh tanaman, semua jenis tanah dan juga fase pertumbuhan untuk mencegah *over* atau *under-estimate.*

Kata Kunci: Jenis tanaman, N_2O, tanah yang dikelola, tadah hujan

INTRODUCTION

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N_2O has an important role in the climatic system as well as in the atmospheric ozone layer. N_2O is a greenhouse gas (GHG) which potentially resulting from microbial activity in the process of denitrification and nitrification in the soil, therefore, the agricultural system is a major source of anthropogenic N_2O emissions (Davidson *et al.* 1996; Wrage *et al*. 2001;Barton *et al*. 2015). Asia consumed 58.6% of the total world fertilizer consumption (FAO 2010). The needs for food and energy raises along with the raise of human population, this causes an increase in inorganic N fertilizer (to improve yield), which in turn led to an increase of N_2O emission. N_2O emissions resulting from human activities, has increased by 150 Tg N yr^{-1} (Mosier 2002), with global N_2O concentration in the atmosphere is 320 ppbv, while in the pre industrialization was only by 270 ppbv (IPCC 2007), and this emission from agriculture has been assumed to increase by 35-60% until 2030 (IPCC 2007). Stehfest and Bouwman (2006) estimated that the global annual emissions from fertilized cropland are 3.3 Tg N_2O-N yr^{-1}.

The emissions depend on the amount and chemical composition of fertilizer (Baggs *et al.* 2002;Vallejo *et al*. 2006), which both affect denitrification and nitrification. But, the effect of fertilizer also depends on type of crops, water regimes, temperature, soil moisture, etc. Commonly, nitrogen is a limiting nutrients in intensive cropping systems which applied to rice crops, maize and perennial crops. However, the relationship between agronomic management and N_2O emissions depends on more than just the amount of N input, it depends on a complex interaction between climatic factors, soil properties and soil management (Buchkina *et al*. 2013).For both intensive, conventional and low-input, organic cropping systems, N_2O emissions are a dominant factor in the GWP (Robertson *et al*. 2000; Adviento-Borbe *et al*. 2007).

Agriculture accounted for about 10-12 % to global GHG emission, of which 60% are nitrous oxide (N_2O) and the rest are methane (CH_4). Indonesian Second National Communication (2010) stated that agriculture as a managed soil contributed for about 79% of the N_2O emission nationally.Managed soils as describe in IPCC's guideline (IPCC 2007) are soils where human interventions and practiceshave been applied to perform production, ecological or social functions and are mostly in aerobic condition.

Indonesia is an agricultural country, of the 200 million ha of land territory, about 50 million ha are devoted to various agricultural activities (Statistics Indonesia 2014). There is nearly 20 million ha of arable land, of which about 40% is wetland (*e.g.*, rice fields), 40% is dry land, and 15 % is shifting cultivation. Depending on the source of water and the provision of irrigation facilities, land is classified as technical irrigation areas, semi - technical irrigation areas, simple irrigation areas, village irrigation areas, inland and tidal swamp and rainfed areas. Over 50% of rainfed areas exist in Java Island. 180.952 ha in West Java, 268.970 ha in Central Java and 240.273 ha in East Java. Rainfed area is vulnerable to drought (total annual rainfall < 1,500 mm yr^{-1}), has a very low productivity, mostly because of low quality of soil (low CEC, low C-content, low N and K) therefore the use of synthetic fertilizer to improve yield are a must, and sometime becomes excessive. N_2O emission from agriculture is the 6th contributor to GHG emission in Indonesia (Indonesian Biennial Update Report 2015). There is still lack of N_2O emission data from Indonesian managed soils in rain-fed area.

Therefore, the research of N_2O measurement from different crops, different management and also different sampling time were needed to be done. The aims of this research were to investigate N_2O emission from different crops and factors that affecting, it also to identify things that were needed to be consider in conducting N_2O measurement from managed soil.

