

RSPO

Roundtable on Sustainable Palm Oil

GHG emissions from palm oil production

**Literature review and proposals for
amendments of RSPO Principles & Criteria**

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1 Introduction

When the RSPO Principles & Criteria were first agreed in 2005, greenhouse gas (GHG) emissions from palm oil production were not a subject of particular attention within RSPO. Since then, a number of developments have changed this.

Firstly, the attention for climate change in general has increased, and more specifically the contribution of certain land use (changes) to climate change. A report by Delft Hydraulics [9], quantifying GHG emissions from peatlands in Indonesia, has put particular focus on the (perceived) contribution of the palm oil industry to climate change.

Secondly, European governments increasingly request GHG emission information of biofuels placed on the market, including palm oil derived products (e.g. the EC Renewable Energy Directive [12]). In 2005, the biofuel market segment for palm oil was only at the very early stages of its development.

Thirdly, it has become increasingly apparent that there is a relation between the two foregoing developments: additional palm oil demand, i.a. driven by new biofuel markets, increases pressure on land for extension of plantation acreage, which may (indirectly) result in additional GHG emissions from land use change.

Given these recent and ongoing developments, it is clear that sustainability of palm oil production can only be claimed when explicit consideration has been given to aspects of greenhouse gas emissions. GHG emissions shall get a clear position in the RSPO Principles & Criteria. *The central question is: how and to what extent?*

To provide an answer to this question, RSPO in March 2009 have established a Working Group on Greenhouse Gases (GHG Working Group).

The Terms of Reference for the GHG Working Group

In its Terms of Reference for the GHG Working Group, the RSPO Executive Board have specified the background and the objectives:

The GHG Working Group is envisaged to be a short-term, multi-stakeholder expert panel which shall review the current Principles & Criteria in relation to GHG emissions in the production of palm oil and to advise the Executive Board on options for adjustment of the RSPO P&C.

The GHG Working Group is not envisaged to develop a separate certification or auditing scheme, nor should it develop a comprehensive methodology for assessment and monitoring of biomass and GHG emissions from palm oil operations. Rather, the GHG Working Group shall incorporate key features into the existing P&C framework to provide credible proxy measures for GHG emissions, including those originating from above and below-ground carbon pools from natural and anthropogenic land cover types that are converted to oil palm plantations. The proposed changes to the RSPO P&C will enable managers and certifiers to assess GHG emissions associated with the establishment of new plantations, ongoing operations in

plantations and processing facilities, as well as identify lands where new oil palm plantations are inappropriate. While doing so, it will strive to align and coordinate the RSPO P&C for palm oil production with complimentary standards to promote the use of biomass for fuel applications and sustainable forest management.

In detail, the ToR specifies the objectives of the Working Group as follows:

- Review and synthesize relevant information on palm oil production and GHG emissions, particularly related to the development of plantations, but also including plantation operations, industrial processing and the transport of palm oil;
- Identify options for avoiding or mitigating GHG emissions at all stages of the production chain;
- Provide technical guidance and recommendations on how to address GHG emissions from palm oil production and processing within the RSPO Principles & Criteria;
- Provide specific recommendations for modifying of the existing RSPO P&C terminology, in order to establish auditable and achievable indicators for units of certification;
- Coordination with similar certification schemes under development in forestry, agro forestry and biofuels industries;
- Provide objective information from peer-reviewed sources to guide communication related to the sustainability of palm oil in the context of biofuels and bioenergy

The composition of the working group has been detailed in Annex I.

About this document

This document comprises two main elements: Chapter 2 includes the results of the literature review on GHG emissions from palm oil production. Chapter 3 includes the GHG-WG's recommendations for inclusion of GHG emissions in RSPO Principles & Criteria.

Based on the input provided during the public consultation, this document will be amended and elaborated, and ultimately be a background document for the GHG Working Group's recommendations to the RSPO Executive Board.

2 GHG emissions of palm oil production – literature review

2.1 Introduction

2.1.1 Scope of the literature review

Numerous studies have looked into GHG emissions related to the development and operations of oil palm plantations, processing of fresh fruit bunches at palm oil mills, as well as further transport, processing and end-uses of palm oil and palm oil derived products. In the framework of the GHG Working Group, a significant number of studies have been reviewed (Refer to Chapter 4).

The primary objective of the literature review has been to identify major categories of GHG emissions during palm oil production, specify orders of magnitude for these emissions, and highlight any (scientific) (un-)certainties as regards the (level of) GHG emissions from palm oil production. The literature review is meant to provide a solid, objective basis for discussions on how to include GHG emissions in the framework of RSPO Principles & Criteria.

As RSPO Principles & Criteria focus primarily on palm oil production (and do not cover sustainability aspects of further downstream transport and processing of palm oil products) the literature review has concentrated on GHG emissions related to growing oil palms, and processing of FFB in palm oil mills. GHG effects of further downstream transport and processing of palm oil products have not been considered, neither has a full LCA (methodology) for certain end-products been developed.

Both GHG emissions related to operations of existing plantations, as well as emissions related to land use change when developing new plantations, have been considered (refer to 2.2.2 for more details).

2.1.2 Methodology

GHG Working Group members have been asked to submit publications which they thought would be relevant in the framework of the literature review. Additional literature has been collected through internet search and via scientific libraries.

The literature collected and reviewed does not provide full coverage of all existing, potentially relevant, publications. However, we believe that the review covers all relevant issues in relation to GHG emissions from palm oil production, and is a good representation of the different scientific opinions and other views on the subject. This is strengthened by the fact that GHG Working Group members represent various relevant stakeholder groups, and accordingly does the input they provided to the literature review.

The main findings of the literature review have been summarized in this Chapter. Full documents have been made available at www.rspo.org/current_projects/greenhouse_gas_WG.

2.2 Results -qualitatively

2.2.1 Type of documents

The documents reviewed vary considerably in scope and size, and can roughly be categorized as follows:

- Life Cycle Assessments (LCA), to assess the GHG effects of a specific palm oil application, e.g. a well-to-wheel analysis for palm oil biodiesel (Refer e.g. to [32]). This includes also studies which have been carried out for the development of 'CO₂-tools' by various European governments (Refer e.g. to [8], [27], [56], [39]);
- Studies which focus primarily on changes in carbon stocks, when palm oil plantations replace other land uses (Refer e.g. to [9], [22] and [32]);
- Studies which focus on environmental impacts, including GHG emissions, of operations at oil palm plantations and palm oil mills (Refer e.g. to [61]);
- Other studies (Refer e.g. to [19] and [20]).

Studies have been executed by scientists and researchers from various universities, research institutions and consultancy firms, primarily in South-East Asia and Europe. In addition, plantation industries, downstream palm oil processors/users, NGOs and governments, have commissioned and/or executed studies.

2.2.2 Categories of emissions

In literature, GHG emissions from palm oil production have generally been categorised as follows [3], [39], [42]:

1. Emissions arising from operations during oil palm growing and FFB processing, or more precisely:
 - 1a. Emissions related to the use of fossil fuels for plantation internal transport and machinery;
 - 1b. Emissions related to the use of fertilizers;
 - 1c. Emissions related to the use of fuels in the palm oil mill, and the use of palm oil mill by-products;
 - 1d. Emissions from Palm Oil Mill Effluent (POME).
2. Emissions arising from changes in carbon stocks, during the development of new plantations, and during the operations of plantations. This includes in particular changes in aboveground and underground biomass and soil organic matter (including peat).

The first category, emissions from operations, is discussed in Section 2.3. The second category, emissions from changes in carbon stocks, is discussed in Section 2.4.

In addition to the above specified categories of emissions, 'GHG emissions from indirect land use change' are regularly debated in the public domain, particularly in relation to biofuels (refer to Box 1 below). The GHG-WG has acknowledged the relevance of this category of GHG emissions, but has concluded that there is still scientific lack of clarity how GHG emissions from indirect land use change can be quantified, and how they can be dealt with in the framework of a biomass sustainability certification scheme such as RSPO. As the focus here is on emissions which can directly be attributed to the RSPO unit of verification, GHG emissions from indirect land use have not been studied in detail.

The GHG-WG recommends that RSPO will closely follow developments in science and policies towards measuring and attributing GHG emissions from indirect land use change, and reconsider the issue once conclusions have been reached.

Box 1 GHG emissions from indirect land use change

Indirect land use change occurs if the use of palm oil from an established plantation for biofuel purposes leads to an establishment of new plantations on agricultural land. The crops cultivated on that land are 'outcompeted' and subsequently displaced to other areas, i.e. 'leaking' from agricultural land into natural forests, for example. This indirect land use change may result in significant GHG emissions, as a result of changes in carbon stocks.

Policy makers are investigating possibilities to quantify GHG emissions from indirect land use change, and how these shall be included in carbon balance/LCA methodologies. For example, the EU in Article 19.5 of the Renewable Energy Directive [12] states that: *'The Commission shall, by 31 December 2010, submit a report to the European Parliament and to the Council reviewing the impact of indirect land-use change on greenhouse gas emissions and addressing ways to minimize that impact. The report shall, if appropriate, be accompanied by a proposal, based on the best available scientific evidence, containing a concrete methodology for emissions from carbon stock changes caused by indirect land-use changes, ensuring compliance with this Directive, in particular Article 17 (2).'*

2.2.3 Units of calculation

In literature, GHG emissions from palm oil production are either expressed 'per hectare' or 'per tonne CPO/FFB'. A 'per hectare' basis is generally applied for emissions related to land use change and/or change in carbon stocks. A 'per tonne CPO/FFB' basis is generally applied for emissions related to operations at the plantation and mill.

In the literature review, both expressions have been quoted. However, for the purpose of comparing orders of magnitude, emissions 'per hectare' have also been converted to a 'per tonne CPO/FFB' basis. For this conversion, a yield range of 3.2 - 4 tonnes CPO/ha*yr has been applied.

2.3 Emissions arising from operations during oil palm growing and FFB processing

This section discusses emissions arising from operations during oil palm growing and FFB processing:

- Emissions related to the use of fossil fuels for plantation internal transport and machinery (2.3.1);
- Emissions related to the use of fertilizers (2.3.2);
- Emissions related to the use of fuels in the palm oil mill, and the use of palm oil mill by-products (2.3.3);
- Emissions from Palm Oil Mill Effluent (2.3.4).

2.3.1 Emissions related to the use of fossil fuels for plantation internal transport and machinery

Fossil fuel use comprises mainly diesel consumption in agricultural machinery used in nursery, maintenance, harvesting, collection procedures, milling, and other estate internal transport.

Studies vary in the assumptions of how much diesel is required per hectare or per tonne of product.

Nikander [39] has estimated diesel consumption at 58-70 liters per hectare per year, and CO₂-eq emissions at 3.1 kg CO₂-eq per liter diesel, equaling 180-217 kg CO₂-eq/ha*yr.

Damen and Faaij [7] have assumed that all transport within the plantation takes place with 5 tonnes capacity trucks, with a diesel consumption of 1.8 MJ/tkm, and an average distance from harvesting to mill of 10 km (20 ton CO₂-eq/TJ diesel). At their assumed FFB yield of 20 tonnes/ha this leads to a CO₂-eq emission of 36 kg CO₂-eq/ha*yr. This figure only covers FFB transport from harvest to mill.

