Extended abstract No. 16

ASSESSING THE EMPIRICAL BASIS OF PEAT CO_2 EMISSIONS ESTIMATES FROM OIL PALM PLANTATIONS ON TROPICAL PEATLAND

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SUMMARY

This presentation reports the results of a desk-based study aiming to assess the empirical basis of peat surface CO_2 emissions from oil palm plantations on tropical peatland in Southeast Asia. We reviewed the literature to determine a best estimate of CO_2 losses from drained peat under oil palm cultivation. Our review indicates that previous assessment of CO_2 emissions from oil palm plantations lack a robust empirical basis and have systematically underestimated CO_2 losses resulting from drainage and peat degradation. On the basis of the review, we present a revised estimate and uncertainty range for peat CO_2 emissions from oil palm plantations.

KEY WORDS: Palm oil, Southeast Asia, carbon, greenhouse gas, literature review

INTRODUCTION

Increase in palm oil production has been a key factor in meeting the rising international demand for vegetable oil (Carter et al., 2007). In recent years, palm oil has found a new market as a biofuel feedstock because an increasing number of governments are adopting mandates for biofuel (e.g. biodiesel) for greenhouse gas mitigation (Laborde, 2011; Marelli et al., 2011). Expansion in global palm oil production, led primarily by Indonesia and Malaysia, has been accompanied by rising concern over the impact of the palm oil business on tropical forests and peat swamp forests in particular (Fargione et al., 2008). Indonesia and Malaysia currently meet more than 85% of global palm oil production. In both of these countries, the increasing global demand for biofuels is accelerating rates of oil palm plantation encroachment into peatland areas (Fargione et al., 2008; Miettinen *et al*., 2012).

Tropical peat swamp forests are one of the Earth's densest carbon sinks and largest repositories of terrestrial organic carbon (Page et al., 2011b). In natural peat swamp forest, peat (and carbon) have accumulated over millennial timescales owing to a positive net imbalance between high rates of tropical primary production and reduced rates of organic matter breakdown in permanently saturated soil conditions (Hooijer et al., 2010). The establishment of oil palm plantations on tropical peatland requires replacement of native vegetation and drainage to meet agronomical requirements of the oil palm crop. Whilst carbon losses from land clearance and biomass replacement are substantial, transfers of previously stable peat carbon to the atmosphere in the form of CO_2 following drainage are increasingly recognised as a major driver of atmospheric carbon loading and anthropogenically driven climate change (Hooijer et al., 2010). In the case of palm oil derived biofuels, recent life cycle analyses have indicated that CO_2 emissions from degrading peat lead to biofuel carbon debts repayable at centennial timeframes or longer (Fargione et al., 2008; Gibbs et al., 2008; Wicke et al., 2008). Despite this, some authors have suggested that estimates of CO_2 emission from drained peat may have been underestimated (e.g. Edwards et al., 2010).

We present new findings, based on a review of the literature, of peat surface CO_2 emissions from oil palm plantations on tropical peatland (Page et al., 2011a). The review was conducted on behalf of the International Council on Clean Transportation (ICCT) and aimed to provide guidance to economic modellers on the most appropriate value and uncertainty range for representing drainage-related CO_2 emissions for use in assessments of indirect land use change (iLUC) and the carbon intensity of biofuel consumption (e.g. Al-Riffai et al., 2010; Edwards et al., 2010; Laborde, 2011). The objectives were to: (i) review and assess the current state of knowledge of rates of CO_2 (and other greenhouse gas) emissions from peatland used for oil palm plantations in Southeast Asia; and (ii) to derive a best estimate and uncertainty range for these emissions.

MATERIAL AND METHODS

We conducted a review of the available literature pertaining to carbon and greenhouse gas emissions from oil palm plantations on peatland in Southeast Asia (Page et al., 2011a). In the first stage of the assessment, we identified a number of publications reporting estimates of total losses of carbon from palm oil plantations on peatland. To assess the empirical basis of the values used to represent CO_2 emissions from drained peat, we traced CO_2 emissions estimates back to source publications and mapped connections between these and subsequent articles. We also identified a number of more recent publications providing empirical estimates of CO_2 loss. We aimed to assess the empirical foundations, accuracy and validity of these estimates by evaluating the approaches and methodologies employed in obtaining them.

