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DEVELOPING CARBON SEQUESTRATION MODEL FOR INDONESIAN PEAT SWAMP FORESTS USING SOIL AND BIOMASS CARBON STOCK AS PROXY: OPTIONS AND OPPORTUNITIES FOR PEATLAND MAPPING AND CARBON TRADING IN INDONESIA

Syed Aziz Ur Rehman[1], Wahid Ullah[2], Muhammad Khurshid[3]

[1]Department of Soil Sciences and Land Resources, Bogor Agricultural University, Bogor, Indonesia
[2]Department of Natural Resources and Environmental management, Bogor Agricultural University, Bogor, Indonesia
[3]Department of Environmental Sciences, University of Peshawar, Peshawar, Pakistan

E-mail of Corresponding Author: syedaziz88@gmail.com

ABSTRACT

Peat C loss in Indonesia has never been estimated using the C stock change method in a synchronic experiment because of difficulty in Identifying an after-Land Use Change (LUC) location with an initial peat depth similar to that of the before-LUC location due to substantial spatial variability of peat depth, lack of maps locating the position of peat domes and sporadic presence of pristine peatlands at close distance to converted lands. Nevertheless, indirect methods so-called proxy variables or "proxies" can be used for assessing the emission reduction and establishing carbon sequestration scenarios. The vegetation proxy approach provides the basis for peatland GHG accounting which covers all main factors that determines ecosystem level carbon dynamics. Therefore we recommend carbon stocks in soil and biomass as a proxy tool for developing carbon sequestration model which is a more conservative approach, easily adaptable and having other associated benefits like resource inventory and national level peat swamp forest (PSF) mapping. This can be done for both PSF already converted and also for developing carbon markets and climate change mitigation scenarios in future. This involves a synchronic experiment of carbon stock determination and comparison by taking PSF-vegetation and soil in intact-state versus any land uses in post-converted statuses. This methodology disregards the debate of separating heterotrophic and autotrophic respiration and instrumental shortcomings for flux measurement; instead the net CO_2 emission overtime time can be estimated as the difference of carbon stocks in land units with similar permanent soil characteristics but different management interventions today.

Keywords: Carbon Sequestration, Carbon trading, GHG Fluxes, Land use change, Modelling, Proxy, Tropical Peat Swamp Forests

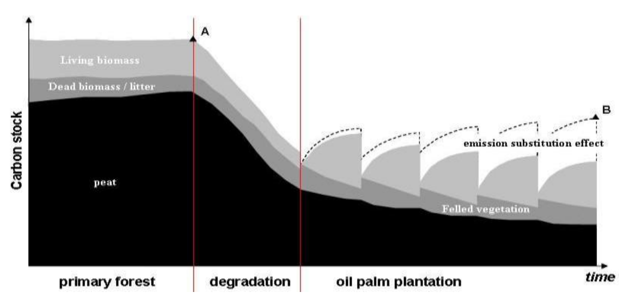
INTRODUCTION

Globally, peatlands cover an area of 400 million hectare, equivalent to 3% of the Earth's land area and storing terrestrial carbon, as much as 528 Pg or one-third of global soil carbon (Murdiyarso., *et al.* 2010). The tropical peatland area is 439,238 km^2 (~11% of global peatland area) of which 247,778 km^2 (57%) is in Southeast Asia. A single country, Indonesia, holds the largest share (57.4 Gt, 65%) (Page. *et al.* 2011), approximately

21Mha, distributed mainly in Sumatra (7.2Mha), Kalimantan (5.8Mha) and Papua (8.0Mha) (Murdiyarso., *et al* 2008). Peatlands provide many important ecosystem services, including water regulation, biodiversity conservation, (Murdiyarso., *et al* 2005) and carbon sequestration and storage (Page., *et al* 2004).Any change to the natural balance between water, soil and vegetation will result in GHG emissions (Joosten., *et al* 2012).