Wood and Corley [58] have estimated energy use for vehicles and machinery at 4.7 GJ/ha*yr. Assuming a specific emission of 0.086 kg CO₂-eq/MJ diesel, this would however result in an annual emission of 404 kg CO₂-eq/ha*yr.

ERIA [11] have estimated diesel consumption at the plantation stage at 33 liter/ha*yr, for transport from plantation to mill at 1.5 liter per tonne FFB, and at the palm oil mill at 0.45 litre/tonne FFB. The study has assumed an average FFB yield of 19 tonne FFB/ha*yr, so that the overall diesel consumption equals 70 liters per hectare per year. The study has quoted a specific emission of 3.208 kg CO₂-eq/ton diesel, resulting in an emission of 225 kg CO₂-eq/ha*yr.

Conclusion: Based on the literature review, GHG emissions related to the use of diesel plantation internal transport and machinery, are in the order of 180-404 kg CO₂-eq/ha*yr. Based on a yield range of 3.2-4 tonne CPO/ha*yr, GHG emissions per tonne of CPO are in the order of 45-125 kg CO₂.

2.3.2 Emissions related to the use of artificial fertilizers

Common palm oil fertilizer inputs comprise nitrogen fertilizers (either ammonium nitrate, ammonium sulphate, urea and/or ammonium chloride), phosphate rock (P₂O₅), potassium chloride (K₂O) and kieserite (MgO). Literature references on quantities of fertilizer inputs have been summarized in Table 2.1.

Table 2.1 Fertiliser inputs in oil palm plantations, according to various studies.

Input	Damen and Faaij [7]	Corley [5]	Nikander [39]	ERIA [11]
Ammonium nitrate (kg N/ha/yr)	100	-	96-100	93
Ammonium sulphate (kg N/ha/yr)	--	88.2	-	-
Phosphate rock (kg P ₂ O ₅ /ha/yr)	45	34.6	28-45	114
Potassium chloride (kg K ₂ O/ha/yr)	205	252.0	172-205	200
Kieserite (kg MgO/ha/yr)	50	39.2	33-48	27

Chen [4] has, in a LCA study, calculated fertilizer inputs on a per tonne CPO basis. His figures are – converted to a per ha basis- in the same order of magnitude as the figures specified in Table 2.1.

GHG emissions related to the use of fertilizers in palm oil plantations comprise of two elements [7], [10], [11] [39], [42]:

- Emissions which occur during the production and (international) transport of fertilizers, in particular due to the use of fossil fuels. Emissions vary between the type of fertilizers, as well as country and mode of production;
- N₂O emissions which occur during the application of nitrogen fertilizer. According to IPCC guidelines [27] 1% N₂O-N of total N applied is emitted during fertilizer application. The Global Warming Potential of N₂O is 296 times stronger than CO₂.

Nikander [39] has estimated overall greenhouse gas emissions from fertilizer and pesticide use between 1,086 and 1,500 kg CO₂-eq/ha*yr. N₂O emissions during application of nitrogen fertilizer have been calculated at 616 kg CO₂-eq/ha*yr, which amounts to 40-60% of total fertilizer related GHG emissions.

Wijbrans and Van Zutphen [56] have estimated total GHG emissions related to the use of chemical fertilizers at 1,409 kg CO₂-eq/ha*yr.

The default value of the greenhouse gas calculator of the UK Renewable Fuels Agency [42] is also in the range of 1,000 - 1,500 kg CO₂-eq/ha/yr, whereby the exact value depends on the assumptions made as regards exact quantities and type of fertilizers.

ERIA [11] have estimated that overall CO₂-eq emissions related to the use of the fertilizer mix equal 17.3 kg CO₂-eq/tonne FFB or, at 19 tonnes FFB/ha*yr, 330 kg CO₂-eq/ha*yr. From the study, it is not clear why this value is so much lower than those from other references.

Wahid et al. [53] have estimated energy use by fertilizers at 10.25 GJ/ha*yr, but do not specify what this figure exactly includes (production, transport, etc.).

N.B. GHG emissions resulting from the production of pesticides used in palm oil plantations, is generally considered negligible in comparison to the GHG emissions from fertilizers (ref e.g. [37]).

Conclusion: Based on the literature review, GHG emissions related to the use of artificial fertilizers and pesticides, are in the order of 1,000-1.500 kg CO₂-eq/ha/yr. Based on average yields (3.2-4 tonnes CPO/ha*yr), GHG emissions per tonne of CPO are in the order of 250 – 470 kg CO₂-eq/tonne.

2.3.3 Emissions related to the use of fuels in the palm oil mill, and the use palm oil mill by-products (excluding POME)

The milling process requires steam, which is generated in boilers generally fuelled by fiber and shell. As these are both biomass streams, and boiler GHG emissions other than CO₂ are considered negligible, the energy generation process is CO₂-neutral, and largely independent from fossil fuels.

Another solid residue from the palm oil mill are empty fruit bunches (EFB). These can be used as mulch in the plantation, be composted or landfilled, or utilized as a biofuel, each of which has specific GHG emission characteristics.

Application as mulch is currently common practice. Application as mulch has the potential to contribute to GHG emission reduction, as it may reduce the need for artificial fertilizers, improve carbon sequestration in the soil and soil organic matter. However, no quantitative data on GHG effects are available. Like in various studies (e.g. [11], [39], [48]) it is concluded here that application of mulch is carbon neutral.

Landfilling of EFB leads to methane emissions, as a result of anaerobic decomposition processes [41].

GHG emissions of further transport and treatment of palm kernels are not considered here. In LCA methodologies, generally part of the GHG emissions are attributed to by-products produced, refer to Box 2 below. However, as no full LCA is developed, this is considered less relevant here.

Box 2. Allocation of emissions to by-products

The production of Crude Palm Oil involves generation of by-products (PKO, PKM) and residues. In LCA methodologies, it is common to allocate the overall emissions associated with the production of the main product (CPO), between the main product and the by-products. Various allocation methods exist, including:

1. *Allocation by market prices*, i.e. allocation of the emissions proportional to the market prices of the main product and the by-products;
2. *Allocation by energy content*, i.e. allocation of the emissions proportional to the total energy content of the main product and the by-products;
3. *System expansion*. The by-products are included in the project boundary. For each by-product, the baseline production processes are identified. Respectively, the emissions associated with the production of the by-products in the absence of the activity are included in the baseline emissions.
4. *Attributing all emissions to the main product*. As a conservative approach, all emissions from production process are accounted as project emissions where the main product is produced.

In this document, GHG emissions are expressed per tonne CPO, without allocating overall emissions between main product and by-products. As in method 4 above, this is a conservative approach, ignoring the fact that besides CPO other useful products are produced.

Conclusion: Efficient re-use of palm oil mill by-products and residues saves significant quantities of fossil fuels. Based on the literature review, it is assumed that no net GHG emissions arise from the use of fuels in palm oil mills, and from application of the palm oil mill by-products and residues.

2.3.4 Emissions from POME

During the milling process, wastewater is produced, which is generally referred to as palm oil mill effluent (POME). The wastewater is heavily polluted with biodegradable organic material, typically up to 80,000 mg/l COD, and needs treatment prior to discharge.

The most common POME treatment system consists of a pond or lagoon treatment system. The naturally available oxygen in this system is generally insufficient to cater for all aerobic decomposition of the organic material in the wastewater. As a result, the decomposition turns anaerobic, resulting in the production of biogas, which dissolves from the ponds into the atmosphere. POME derived biogas consists for a significant part of methane (CH₄), which represents a substantial GHG emission source. Most studies indicate a typical methane content in biogas of 65% (e.g. [53], [8], [42]). Yacob et al. ([60] and [61]), however, have measured lower methane contents (54% on average), which they attributed to the large variation in chemical properties of POME, and to the lack of operational control of the tanks.

Wijbrans en Van Zutphen [56] have calculated that the POME methane release equals 9 kg/tonne FFB (at 0.7 m³ POME/tonne FFB, 28 m³ biogas/m³ POME and 65% CH₄ in the biogas). This results in considerable extra GHG emissions of 190 kg CO₂-eq per tonne FFB. The figure of 28 m³ CH₄/ m³ POME has also been mentioned by others as a 'common practice' figure (e.g.[8] and [42]).

Nikander [39] has used a POME emissions range of 2,500 - 3,800 kg CO₂-eq/ha*yr.

ERIA [11] has specified a POME generation rate of 0.7m³/tonne FFB, 28 m³ of biogas/tonne of POME (with 65% CH₄), and 19 tonne FFB/ha/yr.

Yacob et al. ([60] and [61]) have calculated a methane emission of 5.5 kg CH₄/tonne POME discharged, equaling, some 9 m³ CH₄/tonne POME. This figure is significantly lower than all other data found in the literature review, and can most likely be attributed to the specific lay out of the treatment system monitored.

In recent years, palm oil mills have applied various technologies to improve the treatment of POME, while also reducing methane emissions. These include technologies for biogas capture, which is subsequently flared, or in some cases converted to electricity/heat for local use. Flaring of biogas, or conversion of biogas to electricity and/or heat, results in conversion of methane to CO₂, which is biogenic: consequently, GHG emissions are reduced with a factor 23. Biogas capture technologies are eligible as CDM project, thus having the potential of generating significant revenues through the sale of carbon credits. The efficiency of GHG emission reduction through biogas capture varies widely ([60] and [61]).

Another option for improved POME treatment is to co-compost the material with EFBs, thus generating a high quality compost with valuable C:N ratio, while also significantly reducing POME discharge. Schuchardt et al. ([46] and [47]) have demonstrated that this technology has the potential to significantly reduce POME quantities, while Lord et al. [34] managed to achieve a zero discharge of POME.

Other technologies which contribute to reducing methane emissions from POME include decanters prior to pond treatment, thus removing a significant amount of suspended solids, as well as denitrification technologies. No literature data have been found on the practical applications and the efficiency of these technologies.

Conclusion: Based on the literature review, GHG emissions from POME, are in the order of 2,500 – 4,000 kg CO₂-eq per ha*yr, or 625 – 1,467 kg CO₂-eq per tonne CPO (based on a yield range of 3.2-4 tonnes CPO/ha).

Various technologies have the potential to significantly reduce methane emissions from POME, including biogas capture, decanters, co-composting with EFB, and denitrification. Emission reduction efficiencies for biogas capture technologies vary considerably in practice. For other technologies, no quantitative data on emission reduction efficiency have been found.

2.4 Emissions arising from changes in carbon stocks

2.4.1 General

This Section reviews emissions arising from changes in carbon stocks, during the development of a new plantation, and during the operations of a plantation. These emissions are in particular related to changes in aboveground and underground biomass, as well as soil organic matter (including peat).

Establishing and operating palm oil plantations may have three different impacts upon aboveground and belowground carbon stocks, namely [27], [19]:

- The establishment of a plantation leads to the removal of originally present aboveground and belowground biomass, e.g. forest, grassland;
- A palm plantation stores carbon through the growth of oil palms;
- Establishing and operating oil palm plantations on peat requires ongoing drainage, thus causing ongoing peat oxidation.

