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FLUVIAL ORGANIC CARBON LOSSES FROM OIL PALM PLANTATIONS ON TROPICAL PEAT, SARAWAK, SOUTHEAST ASIA

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SUMMARY

The conversion of tropical peatlands into oil palm plantations can result in significant perturbations to the terrestrial carbon cycle. However, dependable estimates of gaseous and fluvial carbon losses from oil palm plantations are few (Evans *et al*., 2014). Here, we present preliminary data that quantify the effect of establishing oil palm plantations on tropical peat fluvial organic carbon losses. The study focuses on two oil palm estates in Sarawak, Malaysia and nearby stands of peat swamp forest. Concentrations of dissolved and particulate organic carbon in the water draining these areas is being monitored at weekly to bi-monthly intervals, allowing a comparison between these two land covers.

***Keywords**: fluvial organic carbon, oil palm plantations, tropical peatlands, Southeast Asia*

INTRODUCTION

The tropical peatlands of Southeast Asia are important stores of carbon. They hold approximately 69 GtC, equivalent to 14% and 77% of the global and tropical peat carbon pools, respectively (Page *et al.*, 2011). These ecosystems are currently experiencing significant degradation in the form of deforestation, drainage and burning, to convert them into other land-uses (Miettinen *et al*., 2011). One example is the conversion of tropical peat swamp forest (PSF) into oil palm plantation (OPP), which is increasing throughout Southeast Asia (Miettinen *et al*., 2011). Predictions suggest that OPP expansion is likely to double or triple from 3 million ha to 6-9 million ha by 2020, across Peninsular Malaysia, Borneo and Sumatra (Miettinen *et al.*, 2012a), with further studies suggesting that approximately 23% and 93% of Malaysian peat could be under oil palm by 2020 and 2030, respectively (Miettinen *et al.,* 2012b).

The conversion of PSF to OPP requires significant land modifications, mainly drainage and deforestation, exposing previously saturated peat layers to aerobic conditions and promoting rapid organic matter decomposition (Evans *et al*., 2015). This leads to perturbations to the terrestrial carbon cycle; often converting these natural sinks into sources. Estimates suggest that CO_2 emissions from the conversion of PSF to OPP contributes between 33 to 100 Mg $CO_{2\text{-eq}}$ $ha^{-1}yr^{-1}$ (Germer & Sauerborn., 2008; Hooijer *et al*., 2010) and accounts for approximately 16% and 32% of the total land-use emissions from Indonesia and Malaysia, respectively (Agus *et al*., 2013).

There is increasing interest in the importance of fluvial carbon losses in the global carbon cycle. At present only one study (Moore *et al*., 2013) has reported on the considerable losses of dissolved organic carbon (DOC) from degraded tropical peatlands experiencing little management. However, the study was based on a limited number of field sites and so more data are needed in order to understand the dynamics of DOC in more intensively managed peatlands with controlled drainage.

DOC is both biologically and chemically reactive (Evans *et al*., 2015). The labile carbon fractions can be metabolized by in-stream fauna, and subsequently oxidized, leading to indirect atmospheric carbon dioxide (CO_2) emissions (Evans *et al*., 2015). In addition, the more recalcitrant constituents of DOC are also believed to be broken down via photochemical processes, so may actually be more ‗reactive' than the labile component as a result of this process (Evans *et al*., 2015). Consequently, the degradation of DOC into its gaseous metabolic products, and subsequent efflux from peatland surface waters, could represent a hidden and important contributor to atmospheric greenhouse gas emissions.

The aim of this study is to address the knowledge gap surrounding fluvial carbon losses from oil palm plantations established on tropical peat. The results will be used to help identify all carbon emissions from land-use change, as well as potentially contributing to derivation of IPCC Tier 2 emissions factors. Collectively these will

allow Malaysia to monitor, report and verify their land-based greenhouse gas emissions in a more effective way.

METHODS

The study sites are located within the Malaysian province of Sarawak and are concentrated within the Sebungan (SE) and Sabaju (SA) oil palm estates. These two estates are situated east of the coastal town of Bintulu between Latitudes 3°07.81‘ N and 3°14.91‘N and Longitudes 113°18.72‘ E and 113°32.19‘. The estates range in age from mature (established 2007, 9 years old) to immature (established 2010, 6 years old). Main and collection drains are being monitored (sampling frequency 1-2 weeks) over a 12-month period in four main plantation study areas: Sebungan (SE), Sabaju 1 (SA 1), Sabaju 3 (SA 3) and Sabaju 4 (SA 4). Nearby stands of peat swamp forest are also being monitored, allowing a comparison between these two land cover types.

The concentrations of both dissolved (DOC) and particulate organic carbon (POC) in the water draining both estates and forest sites are being quantified. Within the OPP estates, water samples are collected from a combination of i) ―mini catchments”- collection drains, draining water from individual plantation blocks of a known area and ii) ―large catchments”- main drains, draining water from multiple plantation blocks of a known area.

A combination of salt dilution gauging and stage recording is being used to generate rating curves for individual channels, allowing discharge measurements and DOC and POC fluxes to be generated throughout the sampling period. These data will be used to calculate total organic carbon (TOC) fluxes (g C m^{-2} yr^{-1}) for the ―mini” and ―large” catchments based on their areas. Eventually these estimates can be up-scaled to give an amount for the whole plantation area.