The most rapid degradation of tropical peatland is currently taking place in Southeast Asia where there are strong economic and social pressures for timber, land for agriculture and plantations of oil palm and pulp trees (Koh *et al.*, 2009, Hooijer., *et al* 2010,). Thus currently prominent land uses on organic wetland soils include agriculture (oil palm, rice, sago palm and vegetable crops), silviculture (timber estates, rubber plantations) and aquaculture (shrimp and fish ponds; largely confined to converted mangroves) (Murdiyarso, *et al* 2012). Since 1990, 5.1 Mha of the total 15.5 Mha of peatland in Peninsular Malaysia and the islands of Borneo and Sumatra has been deforested, drained (Hooijer., *et al* 2010) and burned while most of the remainder has been logged intensively (Jauhiainen., *et al.* 2012). Thus these ecosystems no longer are functioning as C-accumulating systems. Anthropogenic activity is the principal cause of this shift (Jaenicke., *et al* 2008), although longer-term climate induced changes are also important in some locations (Miettinen., *et al* 2010), resulting in net carbon flux to the atmosphere and loss of carbon sequestration function (Page ., *et al* 2010).

The mean rate of peat C loss associated with oil-palm cultivation (5.2 Mg of C per hectare per year) is more than 7 times that of peat C accumulation rate in the forest which demonstrates how fast and intensively LUCC in tropical peatlands may affect the C cycle (Murdiyarso., et al 2010). Losses from the biomass amounted to be 158 Mg C ha^{-1} whereas those from the peat reached 270 Mg C ha^{-1} over 25 years (see Fig. 1), which is the rotation period of an oil palm plantation .(Verchot., *et al* 2012). Belowground carbon pools of tropical wetlands are quite high (Warren., *et al* 2012) and therefore peat C loss associated with LUCC (249.9 Mg of C per hectare over 25 y) is greater than C loss from the change in aboveground biomass C stocks. However, peat losses will not cease after this period and will persist as long as management promotes organic matter oxidation. Additionally, the mineral contact beneath the peat is not always regular. Thus, calculating both the volume and the carbon density of tropical peat is often not possible without very intensive measurements at each site (Murdiyarso., et al 2010).While the links between peatland utilization and CO_2 emission are relatively well established for temperate and boreal peatlands there is relatively little information on CO_2 emission from drained peatlands in the tropics (Hooijer., *et al* 2010).



(Fig. 1) Aggregate emission substitution consequence(dashedline) while conversion from primary peat forest through adegradation anddrainage phase in five alternations ofoilpalm, showing temporal evolution ofon-sitecarbon stock sinliving biomass (palegrey), dead biomass(darkgrey), and peat (black); the Carbonstor edinlogged timber andharvested product sarenot integrated as these are isolated from the site.

Proxy analysis for carbon sequestration in Peat Swamp Forests

To be able to determine the carbon-effects of conversion of the peat swamp forests, it is crucial to quantify the carbon content and carbon dynamics of these forests and to combine that with data on the status of the peat swamp forests that remain today (Verwer., *et al* 2010).An accurate assessment of soil carbon stock changes following land use change requires carbon stock measurements over the full depth of the peat profile, because changes occur at greater depths in drained soils; losses are not limited to the top 30 cm as they are in mineral soils (Verchot., *et al* 2012). There is a pressing need for accurate C assessments in tropical wetland ecosystems to establish baseline C stocks, and real and potential C losses from disturbance (Warren. *et al* 2012). Thus scientists believe that an improved understanding of the magnitude of the tropical peatland carbon store is now essential given the current interest in: (1) Emissions of greenhouse gases (GHGs) from drained and degrading tropical peatlands.(2) The role that tropical peatlands could play in carbon offset and carbon trading agreements (Page., et al 2007., Page., *et al* 2011). Standardized methods and protocols are needed for effective monitoring, reporting and verification of emissions from land use and land cover change in tropical wetlands (Murdiyarso. *et al* 2011).

Carbon emissions from LUC can be estimated by quantifying either the changes in C stocks or the changes in C fluxes (IPCC 2006). Both approaches can be applied diachronically (measurement at two points in time, at least, at one site being converted during the monitoring period) or synchronically (measurement at the same time in at least two sites, which have the same initial state). Diachronic experiments are generally opportunistic and rare because they require a long period of field observation. Synchronic experiments are far more common and are classically applied for estimating biomass C stock changes. A synchronic assessment of peat C loss uses the stock change method i.e. by calculating the difference of stocks before and after LUC, requires C stocks measurements over the full depth of the peat profile.

