This document is a useful update of the 2006 IPCC Guidelines and especially the inclusion of supplementary guidance on estimating GHG emissions and removals from drained organic soils. However, opportunities have been missed to include some of the latest research findings in this area in relation to CO_2 emissions from oil palm and pulp tree plantations. It would seem that there is a lack of understanding of peatland and peat-forming processes with a tendency to simplify in some areas and complicate in others.

The introduction (2.1) states that this chapter 'summarizes and harmonizes emissions factors for organic soils in all land use categories" but unfortunately it doesn't assess and harmonize the methods used to obtain primary research data obtained in the field for the essential components of emissions factor calculations. These seem to be taken at face value as if they are all correct and relevant when scrutiny reveals they have been obtained at different periods over at least the last 30 years and carried out on many different geographically separated sites under numerous land uses with different degrees of standardization, replication and computation. Some data are quite obviously incorrect but there has been no quality evaluation. This needs to be carried out before precise emissions factor values can be accepted as reliable.

It is clear that major input to this chapter has been made by some who are not tropical peatland specialists and have not carried out primary field research on this important ecosystem (e.g. CIFOR). One must regard metadata analyses with caution since by definition they are using all data that can be found by trawling the literature whether in peer reviewed publications, official reports or 'grey' literature and of course there is a tendency for the same data to be used in different reviews in different ways.

In terms of the IPCC Guidelines it is important to know what the baseline is in each case. For land remaining in a land use category, which in tropical SE Asia means forest, it is necessary to know if peat is still accumulating (relatively undisturbed and undrained) or not (selectively) or if superficial drainage channels have been constructed that are causing deeper water drawdown, enhanced oxidation and loss of peat and carbon (illegal logging). For land use change to another land use the baseline has to define the starting point, peat swamp forest, degraded forest, deforested land or other.

2.2 Land remaining in a land use category

A peatland can be regarded as a 'dual ecosystem' in which the surface vegetation and the peat below have evolved and co-existed for thousands of years (Rieley, 2007). The plants contribute to the accumulating peat and a 'dynamic equilibrium' is reached under conditions of high rainfall and high water table. The only contact between these two components is the root zone in the uppermost layer of peat which is subject to water level oscillation and experiences alternating aerobic and anaerobic conditions. This zone is known as the acrotelm in boreal and temperate bogs while in tropical peat swamps it is the distance between the peat surface and the lower limit of water table drawdown in the dry season. In both instances it is where much biological activity takes place, especially root (autotrophic) and microbial (heterotrophic) respiration but also nutrient release, recycling and uptake. In boreal and temperate zone bogs the dominant peat formers are species of *Sphagnum* moss together with a range of herbaceous and shrubby plants most of the dead material of which (plant litter), above and below ground, is decomposed although a small proportion may be added to the peat in the catotelm. In tropical peat swamp forests the peat formers are rain forest trees the above ground litter of which is mostly decomposed completely while the main source of organic matter to the peat accumulating in the permanently waterlogged zone below is the fine roots of the trees (Brady, 1997). In all peatlands only a few millimetres or so are added to the peat thickness per year but over a thousand years this can be a metre or so and will continue until the height of the peat dome above the drainage base of the peatland increases and the high water table necessary for peat accumulation can no longer be maintained. This is a natural process and eventually peat bogs will stop accumulating peat and start to degrade. Changes in climate to lower and/or more periodic rainfall will hasten this process. Any impact that affects the hydrology and vegetation on a peatland will disrupt the dynamic equilibrium, stop peat accumulation and speed up degradation and loss of carbon from the long term peat store.

The methodology for determining carbon losses as a result of different logging and timber extraction practices is well defined and should be possible to implement for tropical peat swamp forest as it is for mineral soil forests. What is more difficult is to determine the amount of peat and carbon that is lost through peat decomposition under different degrees of forest degradation. Current CO_2 emission measurement techniques can only determine total emissions (autotrophic plus heterotrophic) from the peat surface over relatively small time periods, mostly during a few hours in the middle of the day). These CO_2 emissions are usually much greater than those obtained from the peat surface under other land uses owing to the much larger vegetation biomass of trees and associated shrubs and ground plants. Eddy Covariance techniques are not sufficiently sensitive yet to provide the data required and are obtained from single towers representing vast areas of tropical peatland constructed in gaps made in the canopy. The only way to obtain reliable estimates of peat oxidation/decomposition is to measure peat subsidence using a network of subsidence markers inserted firmly into the mineral substrate underneath the peat deposit. This of course takes labour, money and time! For this category emissions from CH_4 can be regarded as zero and from N_2O as negligible (1.4-3.5% according to Rieley, 2012). In my opinion the inputs from litter can be ignored since this falls onto the surface where it is decomposed quickly and disappears from the system. Larger dead branches and fallen trunks also decompose but over a longer time scale while some of them may eventually become incorporated into the accumulating peat. For the purposes of the IPCC calculations these are irrelevant and only become important once they are incorporated as components of the peat inside the permanently saturated zone. There are also matters concerning POC and DOC Carbon removal in this category that I shall come back to later.