MATERIALS AND METHODS

Site Description

The research was conducted at farmer's field in Pati and Blora District from March to November 2013. The selected sites were represents various crops and cultivated in a large scale. The soil was classified as Vertisol and Inceptisol according to The Soil Taxonomy System of USA (Soil Taxonomy 2014). Altitude in Pati ranges from 10 to 40 m above sea level, annual mean temperature is 30 ^{o}C, and annual rainfall is in the average of 1503 mm, of which nearly 70% falls in rainy season (October-March). As a rainfed region, 100% water supplies are provided by the rainfall, because irrigation is not practiced in the region. Meanwhile for the site in Blora, altitude is 35 m above sea level, the annual mean temperature is 28 ^{o}C, and annual rainfall is in the average of 1700 mm.

There were 4 different experimental sites with 4 different crops. Those were mungbean, rubber plantation and sugarcane which was located within Pati District, and maize crop which was located in Blora District. Pati and Blora are side by side. The selected crops were representing the priority commodities in Indonesia. The mung bean site was only cultivated once in a year because it followed the cropping pattern in the area, which was rice-mung bean-rice. The sugarcane site was cultivated in a whole growing season for the last 5 years. Those were two age type of the rubber plantation: matured rubber (age above 4 year) and young rubber (age 0-4 year). For the matured rubber, they were on their fifth growing year when the research was conducted and for the young rubber, since they were not yielding yet, the farmer also cultivated cassava in between the young rubber. The maize site was cultivated twice in a year. Organic and inorganic fertilizers were used for all the sites. The description of fertilizer applied, and the relevant chemical and physical soil properties are listed in Table 1.

Experimental Designs

In each sampling site, there were no special treatment, gas sampling were conducted in the existing farmer site. Before the gas sampling, we planted an anchor to placing the chamber on each sampling points. These anchor intended to minimize the gas leakage.We were using 60 × 20 × 30 cm polycarbonate chambers, and the anchors were 60 × 30 cm. For the sugarcane, mung bean and maize sites, the gas sampling followed the time of fertilization. Those were 2, 5, 9, 29 and 50 days after fertilizing for sugarcane site. Sampling points followed the sugarcane rows, there were 3 points and then replicated in 4 points backwards. Gas sampling in mung bean site, were taken at 4 point, and considered as replication. The sampling time also followed the time of fertilization, which were applied once in a week, so the gas sampling was taken in 2 and 5 days after fertilization in three weeks in a row, so there were 6 measurements. There were 8 sampling points for the maize site which were taken at two different types of soil, vertisol and inceptisol, so there was 4 sampling points each soil types considered as replication. Sampling time also followed the time of fertilization, that were 2, 5, 9, 14, 28, and 42 days after fertilization.

Sampling time at rubber plantation was a bit different than the other site. The gases sampling did not follow the fertilization time, because when we conduct the research, there were still no rain, even if it should be the rainy season, that was why the farmers had not applied any fertilizer yet. So, we decided to take the gas samples in every week for about 5 weeks, only as a baseline emission. The sampling points were also different. In rubber site, we took the samples on the plate under the rubber

Table 1. N-fertilizer and soil properties at 4 different sites

Crops	Source of fertilizer applied	Amount of N ($kg\ ha^{-1}\ year^{-1}$)	Soil properties				Particle size distribution (%)		
			Water content	N	C	pH	sand	silt	clay
Sugarcane	Ammonium sulfat	132	2.74 ± 0.3	0.05 ± 0.01	0.86 ± 0.1	5.8 ± 0.2	42.2	33.2	21.6
Maize (vertisol)	Urea	147.2	4.27 ± 0.3	0.12 ± 0	0.75 ± 0.2	7.37 ± 0.1	6.8	25.2	68.1
Maize (Inceptisol)	Urea	184	3.02 ± 0.1	0.08 ± 0	0.77 ± 0.2	6.26 ± 0.2	10.9	38.8	50.3
Mung bean	Urea	30	2	0.08	1.17	6.7	7.54	41.64	50.8
Mature rubber	Urea	120	±	0.11 ± 0.02	1.12 ± 0.01	5.8 ± 0.1	3.8	46.3	49.9
Immature rubber	Urea and inorganic compound	35.58	±	0.08 ± 0.01	1.42 ± 0.36	6.32 ± 0.1	9.3	14	76.7

and in between the rubbers. We were taking into account that the fluxes from those two different points were significantly different, considering there were any effect from root respiration (but the effect of root respiration itself, were not our concern in this research) at the plate under the rubber and also this place was where the fertilizers were applicated. For the young rubber, since it was not yielding yet, as mention previously, farmer also cultivated cassava in between the plant. The sampling points were replicated 4 times.