Peat C loss in SEA has never been estimated using the C stock change method in a synchronic experiment. Identifying an after-LUC location with an initial peat depth similar to that of the before-LUC location is nearly impossible due to the substantial spatial variability of peat depth, the lack of maps locating the position of peat domes, and the sporadic presence of pristine peatlands at close distance to converted lands (Hergoualc'h *et al* 2013). Indeed, adequate techniques exist to measure these fluxes in detail, but these are generally too complex and too expensive for widespread monitoring. Therefore, indirect methods via so-called proxy variables or "proxies" are used for assessing the emission reduction (Joosten and Couwenberg, 2009).

Also in climate politics the most important variables GHG fluxes are often addressed via proxies i.e. carbon *stock change*. We can use carbon stock changes to estimate CO_2 fluxes from vegetated land, where simultaneous uptake of CO_2 by photosynthesis and emission of CO_2 by respiration of plants, animals, and microbes make assessing net CO_2 fluxes complicated. Instead of measuring all fluxes to and fro, it is simpler to determine the change in carbon stock, which integrates all fluxes over longer time. Whereas carbon stock change can thus be seen as a proxy for CO_2 fluxes, the stocks themselves are also not directly assessed e.g. using allometry and regression equations. Further in forests we estimate the average increase in wood volume (m^3/ha/yr), multiply by the average C- content of wood and use the C-to-CO_2 conversion factor of 44/12 to estimate the volume of sequestered CO_2 (ton/ha/year) (Joosten., *et al* 2009). Thus vegetation proxy approach may provide the basis for peatland GHG accounting (Worrall, *et al* 2010); and according to Couwenberg., *et al* 2011, vegetation seems to be well qualified for indicating GHG fluxes because:

- It is a good indicator of water level, which in turn strongly correlates with GHG fluxes

- It is controlled by various other site factors that determine GHG emissions from peatlands such as nutrient availability, soil reaction (pH) and land use (history)
- It is itself directly and indirectly responsible for the predominant part of the GHG emissions by regulating CO_2 exchange, by supplying organic matter (including root exudates) for CO_2 and CH_4 formation, by reducing peat moisture and by providing possible bypasses for methane fluxes via aerenchyma 'shunt species'
- It reflects long-time water level conditions and thus provides indication of average GHG fluxes on an annual time scale
- It allows for fine-scaled mapping, e.g. on scales 1:2,500–1:10,000

Options and Opportunities for Carbon trading in Tropical Peat Swamp forests of Indonesia

Indonesia is one of the greatest emitters of GHGs in the world, with about 80% of national emissions coming from land use and land use change. Recent estimates suggest that carbon loss associated with the conversion of peat swamp forest to oil palm plantation contributes more than 63% to total losses.(Verchot., *et al* 2012). In 1981, "planned deforestation" in Indonesia was legislated; involving 30 Mha of conversion forests. In addition to plantation forests, most of the conversions were allocated for agricultural land development, such as oil palm. Furthermore, in early 2009, the government of Indonesia issued a regulation that allows the development of oil-palm plantations in peatlands with peat depth less than 3 m, which could potentially trigger further deforestation and peatlands degradation (Murdiyarso, *et al* 2010).

In September 2011, Indonesia issued a presidential decree on land-based NAMAs (Nationally Appropriate Mitigation Actions) combining REDD+, peatland emission reductions, restocking of above- and below-ground carbon pools regardless of forest/non-forest status of the land, and reduction of CH_4 and N_20 emissions from agriculture (Presidential Decree No. 61 of 2011). This likely makes Indonesia the first Non- Annex-I country in the world to have such a holistic perspective on emissions from the land based sectors. The presidential decree gives substance to the country's NAMA commitments to reduce its 2020 emissions by 26 percent. Within 12 months of issuance, all districts and cities (more than 400 in total) are meant to provide their own action plans within the sectoral priorities that were established at the national scale (Joosten., *et al* 2012).

From 2013 onwards, coinciding with the second commitment period of the Kyoto Protocol, Annex I Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are given the opportunity to account for GHG emissions by sources and removals by sinks resulting from "Wetland Drainage and Rewetting" (WDR) under Article 3.4 of the Kyoto Protocol. This means that Annex I countries can use peatland rewetting to meet their emissions reduction targets (Joosten., *et al* 2012). Peat-land restoration usually involves techniques to stabilize eroding surfaces, re-establish a suitable vegetation cover and raise and stabilize the water table, and hence encourage waterlogged conditions and wetland vegetation that will enable peat to form again (Worrall, *et al* 2011). In Indonesia Forested wetlands, such as floodplain forests, peatland forests and mangrove forests are thus eligible sites for emission reduction projects because they meet the forest definition requirements given in Intergovernmental Panel on Climate Change IPCC guidelines (VCS., 2013).

