Abstract No: A-373

# ROOT RESPIRATION DRIVES PATTERNS OF TOTAL SOIL $CO_2$ FROM CULTIVATED TROPICAL PEATLANDS

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## SUMMARY

Draining tropical peatlands for agriculture may change the carbon dynamics of the soil. To determine the corresponding rates of peat oxidation, soil respiration can be used, but must be partitioned into its autotrophic and microbial peat oxidation components. The systematic planting of oil palm plantations allows for this if spatial sampling strategies are employed. In this study, soil respiration and root biomass were sampled at increasing distances away from oil palm, into three different surface microforms (harvest path, frond pile, cover crops). Both variables were greatest by the palms and lowest further away from the palms, allowing for root biomass to be used as a predictor of peat oxidation rates. Soil respiration could also be up-scaled spatially to determine plot scale estimates of total soil respiration. Soil respiration showed high variability in estimates and so large sample sizes are encouraged in order to accurately estimate peat oxidation from cultivated peat soil.

***Keywords:*** *peat oxidation, soil respiration, root biomass, tropical*

## INTRODUCTION

Cultivated peat soils have been reported to produce higher carbon dioxide ($CO_2$) emissions than under natural vegetation (Kasimir-Klemedtsson *et al.,* 1997; FAO 2015). Peat soil plays an important role in the carbon (C) cycle, storing approximately 329 – 525 Gt C globally (Immirzi *et al.,* 1992). The majority of peatlands can be found in temperate and boreal zones, with only ~ 11 % of peatland area found in the tropics (Page *et al.,* 2011). Despite being a geographically smaller area, tropical peatlands have been estimated to store between 15 – 19 % of the total peat carbon budget (Page *et al.,* 2011). According to FAOSTAT, during 1990 – 2012 tropical peats produced 45.5 % of the $CO_2$eq emissions associated with cultivated peat soils (FAO 2015). It is therefore important to consider the different sources of $CO_2$ in agricultural peat soils in order to minimise $CO_2$ emissions.

Agricultural cultivation of peat soils can produce $CO_2$ emissions due to increased peat oxidation if the water table depth is artificially lowered (Kasimir-Klemedtsson *et al.,* 1997; Jauhiainen *et al.,* 2005; Hirano *et al*., 2009; Hooijer *et al.,* 2012). This is due to increasing the volume of peat available for microbial communities to decompose. Some estimates of peat oxidation rates from temperate cultivated peat soils have been found between the ranges of 1 and 40.3 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$ (Kasimir-Klemedtsson *et al.,* 1997; Schils *et al.,* 2008). The range of peat oxidation rates estimated from cultivated tropical peat soils is between 7 and 100 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$ (Melling *et al.,* 2005, 2013; Farmer *et al*., 2014; Dariah *et al*., 2013; Hooijer *et al.,* 2012; Jauhiainen *et al.,* 2012). This large range of values is in part due to environmental variations at the time of measurement, such as different water table depths. However it may also be due to differences in sampling strategy.

It can be very difficult to determine rates of peat oxidation, due to other sources of $CO_2$ confounding measurements. For example, taking measurements of soil respiration not only provides rates of peat oxidation, but also includes root respiration and mycorrhizal respiration. Different methods have been developed to partition out peat oxidation rates, including creating root-free soil zones with root exclusion collars, or using C isotope analysis. Unfortunately, these methods are not always practical. For instance, root exclusion collars can alter the soil bulk density when they are installed, and have been found to have an altered water balance due to both the absence of roots and the collar acting as a barrier for drainage, and isotope analysis can be expensive.

Plantations offer a unique opportunity for partitioning peat oxidation rates from soil respiration. Due to the crops being planted strictly in ordered rows, root density would be expected to vary considerably within the plantation. Therefore it may be possible to determine rates of peat oxidation from ‗root-free' soil zones. Once soil

respiration has been effectively partitioned into autotrophic respiration and peat oxidation, it is then possible to consider how plantation management can impact peat oxidation rates.

This work aims to consider the spatial variation of both soil respiration fluxes and root biomass in an oil palm plantation on peat soil. The distribution of root biomass will be used to partition out autotrophic and peat oxidation rates from soil respiration. Soil respiration will be estimated at plot level using area-weighted up-scaling to accurately estimate the $CO_2$ footprint from oil palm plantations.

## METHODS

The study sites for this project were two oil palm estates near Bintulu, Malaysia. The palms were six years old when the study began.