Measurement of N_2O Fluxes

N_2O fluxes were measured using static chamber and gas chromatography techniques (Wang and Wang 2003). The closed chamber was made from 4 mm thick acrylic materials consisted of two parts, a square box (without a bottom, length × width × height = 60 cm x 20 cm x 30 cm) and an anchor (length × width = 60 cm × 20 cm). There were two holes in the top of the box, one hole for placing the thermometer and the other one was for gas sampling which was equipped with rubber septum. The anchor was inserted directly 10 cm into the soil, and the square box was placed on top during sampling and it was removed afterwards. Samples were taken with 20 ml plastic syringes were attached to a three-way stopcock at 10, 20, 30, 40 and 50 min following chamber closure, respectively, and then injected into 10 ml evacuated glass vial. N_2O concentrations in the samples were analyzed in the laboratory within 24 hours following sampling using a gas chromatography (Varian GHG 450 Series, a GC System, Varian, Netherlands). The gas chromatography was equipped with an electron capture detector (ECD) for N_2O analysis. The gas chromatography configurations for analyzing N_2O concentration were at 50°C column temperature, 350 °C ECD temperature and 100 °C injector temperature. The methods for calculating the gas flux were the same as those described by IAEA (1992):

$$E = \frac{Bm}{Vm} \, x \, \frac{\Delta C}{\Delta t} \, x \, \frac{V}{A} \, x \, \frac{273.2}{T + 273.2}$$

where E is N_2O flux (mg m^{-2} min^{-1}), Bm is molecular weight of N_2O (g), Vm is molecular volume of N_2O at standard temperature and pressure (22,41l), $\Delta c/\Delta t$ is changes of N_2O concentration over time (ppm per min), V is chamber volume (m^3), A is chamber area (m^2) and T is mean air temperature inside the chamber during gas sampling (°C).

N_2O flux was calculated based on the rate of change in N_2O concentration within the chamber, which was estimated as the slope of linear regression between concentration and time. All the coefficients of determination (R^2) of the linear regression were greater than 0.80 in our study.

Soil Sampling and Analyses

Fresh soil samples (0-20 cm) were taken from each field, but it was only taken once at all of measurements time. It was taken at the first gas sampling. Three sub samples were collected from each sampling point and composited into one soil sample, mixed and placed in plastic bags after manual removal of visible plant residue and roots. Soil samples were analyzed for soil water content (oven-drying method), total N (Kjeldahl method), total C (spectrofotography), particle size distribution and pH.

Statistical Analysis

The effect of different sampling time, soil types, growth phase and sampling point were analyzed with Minitab version 16 Software, the significant effects

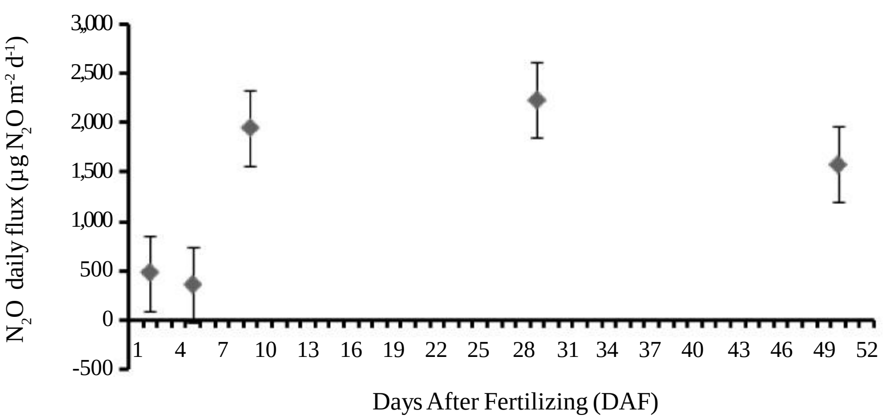

Figure 1. Daily N_2O fluxes from sugarcane site.

of the treatment were examined by using a two-way analysis of variance (ANOVA).When significant differences were detected at P = 0.01, the mean values were compared by using Tukey's pairwise comparison test.