These impacts are discussed separately in Section 2.4.2-2.4.4. Section 2.4.5 discusses the overall effects of palm oil plantations on carbon stocks.

2.4.2 Emissions from removal of aboveground and belowground biomass

This section discusses greenhouse gas emissions which arise when original biomass present on land, is removed to make way for a new oil palm plantation.

The GHG emission which results from changes in aboveground and underground biomass, depends on the original biomass stock present on the land, as well as the question whether original biomass is removed through decomposition, or through burning.

Available literature data concentrate on biomass of intact forests and grasslands. Very limited data have been found on biomass stock of other land cover types typical for areas where oil palm is developed, such as degraded forests, logged over forests, shrub land, etc.

Below, first the typical biomass stock for intact forests and grasslands present in areas suitable for oil palm development are discussed (Section 2.4.2.1 and 2.4.2.2). Secondly, GHG emissions from the removal of these biomass stocks, either through decomposition or burning, are discussed (Section 2.4.2.3 and 2.4.2.4).

N.B. Literature data concentrate on intact primary forests and grasslands. In reality, palm oil in many cases is established on forest lands that have been logged at least once or have been degraded through intensive shifting cultivation or fire. The literature references on carbon stocks quoted here will in many cases be too high, and effectively represent a worst-case scenario. Equally, grasslands may in reality have lower carbon stocks than quoted here, in particular when these grassland are fire dominated.

2.4.2.1 Forest

The quantity of biomass in intact tropical rain forests varies greatly in response to the local environment, whereby the biomass of tropical lowland forests is usually higher than that of upland forests. Germer and Sauerborn [15] have done an extensive review of available data for above ground biomass quantities, and derive a mean value of 295 +/- 152 tonnes/ha for intact tropical lowland forests. This is in line with the IPCC [29] default values for above ground biomass of 225 tonnes/ha in continental Asia, and 275 tonnes/ha in insular Asia.

The belowground biomass is a function of the aboveground biomass, whereby the ratio between the two may vary depending on local circumstances. On the basis of a large number of literature sources, Germer and Sauerborn [15] have derived a mean ratio of 0.18 between aboveground and underground biomass, which is slightly higher than the IPCC [29] default value. Based on the ratio of 0.18, they calculated a mean value for belowground biomass of 47 +/- 26 tonnes/ha.

Based on the above figures, Germer and Sauerborn [15] have calculated the total above and belowground biomass of tropical lowland forests to be 342 +/- 178 tonnes/ha. Based on their assumption that the carbon content of biomass is 50%, which is also in line with the IPCC default value, this equals a carbon stock of 171 +/-89 tonnes/ha.

2.4.2.2 Grassland

The grassland biomass is determined by the floristic composition, precipitation, soil properties, fire, wildlife and other factors. The IPCC [29] default value for above ground biomass on tropical savanna ranges from 4.9 tonnes/ha to 6.6 tonnes/ha, whereby a savanna is defined as 'vegetation formations with a predominantly continuous grass cover'.

A review of literature on typical Imperata grassland in oil palm growing regions reveals an average value for aboveground biomass of 11.2 +/-7.3 tonnes/ha, which is higher than the IPCC range [15]. It is hypothesized that this difference in biomass reflects the usually high soil fertility and favorable rainfall in areas suitable for palm oil production.

No default values for grassland belowground (root) biomass is given in the IPCC reference manual and studies published on grassland root biomass in humid tropics are limited. Germer and Sauerborn [15] have calculated a value for grassland belowground biomass of 15.5 +/-10.1 tonnes/ha.

Germer and Sauerborn [15] have concluded, on the basis of available data, that the biomass of grassland (aboveground and belowground) in oil palm suitable environments is 26.7 +/- 17.4 tonnes/ha. Based on their assumption that the carbon content of biomass in grassland is 43%, this equals a carbon stock of 11.5 +/- 7.5 tonnes/ha.

2.4.2.3 Emission from biomass decomposition

Oil palm plantation establishment requires the removal of the existing forest or grassland plant cover. After clearing, the biomass is, if not burned, broken down by termites, insects and micro-organisms. Decomposition emits the carbon contained in the biomass into the atmosphere as CO₂. A fraction of the carbon is released as methane through the activity of termites. Due to the uncertainty of the effect of clearing on termite populations and associated methane release, no guidance on calculation of this component is included in the IPCC methodology [29].

The CO₂ released by decomposition is estimated as a direct function of biomass volume and carbon content. IPCC [29] have estimated a carbon content of 50% for all carbon stocks. For Imperata cylindrica grassland, additional research has provided a figure of 43% [15].

Decomposition of cleared aboveground biomass and root biomass is a long process. After cutting the vegetation there is an initial rapid loss of easily decomposable root biomass, leaving behind a large fraction of resistant material. Germer and Sauerborn [15] have indicated that exact figures on timelines and percentages decomposed are unknown. However, they assume a complete decay of biomass within a timeframe of 25 years, leading to a total emission from biomass decomposition of 42.0 +/- 27.4 tonnes CO₂-eq/ha grassland, and 627 +/-326.3 tonnes CO₂-eq/ha of forest. These emission figures are equivalent to the removal of a carbon stock of 11.5 +/- 6.7 tonnes C/ha of grassland, and 171 +/- 89 tonnes C/ha of forest.

2.4.2.4 Emissions from biomass burning

Emissions from burning the cleared vegetation depend on the degree of combustion that is achieved, i.e. the proportion of biomass consumed by fire. The IPCC guidelines [29] have stated a default combustion fraction of 50% for cleared forest biomass, while the guidelines also recommend to adjust the value to actual local conditions. Germer and Sauerborn [15] have indicated that as a result of repeated burning, some 40% of the carbon contained in above ground biomass from forest clearing enters the atmosphere through combustion, while the rest is released through decomposition, and also some of the remainder is converted into charcoal.

Grassland aboveground consists mainly of inflammable material, which admits a higher combustion fraction than in forest clearings. The IPCC [29] has recommended general default values in the range from 80% to 85%, if detailed local information is not available.

Germer and Sauerborn [15] have calculated total emissions of aboveground biomass burning and the decay of unburned above and belowground biomass to be 43.5 +/- 28.3 tonnes CO₂-eq per hectare of grassland, and 648.0 +/- 337.2 tonnes CO₂-eq per hectare of forest. These emission figures are equivalent to the removal of a carbon stock of 11.8 +/- 7.7 tonnes C/ha of grassland, and 176 +/-92 tonnes C/ha of forest.

Conclusion: Based on the literature review, GHG emissions from removal of aboveground and underground biomass in intact primary forests are in the order of 635 +/- 330 tonne CO₂-eq/ha. GHG emissions from removal of aboveground and underground biomass in tropical grasslands are in the order of 43 +/-28 tonne CO₂-eq/ha. These figures equal a carbon stock change of 171 +/- 89 tonnes Carbon/ha for intact primary forests, and 11.5 +/- 7.5 tonnes Carbon/ha for grasslands.

2.4.3 Avoided emission through accumulation of biomass at palm oil plantations

Biomass at oil palm plantations can be categorized as follows:

- Aboveground biomass, i.e. the oil palm trees excluding roots;
- Belowground biomass, i.e. the oil palm tree roots;
- Litter from oil palm trees and other vegetation;
- Biomass of ground cover vegetation.

According to [15], the typical biomass accumulation in tree plantations follows a curve of quick initial growth and thereafter a minor increase. A linear equation to calculate the carbon stocks as provided in 'Good Practice Guidance for and use, land use change and forestry' by the IPCC tends to underestimate actual values.

The amount of carbon bound in oil palm plantation biomass is primarily a function of palm growth and the understorey. Published values on the quantity of above ground biomass on oil palm plantations range from 50 tonnes/ha to over 100 tonnes/ha towards the end of the plantations economical live span after 20-25 years.

The root biomass of oil palm increases with the aboveground biomass increase, while its maximum volume depends strongly on soil properties and water availability. Germer and Sauerborn [15] have calculated a time-averaged oil palm root biomass of 20 +/- 5 tonnes/ha.

Biomass of ground cover vegetation decreases with palm growth and heavier shade. Germer and Sauerborn [15] have calculated a time-averaged total ground cover biomass of 2.5 +/- 1.0 tonnes/ha (assuming a fast ground cover establishment with a maximum of 10 tonnes/ha and a linear biomass loss through increased shading to 1 tonne/ha at canopy closure at 5 years after planting).

Based on the above figures, Germer and Sauerborn [15] have calculated a time-averaged total quantity of (above and belowground) biomass in an oil palm plantation of 82.5 +/- 26 tonne/ha. Considering a carbon content of 40.4% for oil palm biomass (Syahrudin, 2005, in [15]) and of

50% for remaining vegetation, both palms and understorey together fix a time averaged quantity 35.3 +/- 11.0 tonne carbon/ hectare within the economic lifespan of oil palm (equaling 129.3 +/- 40.3 tonne CO₂-eq/hectare).

In Figure 1, taken from [15], biomass data from 51 oil palm fields were plotted. Integration of the fitted equation returns a time averaged oil palm *aboveground* biomass of 60 +/- 20 tonnes biomass/ha for 25 years after planting, where the standard deviation is an estimation taking the large variation of the plotted data into account.

Fig. 1 Above ground oil palm biomass – potential vs. linear estimation of time-averaged biomass. The thin solid horizontal line indicates the time-averaged AGB as obtained by integration of the potential curve; the dashed horizontal line represents the time-averaged biomass of the linear curve respectively

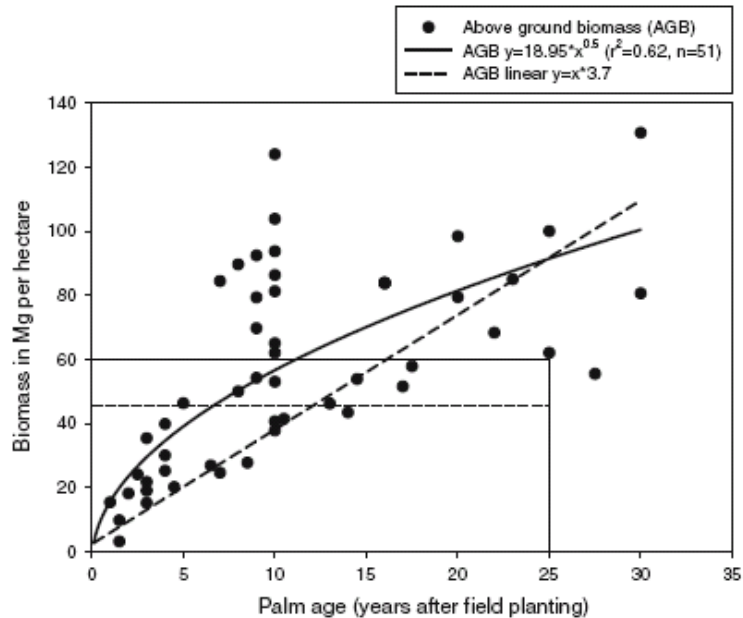


Figure 1. Increase in biomass (tonnes/ha) as a function of palm age [13].