To understand the spatial dynamics in soil respiration, six palms were considered for analysis within a 1 ha plot. Soil respiration measurements were made using an EGM-4 (PP systems). Soil respiration measurements were made at 11 distances away from the palm, along three transects through different land use microforms (harvest path, frond pile and cover crop). Soil respiration measurements were also made at 4.5 m from the palm, in the middle of three palms.

Soil cores of 10 cm diameter by 30 cm were extracted directly below where the soil respiration measurements had been taken. Roots were separated from the soil using the method of Metcalfe *et al.* (2008). Here roots were collected in 10 minute intervals for 50 minutes. The cumulative root masses were extrapolated using log fits and total estimates of root mass were considered at 24 hours – under the assumption that all of the roots would have been collected by then if they had been picked manually for 24 hours.

Soil respiration and root density were considered at different distances from the palm. The relationship between root density and soil respiration was used to estimate peat oxidation fluxes. Soil respiration measurements were also scaled up to plot level using area weighted up-scaling techniques.

## RESULTS

Initial analyses have shown that soil respiration fluxes were greater by the palm and lower further away from the palm (Figure 1). Very high variations in soil respiration estimates were seen between 0 and 1.5 m from the palm.

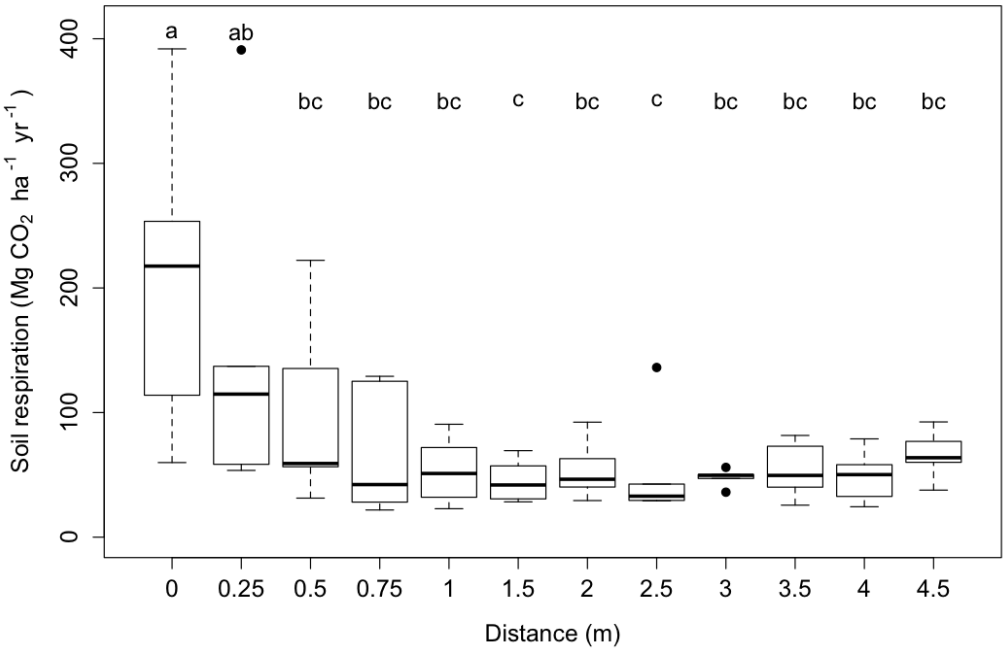


Figure 1: Soil respiration at increasing distances from the oil palm

Similarly, root biomass showed considerable spatial variation within oil palm plantations (Figure 2). Here very high and variable estimates of root biomass were present next to the palm and much lower estimates of root biomass were found further than 1.5 m from the palm. Roots were always present in the soil.