2.3 Land converted to a new land use category

The Chapter 2 (2.2.1: remaining in a land use category) states that it deals with the ‘impacts of drainage and management on CO_2 emissions… primarily by influencing carbon outputs… and thus carbon storage, by affecting heterotrophic respiration…, erosion losses… and loss of DOC…’

In lowland tropical peatland conversion to other managed land uses takes place quickly over a few years and involves deforestation, drainage, fire, water table management at constantly lower levels and periodic cropping or harvesting. In addition, land use change cultivation practices involve removal of vegetation, exposure of the surface peat and replanting at different time intervals from several times a year for arable crops, 6-8 years for paper pulp trees and up to 25 years in the case of oil palms. These different land uses give rise to different rates of peat decomposition and hence CO_2 emissions.

The emission factors provided in this chapter for tropical peatlands converted to a new land use (plantations and croplands) are far too low compared to the values in recent peer reviewed publications (e.g. Hooijer et al, 2012; Jauhiainen et al, 2012).

Table 2.1 Emissions/removal factors for drained organic soils

Since this section (2.2) deals with land remaining in a land use it is unclear why Table 2.1 contains information relating to both LRLUC and LCNLUC (2.3). These should be separated and placed near their respective texts. There should be several emissions factors for Forest Land on peat in the tropics to reflect the different types of impact this ecosystem is subject to (see above). For example, natural peat swamp forest in its most undisturbed condition (no logging or drainage) should be expected to be still peat forming and therefore its net CO_2 emission should be zero (in fact it will be slightly negative to reflect carbon sequestration and peat formation but the IPCC Guidelines ignores this). Emissions from forest land on tropical peat that has been selectively or illegally logged will exhibit positive CO_2 emissions and there are data in the literature to support this except there is a problem to separate autotrophic and heterotrophic respiration.

The emissions factors presented in Table 2.1 for plantation crops of Acacia and oil palm (both are trees by the way and both are harvested) must be a joke since they are far less than any of the peer reviewed credible published data; the former is clear felled every 6 years or so while the latter's fruits are removed throughout each year until it becomes uneconomic and the entire plantation is clear felled. It is strange that no references are listed for any of the tropical peatland land uses and it is shocking that in Appendix 2a.1 where new information is supposed to be presented that Table 2A.4 of emissions factors and uncertainty estimates contains exactly the same values as Table 2.1. None of the new recent information on CO_2 emissions from degraded and managed tropical peatlands has been included.

Values for cropland and shrubland are also too low and simply repeat old default values when new data are available. If shrubland refers to deforested, drained and degraded tropical peatland that is not being used for anything productive so it is subject to continued illegal logging and fire then the value quoted is incorrect by more than a factor of 20 (see for example Rieley & Page, 2008; 2012).

Concerning land converted to a new land use category, in theory the determination of carbon losses (CO_2 emissions) should be more straightforward because the original forest has been removed and the only carbon losses are from the peat which is now subjected to drainage, fire and various management (e.g. cropping, harvesting) practices. The new land use vegetation can be discounted since it is removed periodically according to the cropping/harvesting cycle and makes no inputs to or outputs from the peatland over the lifetime of the crop. By this I mean that at the start of the new land use activity the peatland has been deforested, cleared probably using fire and drained (site preparation) and the CO_2 emissions losses as a result of these procedures should be accounted for (LUC). From this point on we can assume:

1. Arable crops are removed once or more times a year and so their above ground material doesn't add to the peat carbon store; roots are in the aerobic zone above the lowered water table and will decompose more or less completely.
2. Paper pulp trees will be harvested every 6 years or so, the peatland surface will be cleared and prepared for replanting and the procedure will continue for the life of the plantation; leaf litter falling onto the peat surface will be decomposed eventually and will not add to the peat carbon store while roots are within the aerobic drained zone and will be decomposed without adding to the peat below.
3. Oil palm fruits are harvested regularly after an initial growth period of about 5 years until a maximum of about 25 years after planting. During this time the palms accumulate biomass in trunks, leaves and branches but none of these provide permanent long term additions to the carbon stocks above or below ground. Carbon in all parts of the oil palm tree is released and for the purpose of the IPCC Guidelines can be ignored.