RESULTS AND DISCUSSION

Daily fluxes from sugarcane plantation were likely to have a trend following the days after fertilization (DAF). There were small fluxes at 2 and 5 DAF amounted to 485 and 362 ug N_2O $m^{-2}day^{-1}$. It led to a very high increasing at 9 and 29 DAF amounted to 1955 and 2236 ug N_2O $m^{-2}day^{-1}$, and slowly decreasing at 50 DAF with the amount of 1582 N_2O $m^{-2}day^{-1}$ (Figure 1). The fluxes began to soar after a week of fertilizer application. This is lower than what Den mead *et al.* (2010) has discovered from Australian sugarcane soils.

N_2O daily fluxes measured from mung-bean site are presented in Figure 2. The measurements were conducted at 2 and 5 days following fertilizing in a growing season. Mean fluxes at 2 DAF were ranged from 778 – 1488 ug N_2O $m^{-2}day^{-1}$, while at 5 DAF were ranged from 1,370 – 1,906 ug N_2O $m^{-2}day^{-1}$ (Figure 2). This resulted that N_2O fluxes at 2 DAF were always smaller than those at 5 DAF measurements. The farmer applied N fertilizer in liquid form once in a week. The results of the soil analysis showed the dominant fraction was clay. At the research site, C/N ratio was more than 10, which means that the soil organic matter decomposition is still experiencing. That soil organic matter in question might be residual roots of rice plants from the previous crop.

The N inputs for mung bean were very small actually, it was only 30 kg N $ha^{-1}yr^{-1}$, but what we have shown in Figure 2 there was a high N_2O emission from the site. What we could presume is that the emission occurred, due to embedded biomass from previous season, which was rice. In aerobic conditions at the root zone, there will be nitrification forming N_2O. Increasing soil C contents in the surface soil appears to increase the risk of N_2O emissions from a cropped soil (Barton *et al.* 2015; Corsi *et al.* 2012).

As mentioned on methodology, our measurement at maize site, covered two different type of soil, inceptisol and vertisol. Apparently, the emissions from these two soil type were constantly different. N_2O emissions from maize at inceptisol soil tended to be lower than those at vertisol soil. This was in accordance with our previous research at rice field (Susilawati *et al.* 2015). It was likely that N_2O production not only determined from water regimes condition in the farm, but also by soil characteristic as there were no flooding in maize. What we could presumed is that vertisol soil with its characteristic, which physically has a high clay content led to high N_2O emission. Clayey soils tend