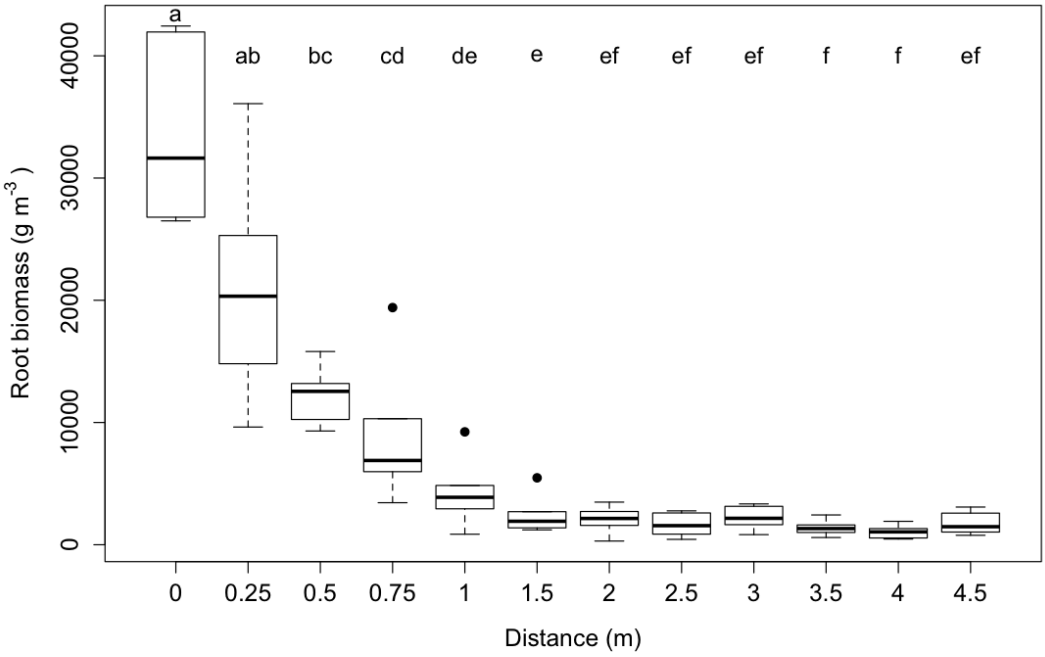


Figure 2: Root biomass at increasing distances from the oil palm.

Peat oxidation was estimated between 26.54 and 52.09 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$ using linear interpolation of soil respiration against root biomass. Area-weighted up scaling estimated total soil respiration to be 76.23 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$ at plot level, giving estimates of autotrophic respiration between 24.14 and 49.69 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$. Soil respiration estimates varied significantly depending surface microform with much greater estimates in the cover crops than either the harvest path or under the frond pile.

## DISCUSSION

Soil respiration fluxes vary considerably in oil palm plantations on peat soil, which can make determining rates of total soil respiration and peat oxidation difficult, in part due to the need for large sample sizes for accurate measurements. Preliminary data presented here shows a high range in total soil respiration fluxes both at different distances from the palm, and within each distance class. The spatial variation of root biomass, also presented here, can be used to explain some of the variation in total soil respiration, as large soil respiration fluxes were present next to the palm where the majority of the roots can be found, and lower soil respiration fluxes were measured further away from the palm where the lowest root biomass estimates were measured. It is therefore important to consider distance from palm as a factor when sampling for total soil respiration, peat oxidation or autotrophic respiration from plantations.

Peat oxidation rates of 26.54 and 52.09 Mg $CO_2$ $ha^{-1}$ $yr^{-1}$ presented in this study fall within the range of measurements determined by Melling *et al.* (2005; 2013), Dariah *et al.* (2013) and Farmer *et al.* (2014) but are lower than estimates by Hooijer *et al.* (2012). The water table depth at the time of measurement for this study was 0.35 cm, whereas the water table depth at the time of study for Hooijer *et al.* (2012) was 0.73 cm The lower estimate presented in this study may be due to a lower water table depth and thus a smaller volume of soil available for bacteria to oxidise.

Surface microform also showed a difference in soil respiration rates, with more respiration being present in the cover crop area than the bare harvest path. The frond piles also had slightly more soil respiration than the harvest path. This increase in soil respiration may be due to increased carbon inputs from the live vegetation and decomposing fronds and not from increased rates of decomposition. Surface vegetation protects peat and prevents peat oxidation, so it is not advisable to remove the vegetation in order to reduce carbon emissions (Dawson and Smith 2007).

## CONCLUSIONS

Soil respiration has been shown to have high but systematic variation in oil palm plantations on peat soil. It is therefore possible to use the planting scheme to engineer experiments that naturally partition total soil respiration into autotrophic and heterotrophic components, based on the variability in root density and therefore autotrophic respiration. We recommend that future studies consider the distance from palm in sampling designs in order to accurately represent areas of high and low root biomass.

Similarly, total soil respiration varies in the different surface microforms, due to carbon inputs from living vegetation. In order to accurately represent total soil respiration in plantations, these microforms need to be considered, to take the carbon fluxes from decomposing shrubby vegetation or old fronds into account.

**ACKNOWLEDGEMENTS**

I would like to acknowledge the Malaysian Palm Oil Board, Sarawak Oil Palm Berhad and the Natural Environment Research Council, UK, for providing the funding for this project.

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