Alternative income sources from peatlands can involve a variety of options, including carbon trading, water, biodiversity and tourism. Oil palm, pulp or rubber plantations could, under certain conditions, help to promote sustainable development of deforested and degraded peatland areas but, in view of the related CO_2 emissions, such development should preferably be contemplated for non-peat areas. There are millions of hectares of *alang-alang* (deforested, abandoned grassland) landscape in Indonesia that could be used for development (Diemont *et al.*, 2001). For large scale developers these areas pose significant constraints as they are already under tenure of local people, and purchasing this land in sufficiently large blocks will bring a variety of administrative nightmares and headaches (Silvius., *et al* 2007). The country also have some 40 Mha of forestland classified as non-forested or degraded by the Ministry of Forestry. A large portion of degraded lands which are characterized by mineral soils may be allocated for sustainable pulpwood and oil-palm development. Therefore, carbon-rich peatlands can be preserved and targeted for rehabilitation as part of enhancement of sinks activities under variety of carbon trading schemes (Murdiyarso., *et al* 2010).

The economic worth of the baseline and the mitigation activity can be compared by considering the minimum price of carbon at which land owners/decision makers would be indifferent between pursuing the Conversion forever or stop conversion activity, for the lifespan of the mitigation project[1]. To do so, we will determine the Net Present Value (NPV) that will fulfill the condition:

$NPVsce \geq NPVcf$

where:

sce, stop conversion expansion activity

cf, conversion forever activity

Our minimum price of carbon will be that estimated by:

$$p^{c}_{\min} = \frac{NPV_{sce} - NPV_{ce}}{\sum CERs(1+d)^{-t}}$$

Where:

CERs, Certified Emission Reductions[2] (carbon credits = 1 ton of CO_2eq)

d, discount rate in the host country here Indonesia

t, time

[1] The mitigation potential will be a hypothetical estimation putting all the external factors persuasive.

[2] The emission reductions can be CER or Voluntary Carbon credits depending on the nature of the investor.

Thus at local scales with willingness to stop conversion and when emission reduction potential is being calculated carbon trade off schemes can be implemented which will preserve ecosystem resistance and resilience to climate change and can be recommended as cost-effective and ecologically sound adaptation strategies.

CONCLUSION AND RECOMMENDATIONS

It is thus concluded that Converting pristine peat swamp forests ecosystem to agroecosytems and industrial plantation leads to decline in organic carbon stocks both in soil and biomass; and that the net carbon emission during course of time is analogous to the net drop of carbon stocks since the time of logging. Similarly the land units with closest distance to intact peat swamps and permuted land uses have similar ecological conditions in general while topography and hydrology in particular, therefore the fall in the carbon stocks of the transformed loci is a function of human induced activities and time elapsed. Thus we conclude that the proxy based methodology is more reliable and less biased in calculating the site-specific GHG emissions based on the existing carbon stocks and has more conservative approach. Since the land conversion and agriculture expansion in Indonesia is going on with an alarming rate therefore finding virgin peat swamp forests adjacent to plantation and agriculture lands with matching characteristics is challenging. But we recommend proxy analysis to be easily follow-able protocol for determining the GHG emissions that can be adopted by current policy makers and resource managers working on resource mapping, sorting and landuse planning requiring less expertise, low technology and finance. However it is recommended that countries which are less technologically advance shall install permanent sampling plots where diachronic experiments can be performed to have more accurate carbon inventories because in peatlands the large proportion of carbon is stored in soil, which have huge spatial variation even in close proximities therefore in cases where permanent sampling plot and historic data exist proxy analysis is not recommended. Similarly it is further suggested that the field surveys in carbon inventories are inevitable because satellite imageries and remote sensing data can be used only to estimate biomass, but soil properties and peat-land parameters like hydrology and depth are decisive factors and will help in selecting comparable plots for any carbon sequestration project.

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