Henson [22] has also quantified carbon sequestration of oil palms in Malaysia. The mean carbon sequestration of an oil palm stand with a 25 year life was found to total 2.09 tonnes carbon/ha/yr (equaling 7.66 tonnes of CO₂-eq), with the oil palms accounting for 80% of the mean carbon storage by the system (and ground cover, litter, and palm products accounting for the remainder 20%). The total carbon accumulated by the palms at the end of the cycle comes to 44 tonnes C/ha. The time averaged in situ standing plantation carbon stock over 30 years was calculated to be 35.4 tonnes/ha, which is similar to the 25 year mean value of 35.3 tonnes carbon/ha for oil palm and understorey determined by Germer and Sauerborn [15], and with a later value by Henson [23] namely 35.87 tonne carbon/ha. Henson has indicated that this figure includes litter in plantations, however that the quantity is generally limited compared to the overall figure (also refer to Table 5 in [25]).

In addition to the above quantified carbon sequestration Henson ([22] and [25]) has identified and quantified other sources of carbon sequestration, including harvested wood products during forest conversion, residues left after palm tree or forest clearing, mill by-product energy generation and mill by-product fertiliser substitution. The potential carbon sequestration has been calculated at 0.615 tonnes/ha*yr. In carbon accounting methodologies [30], only the carbon contained in wood products can be counted as ‘sequestered’, as for the other sources it is assumed that it will be released within a relatively short timeframe (due to consumption or end of life of products).

The time averaged carbon stock of approx. 35 tonnes C/ha, as calculated by various authors using different approaches (see above) is lower than the figure of 55 tonnes C/ha, used by the IPCC as default value. No references have been found as to how the IPCC figure has been derived.

Conclusion: Based on the literature review, the time averaged carbon stock in an oil palm plantation is approximately 35 tonnes carbon/ha, calculated over a 25-30 years standing period. With multiple planting cycles, the time averaged standing stock is expected to remain close to 35 tonnes/ha, as biomass is removed prior to re-planting.

2.4.4 Emissions from peat decomposition

In the past few years, CO₂ emissions from drained peatlands in South-East Asia have been the subject of a fierce debate, which included in particular also the perceived contribution of the palm oil sector. This section summarises scientific certainties and uncertainties as they appear from reviewed international literature.

Box 3. Definitions of peat

There is not one single, agreed definition for peat. M. Mohamed et al. [37] provide the following guidance:

‘Peat in strict definition usually refers to the accumulation of a purely one hundred percent organic material and the distinction between soil and vegetative accumulation is not clear (Andriesse, 1992). Over the years, ‘peat’ has been alternately referred to as ‘organic soils’ and Histosols. Tie (1979) refers to peat as organic soils on the basis of the mass composition i.e. soils that contain at least 65% organic matter or conversely, less than 35% mineral content. The more recent definition of organic soils as adopted by the Soil Division of Sarawak is based on profile partition, i.e. soils that have 50 cm or more organic soil matter within 100 cm or more than twice that of mineral soil materials overlying bedrock within 50 cm (Teng, 1996). On the other hand, USDA defines a soil type as organic soils (or Histosols) if more than half of the upper 80 cm of the soil is organic or if organic soil material of any thickness rests on rock or on fragmented material having interstices filled with organic materials (Soil Survey Staff, 1998)’.

Wetlands International (www.wetlands.org) provides the following definition: ‘Peat is dead organic material that has been formed on the spot. Peat consists of 90% water and 10% plant matter. Peat is formed under conditions where dead plant material is conserved for thousands of years due to a combination of permanent water saturation, low oxygen levels and a high level of acidity. Areas with peat soils are called peatlands’.

And the Peat Society (www.peatociety.org) provides the following definition: ‘Peat is sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material. A peatland is an area with or without vegetation with a naturally accumulated peat layer at the surface’.

Experts agree that in their natural state, tropical peatlands sequester carbon by accumulation in peat and biomass (e.g. [22], [15] and [51]). Drainage and degradation of primary peat forests results in carbon losses mainly through increased decomposition of the peat. Conversion of peatlands to oil palm plantations requires drainage of 60-80 cm below soil surface which thus enhances peat decomposition.

CO₂-emissions increase with drainage depth, with a figure of 9 tonnes of additional CO₂ emission for every extra 10 cm drainage depth quoted by various authors (e.g. [58]). Given the range in data available for overall emissions (see below), this figure is unlikely to be very robust.

Conclusion: Experts agree that in their natural state, tropical peatlands sequester carbon by accumulation in peat and biomass. Drainage and degradation of primary peat forests results in carbon losses mainly through increased decomposition of the peat. Conversion of peatlands to oil palm plantations requires drainage of 60-80 cm below soil surface which thus enhances peat decomposition. CO₂-emissions increase with drainage depth.

The database of CO₂-emission values from drainage and fire is still poor. Most published CO₂ emission data for both intact and damaged peatlands stem from closed chamber measurements

of total (soil) respiration. These measurements cover not only heterotrophic but also autotrophic emissions from the living roots and low vegetation. With the possible exception of some of the measurements of Vasander and Jauhiainen [51] and Melling et al. [35], none of the numerous soil respiration studies from tropical peat soils convincingly manages to exclude autotrophic (root) respiration or short term litter turnover. As the root respiration component may vary between 6 and 67% of the total CO₂ emission from peat soils, these studies are inadequate for determining net emissions from peat oxidation.

Melling et al. [35] have attempted to exclude root respiration by ‘trenching’, i.e. inserting a cylinder into the peat severing roots well before flux measurements and – without indication of drainage depth- arrive at heterotrophic soil flux rates from a 5 year old oil palm plantation of 3.4 – 4.1 kg CO₂/m²*yr. The measurement method (chamber design and sampling method) tends to underestimate CO₂ fluxes by 15-20% [36] or more, however, which means that the actual flux may amount to more than 4.9 kg CO₂/m²*yr.

Other, longer term lifecycle analyses also all arrive at clearly negative values for CO₂ emissions from peat degradation, e.g. 1.8 kg CO₂/m²*yr [15], 3.7-5.5 kg CO₂/m²*annum [41], 3.9 kg CO₂/m²*yr [55], and 5.5-7.3 kg CO₂/m²*yr [13]. Muruyama and Bakar [42] have estimated a CO₂-emissions of oil palm plantations on peat of 54 tonnes CO₂-eq/ha*yr, at 80 cm drainage depth.

Henson [22] has concluded that there is still great uncertainty concerning the magnitude of peat soil carbon emissions and their relationship to drainage intensity and peat subsidence. He cites values of 7.2 tonnes carbon ha/yr [58] and 9.17 tonnes carbon/ha/yr [35]. This equals emissions of approximately 25 to 35 tonnes CO₂-eq/ha*yr.

Conclusion: There is a large variety of quantitative data on CO₂-emissions from drained peatlands, while not all measurement methods applied are reliable in terms of quantifying emission from peat oxidation. Literature data vary between 18 – 73 tonnes CO₂/ha*yr (4.9-19.9 tonnes carbon/ha*yr).

Based on a yield range of 3.2 to 4 tonnes CPO/ha, this would lead to emissions of 4.5 - 22.8 tonnes CO₂/tonne CPO. Expressed in quantities of carbon, this range equals 1.2 – 6.2 tonnes carbon/tonne CPO.

In relation to other relevant GHG, in particular N₂O and methane, the following appears from literature:

- Nitrous oxide emissions from primary and secondary forest sites vary between -63 µg N₂O/m²*hour, and 916 µg N₂O/m²*hour, with 90% of the measured values below 125 µg N₂O/m²*hour (reference).
- Methane emissions show a clear relationship to water level with values generally low (and often negative) for water levels below -20 cm and higher and more variable at higher water levels. Methane emissions from tropical peat swamps are small due to the recalcitrance of the material. Restoration (rewetting) of drained peat soils is unlikely to lead to methane emissions that negate gains in the reduction of CO₂ emissions (Wilson et al. [57]).

Conclusion: Carbon sequestration and emission fluxes in natural peat swamps are some orders of magnitude smaller than the carbon losses from oxidation of drained peat soils. Methane and N₂O emissions from both natural peatlands and from oil palm plantations on peat, are limited.

Vasander and Jauhiainen [51], like a number of other authors (e.g [1]) have made an analysis of uncertainties and gaps in current knowledge, comprising both GHG emissions from natural peatlands and from drained peatlands, and urge for additional research to further quantify data, ‘in particular ecosystem-level measurements of gaseous carbon and other GHG fluxes together with process based studies in order to detail further true overall carbon balances on undrained,

degraded and developed tropical peatland'. Despite the indicated need for further detailing of existing data, also these authors explicitly conclude that 'tropical peat swamp forests form one of the most efficient carbon sequestering ecosystems and important carbon stores and that drained peat 'results in an abrupt and permanent shift in the ecosystem carbon balance from sink to source'.

Conclusion: Various authors have indicated the need to further detail data on GHG fluxes in both undisturbed and drained peatlands. However, this research is not expected to change overall Conclusions 1-3 above, but rather refine and narrow down the data ranges.

2.4.5 Net changes in carbon stocks

2.4.5.1 Carbon stock balances

Based on the figures specified in sections 2.4.1-2.4.4 above, net carbon stock changes have been calculated for the conversion of intact primary forest and grassland to a palm oil plantation. For peat, only the carbon stock change caused by peat decomposition *in the first year* has been calculated. Values have been summarized in Table 2.2.

Again, it needs to be emphasized that in practice oil palm is developed on forest land where in many cases carbon stock values are lower, due to previous logging or degradation, and that the figures mentioned are a worst-case scenario.

Table 2.2 Carbon stock change (tonnes carbon/ha) for plantation replacing grassland and intact primary forest.

	Plantation replacing grassland	Plantation replacing forest on mineral soil	Plantation replacing forest on peat soil
Time averaged carbon stock of previous land use	11.5 +/- 7.5	171 +/-89	171 +/- 89
Time averaged carbon stock of oil palm	35	35	35
Carbon stock loss as as result of one year of peat decomposition ²	0	0	4.9 to 19.9 (annually)
Net change in carbon stock	+16 to +31	-47 to -225	-52 to -245 (after one year)

Notes:

¹A positive sign indicates a net increase in carbon stock

²Peat decomposition is an continuous process. For illustration purposes, only the carbon stock change in the first year has been quantified here. Over a 25 year period, the time averaged net change in carbon stock will range from -169 to -723 tonnes (=net loss)

Henson [22] has examined the carbon balance of oil palm cultivation and palm oil production in Malaysia over the 25 years from 1981 to 2005. He concludes that 'both the present and other studies cited have demonstrated that the nature of land use change leading to oil palm planting is all important in determining whether the crop constitutes a net sink or source of GHG emissions and whether oil palm cultivation reduces or increases, the threat of global warming'.

Conclusion: The carbon loss which occurs when tropical forest is converted to oil palm plantation, by far exceeds the carbon sequestration during one cycle of oil palm growth (25 years). The overall carbon loss is further enhanced when the oil palm plantation is located on peat. When oil palm plantations replace grasslands, carbon sequestration exceeds carbon loss by conversion of grass lands. In that case, palm oil plantations act as a net carbon sink.