In all cases the focus should be on what is happening to the original peat following land use change and the methods used should be simple, reliable and verifiable. Ideally, direct CO_2 emissions measurement data should be used but those in the literature are mostly confusing and unreliable, providing a large range of values whose accuracy and provenance are uncertain. Some of the problems involved are mentioned in the second paragraph in this statement. A major problem has been the difficulty of separating autotrophic and heterotrophic respiration rates and few researchers have managed this successfully. Whilst it is nigh impossible in natural peat swamp forest owing to tree and root densities it is possible in plantations where tree spacing is regular and distance apart is greater. The most detailed and accurate study of heterotrophic respiration at over 2000 locations in an Acacia plantation in which measures were taken to remove any influence of autotrophic vegetation and making correction for lower night time temperature is that of Jauhiainen et al, 2012 who obtained a net CO_2 emissions loss of 80 t $ha^{-1}a^{-1}$. This value incorporates a correction (reduction) for the lower temperature and hence lower rate of peat oxidation at night. This compares favourably with the parallel study of carbon losses using the subsidence method at the same locations in the same plantation by Hooijer et al (2012) that obtained a CO_{2e} emissions loss of 100 t $ha^{-1}a^{-1}$. The larger value from the latter can be explained by the inclusion of POC and DOC losses in water draining from the site that would not be captured in the GHG emissions method.

2.2.1.2 Off-site CO_2 emissions from waterborne carbon losses

The guidance presented for this component is interesting but rather surprising. Most of the carbon that is incorporated into vegetation biomass on peatlands is decomposed *in situ*. Some (most) is released as CO_2 while the remainder is removed off-site in drainage water. This is a natural process and takes place on every peatland in the world. Since at least 90% of annual plant production (perhaps as high as 99%) is transferred from plants to the peat surface as litter (dead parts) and only 10% (as little as 1%) is incorporated into accumulating peat then it is to be expected there is a fairly high POC and DOC loading in drainage streams and rivers. That is why we have blackwater draining from them and this is nothing to do with land use change deforestation and drainage. The baseline for waterborne CO_{2e} emissions therefore should be this high natural output (which may now be impossible since all tropical peat swamps have been impacted to a greater or lesser extent) and the amount included in Table 2.3A for the difference between the natural state and that after and during land use change may well be positive (i.e. less POC and DOC after LUC). The reason for this is that following LUC the plant biomass and litter production may be lower than in the highly stratified natural peat swamp forest and therefore will contribute less after decomposition to waterborne carbon losses. The difference under LUC of course is that the surface peat is now decomposing as it oxidises under a lowered water table regime. Data on waterborne carbon losses are sparse, especially for peatlands converted to arable agriculture and plantations and should be addressed.

CO_2 emissions based on GHG emissions measurements do not include POC and DOC carbon lost in drainage water (e.g. Jauhiainen, 2012) while emissions based on subsidence rates include this component. The IPCC Guidelines need to be clear on which method to use. It would be simpler, and no less accurate, to ignore inputs from litter and fine roots produced by the new vegetation after LUC since these will be decomposed and lost from the system without contributing to permanent carbon stock.

For all LUC categories emissions from CH_4 can be regarded as zero and from N_2O as negligible (0.8-3.4% according to Rieley, 2012).

Appendix 2a.1 Estimation for particulate organic carbon loss from peatlands.

This appendix is confusing because the title only refers to the first three paragraphs and most is concerned with other aspects. From line 869 onwards the text has been transferred virtually intact from Hergoualc'h & Verchot (2011) without much modification. This paper is a review and metadata analysis using methods that are not universally accepted and with results that are disputed. The text contains over simplification of peatland formation, ecology and management and contains many errors and inconsistences. I believe it is a mistake to include it as a template for discussing important issues relevant to IPCC Chapter 2. Instead there should be an independent appraisal carried out by internationally accepted peatland experts with practical experience to resolve problems and suggest ways forward. This appendix, for example, refers to Kool et al (2006) who state that canal construction has led to subsidence of more than 4 metres in a peat dome in Central Kalimantan. The data produced are flawed and do not support the proposition. Just because papers have been peer reviewed and published does not mean their content is accurate and meaningful. Results and conclusions must be reviewed and evaluated by other experts in order to determine their validity or not.

The paper by H&V proposes a system for determining carbon inputs and outputs that is too complex, uncertain and unworkable. It would be better to disregard components that provide carbon that enters the system but leaves it quickly and focus on the carbon stock and losses from it. This would be workable and verifiable. The high degree of uncertainty referred to arises from the inclusion of every piece of data that can be found irrespective of its provenance and reliability. All data should be assessed for consistency of field technique, measurement, standardization and statistical analysis. Unsatisfactory or meaningless data should be excluded and disparate data should not be combined to give meaningless means and standard errors. The individual data sets are not part of a normally distributed continuum and their transformation using metadata analysis or modelling should be treated with caution.

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NB: On a different matter in Chapter 2 concerning Table 2.3 Tier 1 CH_4 emission/removal for drained organic soils in all land use categories it shows an emissions factor of 382 t C $ha^{-1}yr^{-1}$ for peatlands drained for extraction in the temperate zone. I cannot believe this high value and believe it is incorrect. Peat extraction sites are drained and emit some CO_2 but CH_4 is zero or negligible. According to this value methane emission is nearly 200 times greater than carbon dioxide!