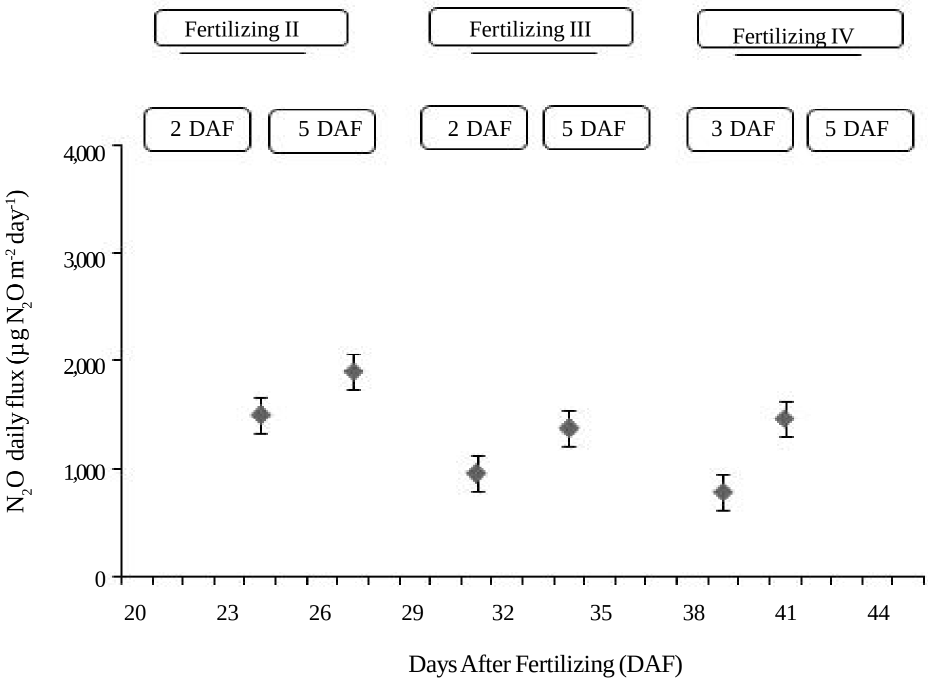

Figure 2. Daily fluxes from mung bean site.

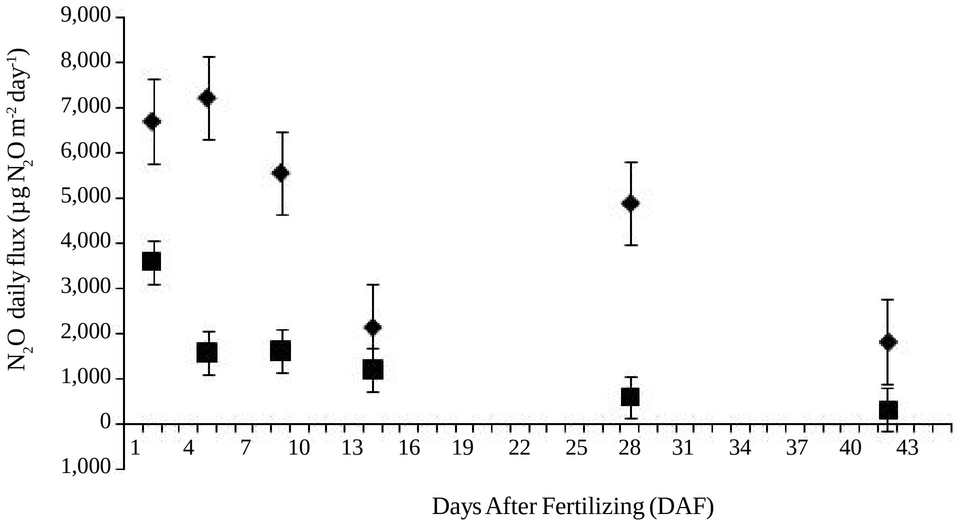

Figure 3. Daily N_2O emission from maize site. —◆—: vertisol, —■—: inceptisol.

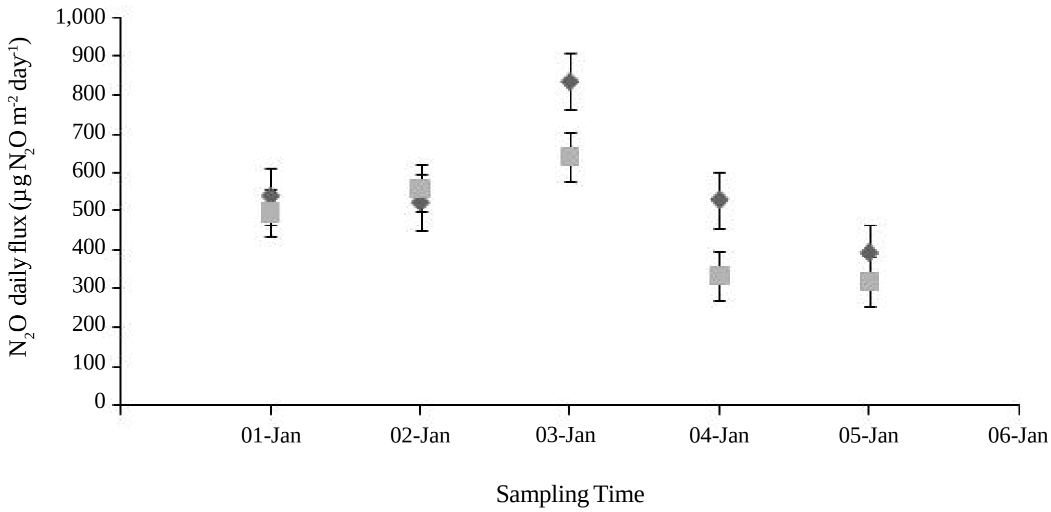

Figure 4.Weekly N_2O fluxes from mature and young rubber plantation sites.

to show greater N_2O emissions than sandy soils (Brentrup *et al.* 2000), due to the small amount of macropores which would increase anaerobic microsites, that led to increasing N_2O emissions.