2.4.5.2 *Carbon payback times*

The terms ‘carbon payback times’, ‘carbon debt’ or equivalent are mostly used in discussions on the GHG balance (well-to-wheel assessments) of biofuels. The carbon payback time has been defined as the number of years required for avoided fossil fuel emissions from biofuels to compensate for losses in original carbon stocks during land conversion.

Gibbs et al. [16] have calculated ‘carbon payback times’ for a number of biofuels, including palm oil biodiesel. The study concludes that under current conditions, the expansion of biofuels into productive tropical ecosystems will always lead to net carbon emissions for decades to centuries, while expanding into degraded or already cultivated land will provide almost immediate carbon savings. No foreseeable changes in agricultural or energy technology will be able to achieve meaningful carbon benefits if crop-based biofuels are produced at the expense of tropical forests.

For biodiesel from palm oil, a carbon payback time was calculated for 30-120 years for non-peat soils in South-East Asia, and more than 900 years for forests on peatlands. The study concluded that degraded lands in Southeast Asia, could provide immediate carbon benefits. However, it also notices that growing biofuel crops on these marginal lands may require significantly more land area than other regions due to relatively lower yields, and will likely require more energy-intensive management such as increased fertilizer application to remain productive.

Fargione et al. [13] have also concluded that converting native forests to biofuel production results in large carbon debts: ‘converting lowland tropical rainforest in Indonesia and Malaysia to palm biodiesel would result in a biofuel carbon debt of 610 tonne/ha of CO₂-eq that would take approximately 86 years to repay’.....’Converting tropical peatland rainforest to palm production incurs a similar biofuel carbon debt from vegetation, but the required drainage of peatland causes an additional sustained emission of approximately 55 tonnes of CO₂-eq/ha/yr from oxidative peat decomposition’....’Peatland of average depth (3m) could release peat-derived CO₂-eq for about 120 years. Total net carbon released would be approximately 6,000 tonne/ha of CO₂-eq, taking 840 years to repay’.

Conclusion: Calculations on carbon payback time –though solely used for biofuels – reinforce the conclusion that intact forest conversion for oil palm plantation leads to very high GHG emissions, which takes decades to centuries to offset, through replacement of fossil fuels and carbon sequestration by oil palms. Producing on peat results in even longer payback times.

2.5 Overall emission of palm oil production

2.5.1 The OPCABSIM model

In the literature review, only one study has been found which specifically models the overall greenhouse emissions of palm oil production. This is the OPCABSIM model developed by Henson [23]. In his study, he has illustrated the model with four calculation examples, which have been summarized in the box below. From the model calculations it appears that the order of magnitude of emissions is comparable to the results above. Specific emission figures are difficult to assess, as references to specific sources are limited [23].

The examples have been abbreviated as NA, CS, IS and PS, and can be summarized as follows:

- NA stands for national average oil palm and represents the average performing Malaysian crop. It is assumed to grow on mineral soil, to have replaced a previous crop of rubber, is grown without return of mill by-products to the field, and is to be replanted after 25 years
- CS stands for a coastal (soil) site, whereby it was assumed that the previous crop was oil palm
- IS stands for an inland site, low to medium productive, with preceding vegetation being grassland.
- PS stands for peat soil.

Table 2.3 Four calculations examples with the OPCABSIM model (Henson, [23], all data are in tonnes Ceq/ha*yr).

		NA	CS	IS	PS	
Carbon gains	Oil palm	-1.628	-2.015	-1.902	-2.021	Includes roots
	Ground cover	-0.059	-0.048	-0.052	-0.095	Includes cover litter
	Oil palm litter	-0.172	-0.217	-0.185	-0.191	Fronde piles etc
	Mill-by products	0	0	0	0	Assumed not returned
	Total gains	-1.859	-2.280	-2.139	-2.307	
Carbon losses	Peat C oxidation	0	0	0	+8.032	Mean rate over 25 years
	Plantation inputs	+0.333	+0.333	+0.333	+0.392	Based on fossil fuel use
	N2O emission –fertil.	+0.166	+0.166	+0.166	+0.176	From N fertiliser
	N2O emission – peat	0	0	0	+0.148	From peat
	Initial biomass loss	+2.466	+2.280	+0.199	+3.474	NA: Mature rubber CS: Mature oil palm IS: Grassland PS: Secondary forest
	Total losses	+2.965	+2.779	+0.698	+12.222	
Carbon balance		+1.105	+0.499	-1.441	+9.915	
Off-site budget items						
Carbon gains	Mill products and by-products	-0.079	-0.127	-0.125	-0.226	CPO, PKO, kernel cake, EFB, fibre, shell, POME
Carbon losses	CH4 from POME	+0.671	+0.900	+0.650	+0.759	
On plus off-site budget						
Total Carbon gains		-1.938	-2.407	-2.264	-2.533	
Total C losses		+3.636	+3.679	+1.348	+12.981	
Carbon balance		+1.698	+1.272	-0.916	+10.448	

(NA = national average; CS = coastal site; IS = inland ; PS = peat soil)

Note: a positive sign indicates a net GHG emission

2.5.2 Summary of emissions from palm oil production

Sections 2.3 and 2.4 have quantified relevant GHG emissions from palm oil production, both from operations at plantations and mills, and from changes in carbon stocks. The categories of GHG emissions, and concluded orders of magnitude, are summarized in the table below

Table 2.4 GHG emissions from palm oil production, including emissions from carbon stock changes (all emissions on a kg CO₂-eq/ha and kg CO₂-eq/tonne CPO basis).

GHG emission factor	Emissions per ha (kgCO ₂ -eq/ha* annum)	Emissions per tonne CPO (kg CO ₂ -eq/tonne CPO)	Note
1.Operations			
1a. fossil fuel use transport & machinery	+180 to + 404	+45 to + 125	-
1b. fertilizer use	+1,500 to +2,000	+ 250 to + 470	-
1c. fuel of mill & utilization of mill by-products	0	0	-
1d. POME	+2,500 to +4,000	+ 625 to + 1,467	-
<i>Total operations</i>	<i>+4,180 to +6,225</i>	<i>+920 to + 2,007</i>	-
2.Emissions from carbon stock change			
2a. 25 year discounted GHG emission from conversion of grass land/forest	+1,700 to + 25,000	+425 to +7,813	Based on a carbon stock change of 11.5 – 171 tonnes C/ha, which is discounted over 25 years and expressed as CO ₂
2b. Annual carbon sequestration by oil palms	- 7,660	-1,915 to -2,393	Henson [22]
2c. Emissions from oil palm on peat	+18,000 to + 73,000	+4,500 to +22,813	-
<i>Total emissions related to carbon stock change</i>	<i>+12,040 to +90,340</i>	<i>+3,010 to + 28,233</i>	-
Total	+16,220 to 96,565	+3,930 to +30,240	-

Note: a positive sign indicates a net GHG emission

The above calculation clearly indicate that converting high biomass carbon stocks to oil palm plantation, i.e. forests and/or peatlands, causes by far the highest GHG emissions. This confirms the conclusion of most literature, e.g. Zah et al. [64], who in a life cycle assessment of various biofuels (including palm biodiesel), concluded that ‘...most of the environmental impacts of biofuels are caused by agricultural cultivation. In the case of tropical agriculture this is primarily the slash-and-burning of rainforests which sets great quantities of CO₂ free, causes air pollution and has severe impacts on biodiversity’.

2.5.3 GHG emissions from further transport and refinery

The previous Sections have focused on quantifying GHG emissions from palm oil production, and have not quantified GHG emissions from further transport, processing etc. To put the GHG emissions from palm oil production in perspective, this Section summarises GHG emissions from further transport and refinery of palm oil.

Transport

Nikander [39] has calculated GHG emissions related to palm oil transport by ship, from Malaysia to Rotterdam (ship load 40,000 tonnes), and further to Porvoo (ship load 12,500 tonnes). He estimated total GHG emissions for the 17,300 km journey at 106 kg CO₂-eq/tonne palm oil.

The (conservative) default values in the RFA CO₂-calculation tool [42], for over land transport of palm oil (mill to port) and overseas transport, have been summarized below:

Table 2.5 RFA default values for GHG emissions from palm oil transport.

Type of transport	Distance	Fuel use	Specific emission	Total GHG emission
Mill to port	250 km	1.89 MJ/t km diesel	0.086 kg CO ₂ -eq/MJ fuel	41 kg CO ₂ -eq/tonne
Overseas transport	16,500 km	0.2 MJ/ t km HFO	0.087 kg CO ₂ -eq/MJ fuel	287kg CO ₂ -eq/tonne

Refinery

The RFA CO₂-calculation tool [42] specifies conservative default values for refinery of CPO in Asia, which have been summarized below:

Table 2.6 RFA default values for GHG emissions for palm oil refinement.

Type of energy input	Specific energy use	Specific emission	Total GHG emission
Electricity	1,093 MJ/tonne	0.137-0.216 kg CO ₂ -eq/MJ	150-236 kg CO ₂ -eq/tonne
Gas	97 MJ/tonne	0.062 kg CO ₂ -eq/MJ	6 kg CO ₂ -eq/tonne
		<i>Total</i>	<i>156-242 kg CO₂-eq/tonne</i>

Based on the data mentioned in [55], a refinery related GHG emission of 75 kg CO₂-eq/tonne palm oil can be calculated, which is much lower than the conservative RTFO default values.

Conclusion: From the above figures it can be concluded that total GHG emissions from transport and refinery together, are in the same order of magnitude as emissions from fertilizer application.

2.6 Summary of conclusions

The literature review has identified major categories of GHG emissions from palm oil production, and –based on the variety of data available- indicated robust orders of magnitude for each category. A number of conclusions can be drawn:

- In plantation and mill operations, GHG emissions from POME far exceed other GHG emissions, such as from fertilizer use and diesel use;
- Various proven technologies exist which can significantly reduce GHG emissions from POME, and consequently overall emissions from operations;
- If palm oil production is located on peat, continuous GHG emissions resulting from oxidation of peat far exceed those from operations;
- Development of new production areas at the expense of high above and/or underground carbon stocks, results in GHG emissions which takes many oil palm cycles to compensate through carbon sequestration in oil palms. These timeframes by far exceed the lifetime of an average (plantation) company;
- If new production areas are developed in areas which are not high in carbon stocks, palm oil production may lead to net carbon sequestration.

3 Proposal for inclusion of GHG emissions in RSPO Principles & Criteria

3.1 Introduction

The GHG Working Group have distinguished two main objectives that shall be achieved by explicit inclusion of GHG emissions in the RSPO Principles & Criteria:

1. Ensure improved credibility of RSPO as palm oil sustainability standard, by defining measures and practices to reduce or avoid GHG emissions of plantation & mill operations and new developments;
2. Ensure the capability for market players to meet the GHG balance reporting requirements set by European and other governments, for the use of palm oil derived products in bio-energy applications. This objective is primarily focused at *reporting* of certain GHG information (also refer to Box 4).

