Abstract No: A-355

THE EFFECT OF NITROGEN FERTILISER ON NITROUS OXIDE EMISSION IN OIL PALM PLANTATION

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SUMMARY

Oil palm is the largest agricultural crop in the tropics, accounting for 13% of all tropical land cover. When it is cultivated on marginal or nutrient-poor land, external inputs of N fertiliser are required to achieve high levels of productivity and yield. However, excess N fertiliser use may lead to negative impacts on the environment, including generation of reactive N-gases (e.g. nitric oxide –NO, nitrous oxide –N_2O), tropospheric ozone (O_3) and nitrate (NO_3^-); all of which may lead to atmospheric pollution and contamination of surface waters. This study investigates spatial and temporal patterns of N_2O fluxes in peatland oil palm plantations associated with existing fertiliser regimes in Sarawak, Malaysian Borneo. Overall N_2O fluxes from plantations on peat were low relative to fluxes reported elsewhere in the literature. This suggests that N inputs were not greatly in excess of plant demand. N_2O fluxes in these plantations was spatially stratified, and influenced by the presence of herbaceous plants, organic residue (excised palm fronds) management and soil moisture availability. N_2O fluxes were enhanced in areas where herbaceous plants or organic residues were present, presumably because the presence of herbaceous plants or excised palm fronds supplies labile C and N for nitrification and denitrification. N_2O fluxes were also enhanced in areas of high moisture content (e.g. near drainage ditches), perhaps because greater soil moisture favoured denitrification.

Key words: *oil palm, fertiliser, nitrous oxide, peatland*

INTRODUCTION

Atmospheric concentrations of nitrous oxide (N_2O) have risen by about 49-50% since the pre-industrial era as results of human activity (Hirsch *et al.*, 2006). Agriculture is the major source of the N_2O, mainly from the soils and N inputs to crops and soil systems. In soils, N_2O is produced mainly through microbial activity through nitrification, denitrification and dissimilatory nitrate reduction (Cayuela *et al*., 2014).

N_2O is a potent GHG and the third most important climate forcing agent after carbon dioxide (CO_2) and methane (CH_4) (Snyder *et al*., 2009). N_2O has a global warming potential (GWP) of 298 times larger than an equal mass of CO_2 over a 100-year period (IPCC, 2007), and also catalyses the destruction of ozone in the stratosphere (Hergoualc'h *et al.,* 2009) due its long lifespan (approximately 120 years). N_2O fluxes from soil generally increase with rising N fertiliser application, agricultural intensification, and poor fertiliser management practices (Allen *et al.,* 2010; Kahrl *et al.,* 2010; Mosier *et al.,* 2004).

Oil palm ecosystems are globally significant environments as they take up approximately 16.4 million hectares of agricultural land worldwide (FAO, 2013). As the availability of suitable mineral soil sites have declined in recent years, the oil palm industry has expanded cultivation into peat lands, especially in Southeast Asia. While the aboveground biomass in tropical forests store large amounts of carbon, the peat soils can contain 18 to 28 times more than the aboveground biomass (Page *et al*., 2011). Mineralisation of peat C stores arising from disturbance or land-use change can lead to large, regionally significant increases in CO_2 emissions. Furthermore, when oil palm is developed on drained peat soils, N_2O emissions may also increase due to accelerated rates of peat decomposition and N mineralisation (Stichnothe and Schuchardt, 2011) as well as nitrogen fertiliser consumption, which vary depending on soil moisture and land-use (Schrier-Uijl *et al.,* 2013). Melling *et al.,* (2007) estimated the N_2O source in the Malaysian oil palm plantation were 566 kg CO_2-eq ha^{-1} yr^{-1}, however, uncertainties were large and data were too limited either to distinguish background emissions from event-based emissions linked to fertiliser application. There has also been a lack of studies that focus on long-term rates and relationship between the emission of N_2O and their driving variables in the oil palm on peatlands ecosystems.

METHODOLOGY

The study was conducted in oil palm plantation located in Bintulu, Sarawak, Malaysia Borneo (3^o 12.691‘ N, 113^o 30.008‘ E). Sampling was conducted within one hectare plot of oil palm planted in 2007 on peat soil and replicated three times. The age of the palms was eight year old (mature palms) at the commencement of the study. Urea was used as the N input at the rate of 106.125 kg ha^{-1} yr^{-1} and was applied by broadcasting method.

In this study, N_2O fluxes from soil were measured using chamber-based methodology (Parkin and Venterea, 2010). Soil collars were installed at least 5 cm into the ground and extend no more than 5 cm above the surface at five different sampling point surrounding the palm. Sampling points were categories into five types; namely, field drain, frond pile, harvest path, inter row and vegetation path. Any vegetation was cut and removed before the collars were pushed into the soil though root growth inside the collars where possible. Gas chamber with dimension of 10.1 cm in diameter and 16 cm high were placed directly on the soil collars.

N_2O fluxes were quantified using an INNOVA portable photo-acoustic spectrophotometer (INNOVA 1412; INNOVA Air Tech Instruments, Denmark). Fluxes were measured from each chamber for approximately two minutes, with a five concentration measurements collected over the enclosure period.

The volumetric soil water content (Θ_v) was measured by portable moisture meter (HH2 Moisture Meter, Delta T Devices, Cambridge) and sampled close to the chamber (within 1-5 cm). Soil temperature, for the top 12 cm, and air temperature were measured using a MultiThermo digital thermometer.