Gas measurement following days after fertilizing at maize site are presented in Figure 3. It was high at 2 DAF and continued to decrease until 42 DAF at vertisol soil. This is showed that as fertilizer applied, the processes involved in denitrification and nitrification running soon after (Dobbie *et al.* 1999). Whilst at inceptisol soil, the denitrification-nitrification were running slowly until peaks at 5 DAF and decreased afterwards. Maize crops only absorbed about 50-60% N input, almost 2 % lost as N_2O emission (Stevens and Laughlin 1998; Stevens *et al.* 1997).

The measurement of N_2O emission at rubber plantation were determined weekly, without considering DAF as there was no fertilizer applied during our measurement. After 5 times measurement, it resulted that N_2O flux was fluctuated for each week, either on the young or mature rubber. The following figure shows that the value of the flux on the young rubber is always higher than the mature. Measurement of N_2O on 2 October at both locations showed a peak, this was occurred after rainfall (data not shown). After the irrigation or rainfall, WFPS increased, making the conditions conducive for N_2O production (Ray *et al.* 2013), which resulted in high N_2O emissions. Many workers have also found that with the increase in WFPS, soil redox potential becomes

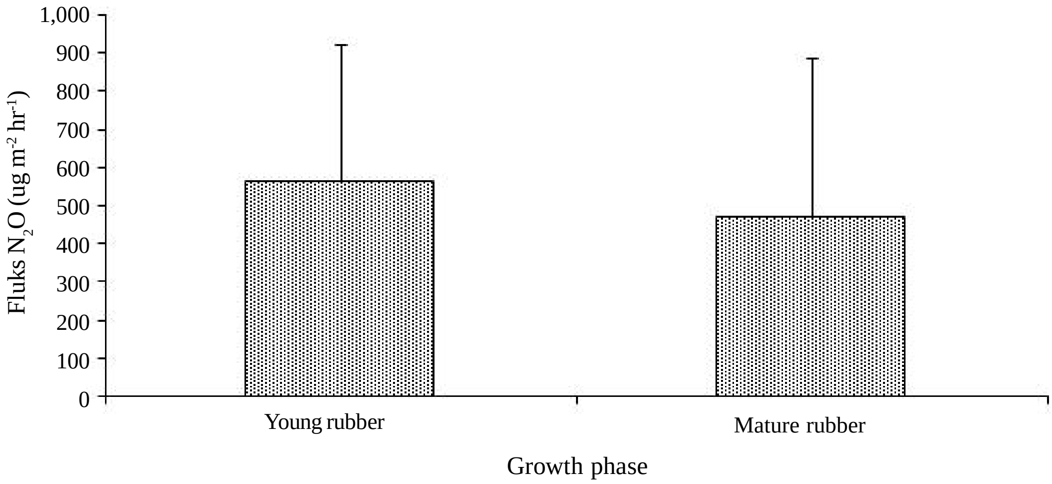

Figure 5. N_2O fluxes from different rubber growth phase.