The GHG-WG has noticed that, although GHG reporting is currently most relevant for biofuels in Europe, this might in the near future become a wider market requirement, e.g. from retailers wishing to provide CO₂-information with their products (refer e.g. to www.carbon-label.com, www.tesco.com/climatechange/carbonfootprint.asp, and www.pcf-projekt.de).

Box 4. The EU GHG balance reporting requirements

The European Commission, in its Renewable Energy Directive [12], requests market actors which place biofuels on the EU market, to meet a number of sustainability criteria. One of these criteria relates to the GHG balance of biofuels.

In order to count towards the mandatory blending targets, biofuels shall achieve a minimum GHG emission reduction of 35% (for biofuel plants which started operations after January 2008 immediately after implementation of the Directive (2011); for biofuel plants which started operations prior to January 2008, from 2013 onwards).

To calculate GHG emission reductions of specific biofuels, a GHG calculation methodology is being developed by the European Commission. The GHG calculation methodology is based on a well-to-wheel approach that includes all significant sources of GHG emissions.

The calculation methodology uses standard (conservative) default values that provide estimates of the carbon intensity of different fuel chains. If a biofuel producer does not provide actual data from his supply chain, automatically the default values for his particular biofuel do apply. However, the calculation model may also be used by individual biofuel producer to provide specific, evidence based, information about their supply chain, i.e. additional qualitative or quantitative GHG emission data (instead of default values). This will improve the accuracy of the calculation, and potentially achieve better GHG emission reductions.

For palm oil biodiesel, the default value has been set at 19% (i.e. that GHG emissions from the palm oil to biodiesel chain are 19% lower than for fossil diesel production chain). This means that the required threshold value of 35% after 2011/2013 can only be achieved by providing supply chain specific, evidence based, information on GHG emissions from palm oil production, transport and processing.

The GHG-WG has concluded that information on GHG emissions from palm oil production can efficiently, and relatively easy, be collected in the framework of a RSPO verification audit. This information can be summarized in the public summary of the verification audit, and subsequently travel

with the palm oil (products). This avoids the necessity for a separate auditing scheme solely for GHG emissions.

Exact quantification of GHG emissions from further palm oil transport and processing is less relevant, as GHG emissions from palm oil production by far exceed emissions from transport and further processing.

Although the exact details of the EU GHG calculation model are not public at the moment of this writing, it is evident that ideally, the following relevant GHG emission information shall be collected during a RSPO verification audit, as they have major impact on the overall GHG balance:

- a. Information on specific fertilizer use (qualitative and quantitatively (kg/ha*yr));
- b. Information on diesel use (per tonne of CPO, FFB or hectare);
- c. Information on POME treatment (treatment technology; in case of biogas capture: quantities of biogas captured and methane content).

It is important to note that the biofuel default values set by the European Commission are the outcome of a EU internal process, and the (scientific) background of the values is not transparent. Although the exact values might be debated (e.g. the 19% for palm oil) this is not something which will change in the short to medium term. Only on the basis of sufficient real supply chain data, default values may be altered in future.

Furthermore, the well-to-wheel calculation methodology is also pre-set. In other words: developing an alternative LCA method is not a sensible option for the purpose of GHG reporting in the EU.

The European Commission methodology for GHG calculations is still being detailed, and is expected to be finalized by the end of 2009, or in 2010. However, it is likely to be similar to the methodology already used in the UK since April 2008, in the framework of the Renewable Transport Fuel Obligation. The software tool comprising the calculation model can be found at www.renewablefuelsagency.org.

N.B. In its list of default values, the European Commission have given explicit consideration to the beneficial effect of biogas capture from POME. The standard default value for palm oil biodiesel has been set at 19%; and the default value for palm oil biodiesel including biogas capture from POME, has been set at 51%. This means that palm oil biodiesel which FFB feedstocks have been processed in a mill with biogas capture, automatically qualifies for the 35% (and later 50%) thresholds.

This Chapter specifies the GHG-WG proposals for amendments to RSPO Principles & Criteria, including Indicators and Guidance. The proposed amendments aim to achieve both of the above specified objectives, i.e. overall reduction of GHG emissions from palm oil production through effective measures, and facilitating reporting of GHG emissions further down the chain (e.g. EU biofuels requirements).

In relation to measures to reduce overall GHG emissions from palm oil production, the focus of the GHG-WG has been on those categories of GHG emissions which have the highest impact (i.e. POME, peat and conversion of carbon stocks). In relation to reporting of GHG emissions, the focus has been on those categories of GHG emissions which need to be reported under EU biofuels legislation (and potentially other carbon footprint schemes), i.e. fossil fuel use, fertilizer use, and POME treatment (Refer to Box 3 above).

In Section 3.2, first a new Criterion 5.7 is proposed, dealing with plans to reduce GHG emissions (Section 3.2.1). Subsequently, further proposed amendments have been 'categorized' according to the categories of GHG emissions from palm oil production, as specified in Chapter 2, i.e.:

- Emissions caused by use of fossil fuels (Section 3.2.2);
- Emissions caused by use of artificial fertilizer (Section 3.2.3);
- Emissions caused by application of palm oil mill residues, excluding POME (Section 3.2.4);
- Emissions caused by POME (Section 3.2.5);

- Emissions caused by carbon stock change (Section 3.2.6);
- Emissions caused by peat degradation (Section 3.2.7).

For each of the categories of GHG emissions, relevant references in the current set of Principles & Criteria have been summarized, after which the GHG-WGs rationale for proposed amendments has been elaborated. Subsequently, the proposed amendments (if applicable) have been detailed.

3.2 Proposals for amendment of RSPO Principles & Criteria

3.2.1 Plans to reduce GHG emissions

Under Principle 5 (*‘Environmental responsibility and conservation of natural resources and biodiversity’*) Criterion 5.6 specifies: *‘Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored’*.

The GHG-WG believes that GHG emission reduction should get a more prominent position under Principle 5, and proposes to add a new Criterion 5.7 specifically in relation to GHG emission calculation and reduction.

It is proposed to re-phrase Criterion 5.6 as follows: *‘Plans to reduce pollution and emissions are developed, implemented and monitored’*.

And phrase a new Criterion 5.7 as follows: *‘Specific plans to reduce greenhouse gas emissions are developed, implemented and monitored’*.

It is proposed to add under Criterion 5.7 the following Indicator 5.7.1:

‘Significant sources of GHG emissions are identified and plans to reduce them implemented’, with the following Guidance:

‘Significant sources of GHG emissions may include emissions from the treatment/re-use of mill residues (POME, EFB), fertilizers, fossil fuels, as well as emissions from peat oxidation’

Furthermore, the GHG-WG recommends to add specific Indicators with respect to POME (Indicator 5.7.2) and Compensating GHG emissions from peat (Indicator 5.7.3). Refer to Section 3.2.5 and 3.2.7 for details.

3.2.2 Fossil fuel use

Criterion 5.4 specifies: *‘Efficiency of energy use and use of renewable energy is maximised’*

The National Interpretation for Malaysia specifies the following Indicators under Criterion 5.4:

‘5.4.1 Monitoring of renewable energy per tonne of CPO or palm product in the mill

5.4.2 Monitoring of direct fossil fuel use per tonne of CPO or kW per tonne palm product in the mill (or FFB where the grower has no mill).’

The National Interpretation for Indonesia specifies the following Indicators under Criterion 5.4:

‘5.4.1. Records of monitoring renewable energy use and its efficiency analysis (energy/ton CPO, or energy/ton palm product).

5.4.2 Records of monitoring of fossil fuels use for operational reason and its efficiency analysis.’

The National Interpretation for PNG specifies the following indicators under Criterion 5.4:

'5.4.1 Monitoring Kilowatt hour per tonne of palm product in the mill from renewable energy sources. Kilogram steam per tonne of FFB. Monitoring trend for the preceding 5 years.

5.4.2 Monitoring Kilowatt hour per tonne of palm product from non renewable energy resources. Monitoring trend for the preceding 5 years.'

The GHG-WG concludes that reporting on fossil fuel use is sufficiently covered by the respective national interpretations. No amendments to RSPO P&C are proposed.

3.2.3 Fertiliser use

Criterion 4.2 specifies: *'Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield'*.

The National Interpretation for Malaysia specifies the following Indicator 4.2.1: *'Monitoring of fertilizer inputs through annual fertilizer recommendations'*.

The National Interpretation for Indonesia specifies the following Indicator 4.2.2: *'Records of efforts to maintain and increase soil fertility (e.g. the use of fertilizer, legume cover crops, compost, and land applications of POME or EFB) based on the results of analysis carried out as in Point 1 above)'*.

The National Interpretation for PNG specifies the following Indicator 4.2.1: *'Records of fertilizer inputs are maintained'*.

All three National Interpretations refer specifically to the monitoring of fertilizer inputs. For the purpose of quantifying GHG emissions, it will be necessary to monitor specifically the type of fertilizers used, and the annual quantities used per tonne of CPO or per tonne of FFB. The GHG-WG recommends to add the following to the existing Indicators:

'Types of artificial fertilizers applied shall be monitored. Quantities of fertilizers per tonne CPO or per tonne of FFB shall be calculated'.

3.2.4 Palm oil mill residues

3.2.4.1 Relevant references in current set of P&Cs

Criterion 5.3 specifies: *'Waste is reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner'*.

The National Interpretation for Malaysia specifies the following Indicator 5.3.3 *'Evidence that crop residues/biomass are recycled (Cross reference Criterion 4.2)'*, with Specific Guidance referring to the discharge of POME only (i.e. no reference of EFB).

The National Interpretations for Indonesia and PNG do not provide a specific Indicator in relation to the recycling of palm oil mill residues (under Criterion 5.3). The PNG Guidance under Criterion 5.3 specifies that *'Improving the efficiency of resource utilization and recycling potential wastes as nutrients or converting them into value added products (e.g. through animal feeding programmes)'*.

Criterion 4.2 specifies: *'Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield'*.

The National Interpretation for Malaysia specifies the following Indicator 4.2.3 *'Monitor the area on which EFB, POME and zero-burning planting is applied'*.

The National Interpretation for Indonesia specifies the following Indicator 4.2.2: *'Records of efforts to maintain and increase soil fertility (e.g. the use of fertilizer, legume cover crops, compost, and land applications of POME or EFB) based on the results of analysis carried out as in Point 1 above'*.

The National Interpretation for PNG specifies Indicator 4.2.3: *'A nutrient recycling strategy should be in place'*, with the Guidance including the following: *'The nutrient recycling strategy should include EFB, POME, other mill-by products, palm residues after replanting and any use of biomass for by-products or energy production'*.

3.2.4.2 Rationale behind proposed amendments

Literature data provide little quantitative data on the GHG effects from potential disposal/recycling routes for palm oil mill by-products, in particular EFB (for POME refer to Section 3.2.4). However, it appears that landfilling of EFB has a worse GHG score than other options, due to the generation of methane emissions.

Current Principles & Criteria stimulate EFB recycling as part of a nutrient management/soil improvement plan. However, landfilling of EFB is not explicitly discouraged. The GHG-WG believes that this shall be done.