The correlation coefficient, Pearson‘s *r*, was chosen to illustrate the relationship between N_2O emissions and environment factors, such as soil moisture (v/v), soil temperature (^oC) and air temperature (^oC).

In this study, log10 transformed data was used to conduct all statistical analysis including one way ANOVA to compare the variability of scores between treatments. All statistical analysis was performed using SPSS 23 software (SPSS Inc., United States), with a probability of 5% to test the significance of treatments effects.

RESULTS AND DISCUSSION

Overall, the mean for N_2O flux was 2.85 kg N_2O ha^{-1} yr^{-1}. N_2O flux was measured from five different sampling points to see the effect of spatial heterogeneity of N_2O flux from the study site as shown in Figure 1. The highest emission of N_2O was from the vegetation path area with the mean (SD) of 1.01 (0.98) mg N_2O m^{-2} d^{-1}, followed by the emission from the harvest path, inter row and the field drain area at 0.99 (0.65) mg N_2O m^{-2} d^{-1}, 0.86 (0.74) mg N_2O m^{-2} d^{-1} and 0.56 (0.4) mg N_2O m^{-2} d^{-1} respectively. The lowest mean emission was recorded from the frond pile area at 0.48 (0.17) mg N_2O m^{-2} d^{-1}. The study showed high N_2O emission from the harvest path area, as it is the most disturbed area due to the heavy managerial task performed on the site such as fertiliser and pesticides application and weeding. In addition, the N_2O emission from the vegetation path area comes from the additional soil organic matter from the vegetation.

A one-way ANOVA was conducted to compare the mean among the sampling points, however, the observed differences in fluxes from different sampling points were not statistically significant.

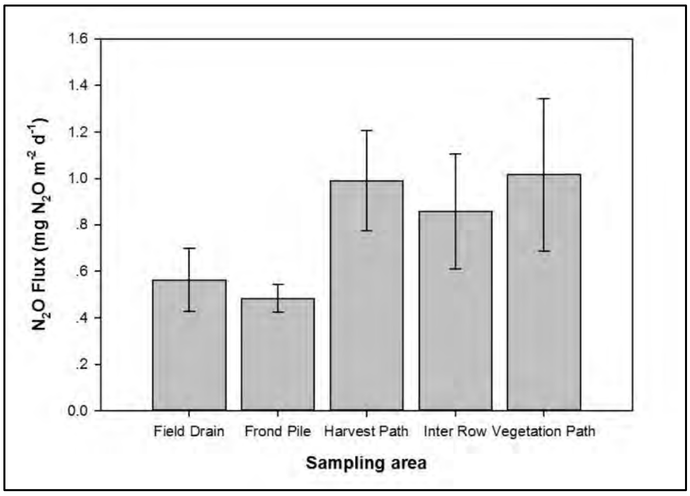

Figure 1: Mean N_2O flux from different sampling points (Bar represents standard error of the mean)

A scatterplot and Pearson‘s *r* analysis was conducted to summaries the correlation between the N_2O emission and the environmental variables (Figure 2) namely soil moisture, soil temperature and air temperature.

Based on Pearson‘s *r*, the highest correlation obtained between N_2O flux and environmental variables was soil moisture ($r = -0.44$, $n = 45$, $p = 0.003$) followed by air temperature ($r = -0.26$, $n = 45$, $p = 0.09$) and soil temperature (r = -0.25, n = 45, p = 0.098). However, based on the Pearson's r analysis, only soil moisture shows a significant correlation with the N_2O emission. N_2O fluxes were also enhanced in areas of high moisture content, perhaps because greater soil moisture favoured denitrification.

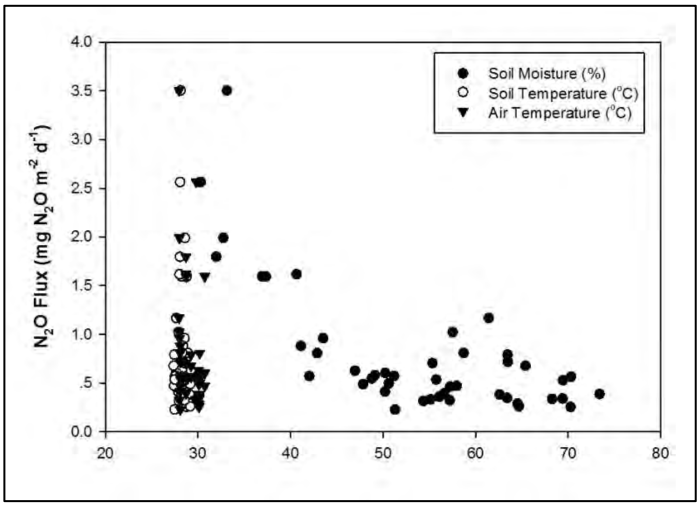

Figure 2: Scatterplot of N_2O flux and environmental variables (soil moisture, soil temperature, air temperature)

CONCLUSION

N_2O fluxes in this plantations was spatially stratified, and influenced by the disturbance and the presence of herbaceous plants, other than the soil moisture availability. Relatively the N_2O emission in this plantation is low compared to the fluxes reported elsewhere in the literature.

ACKNOWLEDGEMENTS

We would like to thank the Malaysian Palm Oil Board (MPOB) for the sponsorship through the MPOB Education Scholarship and also the fieldwork support by MPOB Tropical Peat Research Institute (TROPI)

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