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The impact of nitrogen fertilizer use on greenhouse gas emissions in an oil palm plantation associated with land use change

FARADIELLA MOHD KUSIN
Department of Environmental Sciences and Environmental Forensics Research Centre, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
Corresponding author: e-mail: faradiella@upm.edu.my

NURUL IZZATI MAT AKHIR
Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia

FERDAUS MOHAMAT-YUSUFF
Department of Environmental Sciences and Environmental Forensics Research Centre, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia

MUHAMAD AWANG
SEGi University, Kota Damansara, 47810 Petaling Jaya, Selangor, Malaysia

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RESUMEN

Se estudian las emisiones de gases de efecto invernadero relacionadas con el cambio de uso del suelo en una plantación de palma de aceite específica. Se analizaron las emisiones de óxido de nitrógeno (N_2O) procedentes de la aplicación de fertilizantes nitrogenados durante la etapa de cultivo en palmeras de diferentes edades dentro de la plantación. La emisión de N_2O varía de 19.11 a 22.17 kg de N_2O-N/ha, lo que resulta en la emisión de 1052.26-1209.51 kg de CO_2-eq/ha. Sin embargo, no se encontró una relación evidente entre las emisiones de N_2O o CO_2-eq y la edad de las palmeras. Por otra parte, también se evaluó el impacto del cambio de uso del suelo en el desarrollo de la plantación mediante la evaluación de variaciones en las existencias de carbono dentro de la plantación. La conversión de finca cauchera a plantación de palma de aceite libera el contenido de carbono en el suelo (i.e., produce emisión de carbono), pero dicho fenómeno está previsto en la literatura. En conjunto, las emisiones relacionadas con el fertilizante y las vinculadas con el combustible durante la etapa de cultivo contribuyen con alrededor de 79 y 21%, respectivamente, de la emisión total de gases de efecto invernadero de la plantación. Por lo tanto es probable que la aplicación de fertilizantes nitrogenados incremente las emisiones resultantes de la transformación de finca cauchera a plantación de palma de aceite, pero los valores se encuentran dentro de los límites estimados para una plantación de palma de aceite en Malasia.

ABSTRACT

The emissions of greenhouse gases (GHGs) in an oil palm plantation associated with land use change have been evaluated on a site-specific basis. Nitrous oxide (N_2O) emissions from the application of nitrogen fertilizers during the growth stages of the palm oil were analyzed for palms of different ages within the plantation. The N_2O release ranges between 19.11-22.17 kg of N_2O-N/ha, resulting in the emission of 1052.26-1209.51 kg of CO_2-eq/ha. However, there is no clear relationship between the emissions of N_2O or CO_2-eq and the age of the oil palms. On the other hand, the impact from land use change for the development of the site was also evaluated by assessing the emissions from carbon stock changes within the plantation. The transformation

of a rubber estate into an oil palm plantation loses the soil carbon content (i.e., release of carbon emissions). However, this phenomenon has been anticipated in literature. Overall, fertilizer-related emissions and fuel emissions during the growth stages contribute to about 79 and 21%, respectively, of the total GHG emissions from the plantation. Therefore, it is likely that the application of nitrogen fertilizer may increase the existing carbon emission from the conversion of rubber to oil palm plantation, but the values are within the estimated for a Malaysian oil palm plantation.

Keywords: Carbon stock changes, global warming, greenhouse gas emission, nitrous oxide, nitrogen fertilizer, oil palm plantation.

1. Introduction

The establishment of oil palm plantations in Malaysia has rapidly expanded in the past 25 years, especially in the west coast of the Malaysian Peninsula, where soil is most fertile and productive (Henson, 2005). Oil palm has been extensively planted in parts of East Malaysia on newly explored forest land. Generally, oil palm plantations in this country have been developed from logged-over, degraded forest and also as replacement of other crops such as rubber, coconut and cocoa, since these crops have become less profitable than oil palm (MPOB, 2001; Henson, 2004). Greenhouse gases (GHG) emissions from land use change are regularly debated, particularly in relation to biofuels (e.g., establishing new plantations on agricultural land). Emissions are in particular related to changes in aboveground and belowground biomass, as well as soil organic matter (Brinkmann Consultancy, 2009). Specifically, the establishment and operation of a new plantation lead to the removal of the original aboveground and belowground carbon stocks (e.g., forest, grassland, etc.). On the other hand, a plantation stores carbon through the growth of oil palms.

Oil palm is a perennial crop. There are few important phases in its life cycle, beginning from the agricultural phase (establishment and growth of the plantation) through the oil extraction phase (Castanheira *et al.*, 2014). The growth stages of oil palm include activities related to the development of this plant, whereby typically three stages are considered throughout its lifetime, i.e. nursery, immature plantation and mature plantation (Schmidt, 2007). It is believed that the most significant contribution to global warming from an oil palm plantation is from the agricultural stage, i.e. cultivating (15%), clearing (17%) and replanting (18%) (Schmidt, 2010). The emissions arising from operations during oil palm growth and fresh fruit bunches (FFBs) processing are in particular related to the use of fossil fuels for internal transport and machinery, fertilizers, fuels for the palm oil mill, and emissions from the palm oil mill effluent (POME) (Brinkmann Consultancy, 2009).

Common inputs of oil palm fertilizers comprise nitrogen fertilizers (i.e., ammonium nitrate, ammonium sulphate, urea and ammonium chloride), phosphate rock, potassium chloride and kieserite. The emissions released may vary between the type of fertilizers and the mode of production. Specifically, GHG emissions related to the use of fertilizers in an oil palm plantation include nitrous oxide (N_2O) emissions from the application of nitrogen fertilizers. According to the Intergovernmental Panel on Climate Change (IPCC) guidelines, 1% of N_2O-N is emitted from the total N applied during fertilizer application. Emissions from fertilizer application represent more than 50% of the overall plantation emissions (Schmidt, 2010; Castanheira *et al.*, 2014). The amount of fertilizer used in an oil palm plantation may result in high N_2O emission into the atmosphere, ultimately leading to significant global warming (Corley and Tinker, 2003).

N_2O is a potent greenhouse gas with a global warming potential over a 100-yr. period 298 times higher than carbon dioxide (CO_2) (IPCC, 2007). Agriculture contributes about 42% of the increasing N_2O emission into the atmosphere. N_2O is produced in agricultural soils by microbial transformation of compounds that contain nitrogen, such as fertilizer and animal dung and urine (Giltrap *et al.*, 2014). Artificial fertilizers are applied to boost the crop's growth (De Datta, 1995). The inputs of N-fertilizer can occur through either direct or indirect pathways. Direct N_2O emission occurs from direct addition of N-fertilizer on the soil whereas indirect N_2O emission may results from processes such as N-deposition from the atmosphere, N-fixation by legumes, and decomposition of biomass residues (Schmidt, 2007; Millar *et al.*, 2010). The increase in available mineral N in soil may enhance the formation