3.2.4.3 Proposal for amendments

It is proposed that under Criterion 5.3, the following indicator is added under the respective National Interpretations:

'Landfilling of EFB and other palm oil mill residues shall be avoided'.

3.2.5 POME

3.2.5.1 Relevant references in current set of P&Cs

Criterion 4.4 specifies: *'Practices maintain the quality and availability of surface and ground water'*.

The National Interpretation for Malaysia specifies the following relevant Indicator 4.4.3: *'Outgoing water into main natural waterways should be monitored at a frequency that reflects the estates and mills current activities which may have negative impacts'*.

The National Interpretation for Indonesia specifies the following relevant Indicators: *'Monitoring of effluent BOD'* and *'Monitoring of mill water use per tonne of FFB'*.

The National Interpretation for PNG specifies the following relevant Indicator 4.4.1: *'An implemented Water Management Plan in Compliance with PNG DEC Water extraction and discharge permits and including but not limited to: the Monitoring of effluent BOD (mg/l) trend for previous 12 months, mill water use per tonne FFB trend for previous 5 years, storm water, drains, nursery and domestic usage'*.

Criterion 5.4 specifies: *'Efficiency of energy use and use of renewable energy is maximized'*.

With the Guidance in the respective National Interpretations including the following: *'The feasibility of collecting and using biogas, biodiesel and biofuels should be studied if possible'*.

Criterion 5.6 specifies: *'Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored'*.

The National Interpretation for PNG specifies the following Indicator 5.6.3 in relation to POME: *'The treatment methodology for POME is recorded'*.

The National Interpretation for Indonesia specifies the following Indicator 5.6.2 in relation to POME: *'Records of identification, monitoring, and treatment technology for POME'*.

Under Criterion 5.6, the National Interpretation for Malaysia makes no specific reference to POME.

3.2.5.2 Rationale behind proposed amendments

Based on the scientific evidence presented in Section 2.3.4, the GHG-WG has concluded that the conventional method of POME treatment, i.e. including anaerobic open lagoons, is a significant source of GHG emissions.

As indicated in Section 2.3.4, several technologies are available for effective methane emission reduction from POME, including biogas capture, decanters, co-composting with EFB, and denitrification technologies.

Biogas capture technologies have been well documented in literature, including data on efficiencies, also in the framework of CDM reporting requirements of those projects. For the other technologies, no quantitative data have been found on methane reduction efficiencies.

The GHG-WG have identified and discussed three main options for setting a standard to reduce methane emissions from POME:

- a. Mandatory biogas capture for mills above a certain treatment capacity (threshold capacity to be specified). The main disadvantage of this option is that such a requirement under RSPO P&Cs this would almost certainly lead to a situation where these projects are no longer eligible under CDM (confirmed by various experts on CDM mechanisms, including TUV Nord and Climate Focus). Without CDM carbon credits revenues, palm oil producers represented in the GHG-WG consider investments in biogas capture systems very significant.
- b. Not prescribing a single technology, but instead defining a methane reduction target (% from a certain baseline) or setting a maximum emission ($\text{m}^3 \text{CH}_4/\text{tonne POME}$). The main disadvantage of this option is that for technologies other than biogas capture, verification might be difficult. For these technologies, two methods exist to monitor whether CH_4 emissions are below a certain level:
 - Measure methane fluxes from the POME treatment tanks;
 - Measure oxygen levels in the treatment tanks/ in the composting pile in the case of co composting (as long as oxygen levels are above a certain minimum percentage, the treatment process is aerobic, in other words no significant release of methane).Both methods require intensive measuring, and do only provide *an indication* of methane emissions (reduction), rather than an absolute figure.
- c. Neither prescribing a single technology nor setting a quantitative methane reduction target, but instead requesting that 'the feasibility is studied of reducing methane emissions through the application of certain measures or technologies'. This requirement resembles the current Indicator under Criterion 5.4.

N.B. In addition to the above, the GHG-WG has noted that the position of independent smallholders operating a mini mill requires specific attention in setting standards for GHG emission reduction from POME, as their resources to implement specific measures are generally much more limited than the resources of larger producers.

Note: The GHG-WG has not come to a conclusion as regards the preferred option. It invites stakeholders to comment specifically on the pros and cons of the identified options. In addition, the GHG-WG would in particular welcome information on any practical, operational references/data of technologies other than biogas capture.

3.2.5.3 *Proposal for amendments*

[An Indicator 5.7.2 shall be specified under new Criterion 5.7; the wording of this Indicator depends on the preferred option as indicated in 3.2.5.2]

3.2.6 Carbon stocks

3.2.6.1 *Relevant references in current set of P&Cs*

In the current Principles & Criteria, there is no explicit reference to carbon stocks. Indirectly, there is a reference in various Criteria, e.g. Criterion 7.3 (*'New plantings since November 2005, have not replaced primary forest or any area required to maintain or enhance one or more High Conservation Values'*) and Criterion 5.6 (*'Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored'*).

3.2.6.2 *Rationale behind proposed amendments*

Acceptable carbon stock conversion

A palm oil plantation has a time averaged carbon stock of approximately 35 tonnes carbon/ha (including aboveground and underground carbon stocks, excluding peat, refer to Section 2.4.3). Development of palm oil plantings on land with a time averaged carbon stock exceeding 35 tonnes carbon/ha, will lead to a net reduction in carbon stocks. Development of palm oil plantings on land with a time averaged carbon stock below 35 tonnes carbon/ha, e.g. grasslands, will lead to an increase in carbon stocks (net carbon sequestration by oil palms).

The GHG-WG believes that development of palm oil plantings shall not lead to a net reduction in carbon stocks. This means that new palm oil developments can take place on land which has a time averaged carbon stock below or equal to 35 tonnes/ha.

The GHG-WG has noticed that there are some scientific uncertainties as regards the figure of 35 tonnes/ha: it has been based on a 25 year planting cycle, it does not take into account the carbon contained in the mill products (oil, kernels) which leave the plantation, and it does not factor in the fossil fuel substitution through re-use of palm oil mill residues. Given these uncertainties, the GHG-WG believes that there should be a possibility to develop palm oil on land with carbon stocks higher than 35 tonnes carbon/ha, provided that all carbon losses above 35 tonnes carbon/ha are being compensated through a carbon compensation mechanism (as they cannot be offset through sequestration in oil palms).

In order to ensure credibility of the carbon stocks standard, the possibility for carbon compensation shall be restricted: the GHG-WG has come to a provisional consensus that the quantity of carbon which is compensated through a carbon compensation mechanism, shall not exceed the time averaged quantity of carbon stored in an oil palm plantation, i.e. 35 tonnes carbon/ha. In other words: palm oil may also be developed on land with carbon stocks between 35 and 70 tonnes carbon/ha, provided that the quantity of carbon exceeding 35 tonnes/ha, is compensated for in a carbon compensation mechanism.

Carbon stocks standards of 35 and 70 tonnes carbon/ha shall apply from a certain cut off date onwards (refer to 3.2.6.3). Plantations which were developed prior to the cut off date, will not be

bound to any compensation requirement (although there may still be a 'carbon debt', if carbon losses during land conversion have not yet been compensated through sequestration).

The GHG-WG has concluded that it will be necessary for RSPO to develop guidelines for (acceptable) carbon compensation mechanisms. Some first thoughts have been summarized in Section 3.3.

Note: The GHG-WG would specifically welcome practical examples/illustrations/photos of what the proposed values of 35 and 70 tonnes carbon/ha mean in practice.

Note: The GHG-WG has considered the option of setting forest type specific carbon stock thresholds. In particular, it has been discussed whether for degraded forests a lower threshold should be set, as these forests are often high in biodiversity value. The GHG-WG has concluded that protection of areas with high biodiversity values shall primarily be ensured through a HCV assessment, rather than by carbon stock thresholds.

Verification of carbon stocks

The GHG-WG recommends that carbon stocks will be assessed in the framework of a social and environmental impact assessment.

Gibbs et al. [17] have evaluated various technologies to assess carbon stocks. Most technologies (e.g. use of biome averages, optical remote sensors, radare remote sensors and laser remote sensors) have a 'medium to high' uncertainty as regards quantitative results. Forest inventories and very high resolution airborne optical remote sensors provide reliable quantitative results. However the latter is technically very demanding. On the ground forest inventories provide reliable results, but demand significant human resources.

Niels Wielaard from Sarvision (member of GHG-WG) has concluded that solely relying on ground assessments is not optimal for assessing carbon stocks in the order of 0 to 70 tonnes carbon/ha, as is required here. His written contribution to the WG discussion has been included in Appendix 3.

The GHG-WG has concluded that carbon stocks assessments shall be done in the framework of a social and environmental impact assessment. However, the GHG-WG has not come to a final conclusion as regards the preferred method(s) for assessing carbon stocks.

Note: The GHG-WG invites stakeholders to specifically submit views on the preferable methods for carbon stock assessments.

3.2.6.3 Proposal for amendments

The GHG-WG recommends to add a new Criterion 7.9 under Principle 7:

'No new developments on areas with high carbon stocks after November 2009'

Note: It is assumed that this Criterion will be adopted by the RSPO General Assembly in November 2009; if this were to happen at a later moment, the date in the Criterion shall be amended accordingly.

Indicators under Criterion 7.9 shall include:

- *'Oil palm can only be developed where the carbon stock of the land is equal or lower than 35 tonnes carbon/ha in December 2009;*
- *Where the carbon stock of the land to be converted is between 35 – 70 tonnes carbon/ha in December 2009, then conversion can occur if the amount of carbon exceeding 35 t/ha is compensated through a carbon compensation mechanism;*
- *Land where the carbon stock value is above 70 tonnes carbon/ ha in December 2009 cannot be developed'.*

Note: It is assumed that these Indicators will be adopted by the RSPO General Assembly in November 2009; if this were to happen at a later moment, the date in the Indicator shall be amended accordingly.

And Guidance shall include:

- *'Carbon stocks shall be quantified through a systematic field assessment, e.g. in the framework of a HCVF assessment'.*
- *'Carbon compensation mechanisms need to be in accordance with the Guidelines set by RSPO' [Note: such guidelines are yet to be detailed, refer to Section 3.3]*

3.2.7 Peat

3.2.7.1 *Relevant references in current set of P&Cs*

The current National Interpretations have some specific requirements set in relation to existing plantations on peat (in particular under Criterion 4.3) and in relation to new developments on peat (in particular under Criterion 7.4).

Criterion 4.3 specifies: *'Practices minimize and control erosion and degradation of soils'*

The National Interpretations for Malaysia and Indonesia specifies the following Indicator 4.3.4: *'Subsidence of peat soils should be minimized through an effective and documented water management programme'* [minor compliance issue], and Guidance: *'For existing plantings on peat, water table should be maintained at a mean of 60 cm (within a range of 50-75cm) below ground surface through a network of appropriate water control structures e.g. weirs, sandbags, etc. in fields, and water gates at the discharge points of main drains'*

In the national interpretation for PNG, there is no specific reference to a water management program for plantations on peat soils.