RESULTS

The investigation is currently on-going. Initial results from the first 5 months of the study are presented below. At present, the majority of the fluvial carbon lost is in DOC form (72.8 - 93.1% of TOC: Figure 1). In the plantation main drains and collection drains, respectively (Figure 2), the initial mean DOC concentrations range from 28.9 to 43.7 mg l^{-1} and 23.6 to 43.3 mg l^{-1}. DOC concentrations are variable across all plantation study sites with the highest concentrations found within Sebungan and the lowest within Sabaju 3. DOC concentrations within the forest sites are also variable ranging from 32.2 to 46.7 mg l^{-1}. Based on current DOC concentration data and available discharge measurements, average weekly fluxes from the plantation collection drains range from 0.02 to 0.07 t C $week^{-1}$ ha^{-1}. The lowest fluxes are found within Sebungan and the highest within Sabaju 1 and 3.

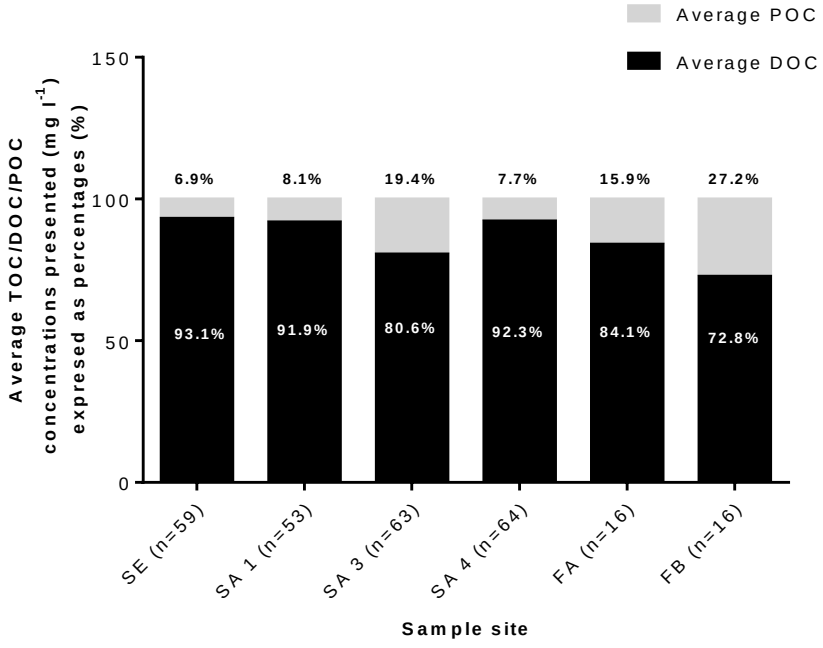

Figure 1: Average TOC concentration from August – October 2015 from all study sites, split into its two components; DOC (black) and POC (grey). Where: SE= Sebungan plantation, SA 1-SA 4= Sabaju 1 to 4 plantations and FA and FB= forest sites.

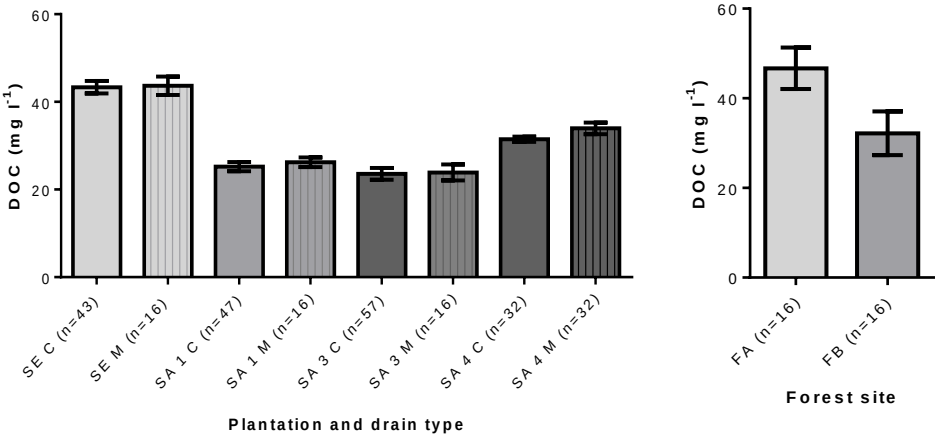

Figure 2: DOC concentrations from the plantation sites (left), where c= collection drain and m= main drain and the forest sites (right), from August – December 2015. Bars display the standard error of the mean

DISCUSSION

The observed contribution of DOC to TOC is consistent with data reported by Moore *et al*. (2013). DOC concentrations are wide ranging across all sites. On-going data collection across both the wet and dry season will help to identify any consistent data trends and allow a fuller picture of temporal DOC dynamics to be established. DOC concentrations from the plantation sites compare well with those reported by Moore *et al*. (2013) for a severely drained and degraded peat swamp forest (48.3 mg l^{-1}). Further work to delineate drainage areas will allow load estimates to be derived, and relationships between management and DOC loss to be evaluated.

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