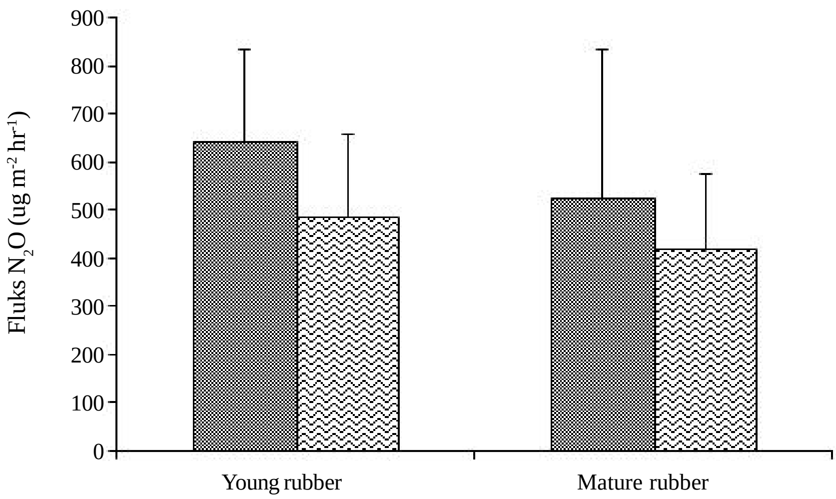

Figure 6. N_2O emission from different sampling points at rubber plantation site.

favorable for denitrification, and soil microbial activity increases with a rise in temperature and soil moisture (Gödde and Conrad 2000; Ding *et al*. 2007; Davidson 2009). Many studies have reported that soil water content expressed as water-filled pore space above 60% (Dobbie and Smith 2003a; Sehy, 2003) and soil temperature above 10°C (Horváth *et al*. 2010; Ma *et al*. 2010) were conducive to enhancing N_2O emissions. Lessard *et al*. (1996) noted that a rise in N_2O fluxes coincided with high soil NO_3-N content and high water content following rainfall.

N_2O fluxes based on cropping phase difference are shown in the following figure. The young rubber turns out produced N_2O fluxes higher than the mature rubber, it is very possible because of the influence of fertilization and also the growth stage itself. In young rubber, there was intercropping with cassava plant, so the influence of fertilization from cassava which were likely to affect N_2O flux. While at mature rubber, the last fertilization were conducted in February.

As mentioned earlier at methodology, each sampling site consisted of two points, which were on the plate under the rubber and in between the rubbers. Figure 6 shows that N_2O fluxes on the plate under the rubber as well as on the side line of rubber plant on young phase were greater than the mature one. The fluxes in each phase on the plate were greater than those between the rubber plants (Figure 6.). This is due to the effect of the fertilizer applied location, which is usually performed at around the rubber plate.

As a whole, N_2O emissions were low for all crops in Indonesian lowland rain-fed area compared to boreal agricultural mineral soils in Finland which were ranged from 0,12 to 12 kg N_2O-N $ha^{-1}year^{-1}$ (Regina *et al.* 2013) and from tropical peatlands in Kalimantan, annual N_2O emissions were higher, ranged from 2,98 to 18,96 kg N_2O-N $ha^{-1}year^{-1}$ for five secondary forest and six agriculture land uses (Hadi *et al.* 2002). Fluxes from rubber plantation were relatively small compare to other measure crops in this study due to N fertilizer. Application of mineral N-fertilizers into agricultural soils usually results in increasing N_2O emissions (MacKenzie *et al*. 1998; Dobbie and Smith *et al*. 2003b; Jones *et al*. 2007; Rizhiya *et al.* 2011). However, there is contradictory information on linearity between applied N rates and N_2O emissions from soils. According to results reported by Gregorich *et al.* (2005), N_2O emission from agricultural soils increased linearly with the applied amount of mineral N fertilizer. At N rates not exceeding or equal to those required for maximum yields, N rates tended to create a linear response in N_2O emissions, with approximately 1% of applied mineral N lost as N_2O (Bouwman 1996; Halvorson *et al*. 2008). The emission from maize were highest among other crops, due to highest N fertilizer (Table 1), this coincide with any other study. As for rubber, there were no fertilizer added prior to the measurement.

Measurement of N_2O fluxes following days after fertilizing showed a very different pattern among crops. Generally, the highest N_2O fluxes occurred in the first or second week after application of N fertilizers to the soil (Liu *et al.* 2005, 2006; Schils *et al.* 2008). According to Zhang and Han (2008), the effect of fertilization disappears approximately two months after the application of N. At sugarcane site, the peak started to increase in 9 and 29 DAF then decreased afterwards. While at mungbean and maize, the fluxes showed a peak at 5 DAF. One form of N loss that is not absorbed by plants is N_2O emissions (Granli and Bockman 1994). After the application of fertilizer and the absorption ineffective, it will appear on soaring N_2O flux and the effect of fertilization disappears approximately two months after the application of N. The application of urea will cause a delay time of N_2O fluxes compare to ammonium nitrate fertilizer, as mentioned by Signor and Cerri (2013). This delay time might be attributed to a reduced availability of N at the beginning of the experimental periods, since the N in urea has to be hydrolyzed before being available for nitrification and denitrification processes.