RESULTS AND DISCUSSION

A number of previous assessments of carbon and greenhouse gas emissions from oil palm plantations on peatland were identified. These differed in scope, some addressing only emissions relating to land use (Germer & Sauerborn, 2008; Murdiyarso et al., 2010), while others quantified life-cycle emissions from the entire palm oil biofuel production-transport-consumption chain (Fargione et al., 2008; Gibbs et al., 2008; Reijnders & Huijbregts, 2008; Wicke et al., 2008; Danielson et al., 2009; Edwards et al., 2010). In all cases, large and sustained emissions from drained peat were identified as the primary factor leading to large-scale CO_2 emissions and long-term biofuel carbon debts. The values used to represent peat CO_2 emissions ranged from 19 to 57 Mg CO_2 ha^{-1} yr^{-1}. Our study found that the majority of these CO_2 emissions estimates were drawn from a restricted pool of observational studies. In many cases, estimates were obtained by calculating the average of a combination of the results of disparate empirical studies with IPCC (2006) defaults for agriculture (73 Mg CO_2 ha^{-1} yr^{-1}) or managed forests (5 Mg CO_2 ha^{-1} yr^{-1}) on tropical organic soils (Fargione et al., 2008; Wicke et al., 2008; Edwards et al., 2010). The small number of observational studies encountered in this review included closed chamber measurements of CO_2 (and other GHGs) and, to a lesser extent, subsidence monitoring.

The majority of previous assessments included estimates of peat CO_2 loss in less than six studies of closed chamber measurements (some of which were not obtained in oil palm plantations). In most cases, these studies reported undifferentiated (e.g. total soil respiration) CO_2 loss that varied greatly from less than 30 to over 100 Mg CO_2 ha^{-1} yr^{-1}. The few studies of differentiated emissions ranged from 40 to 94 Mg CO_2 ha^{-1} yr^{-1} (Couwenberg et al., 2010; Jauhiainen et al., 2012). Closed chamber measurements have not been conducted at an adequate spatial or temporal frequency to provide reliable annual flux estimates or uncertainty ranges (e.g. Murayama & Bakar, 1996; Melling et al., 2005). Daily, seasonal and annual variations in CO_2 emissions have not been addressed systematically and are biased towards certain parts of the diurnal cycle (e.g. Melling et al., 2005). The majority of chamber measurements have been conducted at only a few locations across Southeast Asia and do not account for local and regional variation in biophysical conditions (e.g. regional variation in rainfall). Furthermore, studies typically do not provide detailed descriptions of site conditions (e.g. peat thickness, land use history, fertilisation, drainage depth) or measurement locations (e.g. microtopography, distance from plantation trees, location on peat domes) precluding reliable assessments of the spatial representativeness of flux measurement sites.

Estimates of CO_2 loss based on subsidence monitoring have not been widely used in previous assessments of carbon loss from oil palm plantations. Given the limitations in the majority of closed chamber studies, subsidence measurements (reported as CO_2 equivalents) provide a more robust means of assessing carbon losses from drained peat. Subsidence based estimates are in the range 45 to 135 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} for drainage depths of 0.5 m and 1.0 m (Couwenberg et al., 2010; Hooijer et al., 2010). At optimal plantation drainage depths of 0.6 to 0.8 m, losses are between 54 to 115 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} (Couwenberg et al., 2010; Hooijer et al., 2010). The range is based on assumptions of peat bulk density and carbon content, and the amount of subsidence attributed to peat oxidation. The lower estimates are based on oxidation rates of 40 to 60% (Couwenberg et al., 2010), but more comprehensive and recent assessments indicate oxidation rates in the longer term may account for around 90% of observed subsidence (Stephens et al. 1984; Hooijer et al., 2012). Similar to closed chamber measurements, the majority of subsidence studies have been based on a relatively small number of measurements made at a few locations. A recent exception to this is a study by Hooijer et al. (2012) which combined bulk density profiles with subsidence measurements made at over 200 locations across peat domes. This study estimates losses of 86 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} over a fifty year period, and is the only published estimate to explicitly account for higher rates of CO_2 loss during the early stages of drainage. The results of this study are further supported by extensive closed chamber measurements (>2300) obtained within the same plantation landscape (Jauhiainen et al., 2012).

CONCLUSION

Our review suggests that the values used to represent peat CO_2 in previous assessments lack a reliable empirical basis. We conclude that values of 86 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} (based on a 50 year amortisation period) or 100 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} (assuming a 25 year amortisation period) represent the most robust presently available empirical estimates of CO_2 loss from drained peat under oil palm cultivation (Hooijer et al. 2012). We suggest that future assessments should adopt an uncertainty range of 54 to 115 Mg $CO_{2\text{-}e}$ ha^{-1} yr^{-1} for optimal plantation drainage depths of 0.6 to 0.8 m. We note that these values do not account for regional variations in key biophysical or local factors influencing CO_2 emissions. However, adoption of the best estimate and uncertainty range suggested here will reduce uncertainty in future assessments. Our revised estimate of CO_2 loss from drained peat suggests that a dependency on a limited pool of flux measurements has led to systematic underestimation of CO_2 emissions from oil palm plantations in previous assessments. Our findings indicate that biofuel carbon debts are likely to be significantly larger than previously assumed when palm oil feedstocks are produced on tropical peatland.

ACKNOWLEDGEMENTS

This research was funded by the International Council on Clean Transportation (ICCT), Washington DC, USA. We acknowledge contributions from Dr Stephanie Searle (ICCT) and Mrs Tina Godfrey (University of Leicester).

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