N_2O flux from agricultural soils depends on a complex interaction between climatic factors,soil properties and soil management (Henault *et al.* 1998). The proportion of N_2O in the total flux of N gases emitted from soils is also influenced by soil type (Stevens and Laughlin 1998). Clayey soils tend to show greater N_2O emissions than sandy soils (Brentrup *et al*. 2000), and N management may

Table 2. Significance of the impacts of sampling time, soil type, growth phase and sampling point on N_2O emission from different crops in Central Java.

Crops	Sampling time (DAF)	Soil type	Growth phase	Sampling point
Sugarcane	**	no	no	ns
Maize	**	**		ns
Mung bean	*	no	no	ns
Rubber plantation	ns	no	**	ns

Table 3. Mean and range of N_2O emission among different crops in Central Java.

Crops	(ug N_2O $m^{-2}day^{-1}$)	
	Mean	Range
Sugarcane	1371.4b	90.9 - 8919.5
Maize	3107.6a	311.9 - 9651.6
Mung bean	1326.4bc	227.0 - 3638.9
Rubber plantation	519.1c	16.1 - 2270.7

increase the emission of N_2O, particularly in soils of fine texture and without mobilization before seeding (Chen *et al*. 2008, Tan *et al*. 2009). N_2O emissions induced by soil management practices and by rain were four times greater in a clay loam soil than in a loamy sand (Tan *et al*. 2009). This occurred in our measurement at maize with two different type of soil. Apparently, the emission from vertisol (high clay soil) was bigger than that from inceptisol (a sandy loam soil). Neill *et al.* (2005) reported that emissions in sandy soils occur with greater soil moisture than that necessary for similar emissions in a clayey soil. The fluxes from mung bean site were quite high due to previous crop residue. The higher soil moisture, due to the crop residue in (Baggs *et al*. 2006), can increase microbial activity near the soil surface, consuming the available O_2 and creating anaerobic microsites. Liu *et al.* (2011) studied N_2O emissions in a crop rotation system, in China, and showed that the incorporation of maize and wheat straw significantly increased the soil temperature, due to their heat-retaining property. The biochemical composition of plant residues added to the soil is responsible for higher or lower N_2O emissions (Gomes *et al*. 2009), because the maintenance of straw on the soil surface affects the N mobilization and immobilization and, consequently, the N availability in the soil, and also the nitrification and denitrification processes.

Growth stage also led to significantly different emissions, as we found out in measurement at rubber plantation. Earlier studies have established that higher amount of photosynthesized carbon is allocated to roots during the vegetative growth stages (Fu *et al*. 2002; Meng *et al*. 2013). Increase in available carbon leads to higher activity of denitrifying soil microbes, which causes higher N_2O emissions (Qian *et al*. 1997; Sey *et al*. 2010).

CONCLUSIONS

Nitrous oxide measurements at different site of crops, showed a very different value. Different crops resulted in different N_2O emission due to differences in management, agronomical and environmental factors. Measurement following the days after fertilizer application showed different pattern among different crops. What we could be concluded that daily N_2O fluxes from managed soil ofrain-fed lowland in Indonesia determine by several factors, which were days after fertilizing, fertilizer type and dosage, previous land use, growth phase of crops, sampling point and soil characteristic. The peak time mostly influenced by crop types.Maize has the highest N_2O daily fluxes with the range of 311.9 - 9651.6 ugN_2O $m^{-2}day^{-1}$ and rubber plantation has the lowest with the range of 16.1 - 2270.7 ug N_2O $m^{-2}day^{-1}$. This showed that GHG emissions were having a very high variability in spatial and temporal. Measurement of N_2O from managed soil to determine annual emissions should be done at all crop types, soil types, considering crops growth phase and also high sampling frequency to prevent an over- or under estimation.

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