Criterion 7.4 specifies *'Extensive planting on steep terrain and/or on marginal and fragile soils, is avoided'*.

The National Interpretation for Malaysia specifies the following relevant Indicator 7.4.2: *'Where planting on fragile and marginal soils is proposed, plans shall be developed and implemented to protect them without incurring adverse impacts (e.g. hydrological) or significantly increased risks (e.g. fire risk) in areas outside the plantation'* [minor compliance issue]

The Guidance includes the following: *'Marginal and fragile soils, including excessive gradients and peat soils, should be identified prior to conversion to plantation'* and, specifically for smallholders and small-growers:

‘Scheme managers, small-growers and individual smallholders should avoid establishing new plantings on steep terrain and/or marginal and fragile soils. If it’s the only source of livelihood, it should be developed with the use of appropriate conservation measures’.

The National Interpretation for Indonesia specifies the following Indicators:

‘7.4.1 Maps identifying marginal and fragile soils, including excessive gradients and peat soils, should be available’ [minor compliance issue], and

‘7.4.2 Where limited planting on fragile and marginal soils is proposed, plans shall be developed and implemented to protect them without incurring adverse impacts’ [minor compliance issue],

and the Guidance including:

‘Planting on extensive areas of peat soils and other fragile soils should be avoided referring to national regulations. Adverse impacts may include hydrological risks or significantly increased risks (e.g. fire risks) in areas outside the plantation’.

The National Interpretation for PNG specifies the following relevant Indicators:

‘7.4.1 Where limited planting on fragile and marginal soils is proposed, plans shall be developed and implemented to protect these soils thus minimizing adverse impacts’ [major compliance issue], and

‘7.4.3 No planting on contiguous areas of peat soils > 3 m deep and > 150ha in extent’ [minor compliance issue],

and the Guidance including:

‘Independent smallholders must not establish new plantings on steep terrain and/or marginal and fragile soils, unless such development would represent the only source of livelihood and is developed with the use of appropriate conservation measures’.

3.2.7.2 Rationale behind proposed amendments

On the basis of scientific evidence arising from the literature review (Refer to Section 2.4.4), the GHG-WG has concluded that, from a GHG perspective, palm oil production on peat should in principle be avoided.

The GHG-WG has concluded that, from a GHG perspective, no *new developments* on peat shall be allowed. Within the GHG-WG, the issue has been raised of specific situations in which compelling socio-economic needs could justify new palm oil developments on peat to be RSPO certifiable. However, the GHG-WG has not come to a conclusion on how these compelling socio-economic needs shall be defined, in order to translate this into verifiable indicators within the framework of RSPO verification audits. The GHG-WG has decided to raise this issue as a ‘unanswered question’ in the public consultation, for which specific guidance from stakeholders is sought.

The GHG-WG has concluded that for *existing plantations* on peat, GHG emissions from continuous peat oxidation are in fact unavoidable, and that emissions can in fact only be reduced by applying appropriate water management, in particular by maintaining high water tables.

There has been some (non conclusive) discussion in the GHG-WG as to whether the drainage depths of 60-80 cm (literature review), respectively 50-75 cm (Guidance with Criterion 4.3), are optimal from both an agronomic and a GHG perspective, or whether water tables could be increased further. The GHG-WG recommends that further research will be undertaken into optimal drainage depths, e.g. in the framework of existing cooperation between the governments of Malaysia and the Netherlands, on peat research (outside scope of the GHG-WG).

Based on current evidence, the GHG-WG has concluded that the requirement of a water table between 50-75 cm (as the Malaysian and Indonesian National Interpretations under Criterion 4.3 currently already specify) shall be maintained and strengthened.

The GHG-WG has identified the option of carbon compensation mechanisms as a potentially interesting route to 'offset' unavoidable GHG emissions from existing plantations on peat. Investing in a mechanism project would reduce overall GHG-emissions, and further contribute to the credibility of the RSPO standard.

The GHG-WG has concluded that it will be necessary for RSPO to develop guidelines for (acceptable) carbon compensation mechanisms. Some first thoughts have been summarized in Section 3.3.

3.2.7.3 Proposal for amendments

In relation to new developments on peat, the GHG-WG recommends to add a new Criterion 7.8 under Principle 7:

'No new plantings on peat after November 2009'

Note: It is assumed that this Criterion will be adopted by the RSPO General Assembly in November 2009; if this were to happen at a later moment, the date in the Criterion shall be amended accordingly.

In response to the issue raised in the GHG-WG, that in specific circumstances compelling socio-economic may justify new palm oil developments on peat, a potential Indicator under Criterion 7.8 might be the following:

'New plantings on peat after November 2009 are only allowed if this is justified by pressing social needs. These needs shall be identified and assessed during socio economic impact assessment.'

However, for this to be a verifiable indicator, it will be necessary to clearly define 'pressing social needs', and how these shall be measured or monitored in the framework of RSPO social impact assessments. The GHG WG has not yet concluded if and how this can be done. The GHG WG invites stakeholders to submit specific comments and/or suggestions in relation to this matter.

Guidance under Criterion 7.8 shall include:

'Peat is defined as soils that have 50 cm or more organic soil matter within 100 cm'.

In relation to existing developments on peat, the GHG-WG recommends the following:

1. That the following Indicator under Criterion 4.3 is added to the National Interpretation for PNG: *'Subsidence of peat soils should be minimized through an effective and documented water management program'*, with the Guidance including: *'For existing plantings on peat, water table should be maintained at a mean of 60 cm (within a range of 50-75cm) below ground surface through a network of appropriate water control structures e.g. weirs, sandbags, etc. in fields, and water gates at the discharge points of main drains'*;
2. That the status of this Indicator is amended from 'minor compliance issue' to 'major compliance issue', in all National Interpretations, such as to strengthen the importance of this requirement;

In addition, the GHG-WG has considered the possibility to offset unavoidable GHG emissions from existing plantations on peat, through investments in a carbon mechanism project. However, the GHG-WG has not yet come to a final conclusion as regards the desirability of

formalizing this in an Indicator. Stakeholders are specifically invited to comment on the following, potential, Indicator 5.7.3, which aims to stimulate carbon offsetting:

‘For plantations existing on peat on November 2009, the feasibility shall be assessed of compensating the greenhouse gas emissions from peat oxidation, through a carbon compensation mechanism’.

With the Guidance including: *‘Carbon compensation mechanisms need to be in accordance with the Guidelines set by RSPO’* [[Note: such guidelines are yet to be detailed, refer to Section 3.3]

3.3 Carbon compensation mechanism

The GHG-WG has identified carbon compensation mechanisms as an option to compensate for certain ‘unavoidable’ GHG emissions from palm oil production, including in particular:

- GHG emissions from existing plantations on peat, which are caused by ongoing oxidation of drained peat. Compensation of GHG emissions is only acceptable as an additional mechanism after all reasonable measures have been taken to reduce GHG emissions, in particular increasing height of water tables (Refer to Section 3.2.6.3);
- GHG emissions caused by the removal of biomass/carbon stocks for new plantation developments. Compensation of GHG emissions is only acceptable provided that the conversion threshold of 70 tonnes C/ha is met (Refer to Section 3.2.5.3).

The GHG-WG believes that investing in carbon compensation projects, as an additional measure to direct GHG emission reduction measures, will show RSPO members’ commitment to reducing GHG emissions, and can contribute further to the credibility of the RSPO standard.

As a consequence, it will be necessary for RSPO to set a standard for acceptable compensation mechanism projects. Two main routes have been identified:

1. GHG emission compensation through approved CDM or VCS forestry or peat restoration projects. In this case, palm oil producers would have to purchase accredited carbon credits from these projects;
2. Development of a RSPO specific standard for compensation mechanism projects, which may give larger flexibility for palm oil producers (e.g. to offset GHG emissions through certain measures within the unit of certification or within the own land bank). The development of such a RSPO specific standard would require an in-depth assessment of conditions under which the projects are deemed acceptable, and how they can be verified in the framework of RSPO Principles & Criteria (Refer to Box 5 below). It has been suggested that the ISO 14064 scheme may provide a useful reference.

Box 5

Aspects to be considered when developing a RSPO standard for a compensation mechanism, include, but are not limited to the following:

1. Unit of compensation: stocks versus flows

Carbon compensation may relate to the compensation of a carbon stock loss (e.g. in land conversion) or compensation of a carbon flow (e.g. continuous emissions from drained peatlands). Both have different units, and may be expressed in tonnes carbon or tonnes CO₂ (the latter is usual in international carbon markets).

2. Type and location of projects

A large variety of potential carbon compensation projects could be identified, ranging from reducing industrial processes, up to peatland restoration and afforestation. It needs to be assessed which type of projects are deemed acceptable in the context of compensation of GHG emissions from palm oil

production (like-for-like?). Furthermore, it needs to be assessed which conditions shall apply to the location of compensation projects (e.g. the unit of certification, regional, national).

3. Additionality and leakage

The rule of additionality says that carbon compensation programs should only pay for activities that reduce global emissions compared to a baseline whereby carbon compensation funds would not be available. For example, if an existing stock of carbon is not likely to release a flow of carbon dioxide in the coming year, then paying to protect (carbon compensation) it is not additional—it doesn't reduce global emissions.

Leakage represents the increase in GHG emissions by sources outside the carbon compensation project, which is measurable and attributable to the project activity (e.g. an avoided deforestation project leads to deforestation elsewhere)

4. Sale of carbon credits

The GHG emission reductions realized under a carbon compensation project can potentially be sold as carbon credits, either as Certified Emission Rights (CDM scheme), or as VERs on voluntary carbon markets (e.g. the Chicago Climate Exchange). This will generate additional revenues, potentially to the extent that carbon compensation projects are effectively self financing. In that case, there might be a question of credibility when carbon credits are also claimed in relation to compensating for emissions from palm oil production.

5. Verification aspects

Carbon compensation projects require specific verification methodologies, including but not limited to the aspects indicated above. Verification of carbon compensation projects is unlikely to happen directly in the framework of a RSPO Principles & Criteria verification audit. Effective ways to organize verification will have to be assessed.

The GHG-WG has not yet come to a conclusion as regards the preferred route for setting a standard for carbon compensation projects. It invites stakeholder to specifically comment on the routes identified, and potentially other options.

4 References

- [1] Alterra (2008). Review of carbon flux estimates and other greenhouse gas emissions from oil palm cultivation on tropical peatlands – identifying the gaps in knowledge. Wageningen (the Netherlands), 2008.
- [2] Butler R.A., L.P. Koh and J. Ghazoul. REDD in the red: palm oil could undermine carbon payment schemes. *Conservation letters* (2009).
- [3] CE & University of Utrecht (2007). The greenhouse gas calculation methodology for biomass based electricity, heat and fuels. Utrecht (the Netherlands), January 2007.
- [4] Chen, S.S. (2008). The LCA approach to illustrate palm oil's sustainability advantage. International Palm Oil Sustainability Conference, Sabah – Malaysia, April 2008.
- [5] Corley, R.H.V. and P.B. Tinker (2003). *The Oil Palm –Fourth Edition*. Blackwell Science publishers.
- [6] Couwenberg, J. R. Dommain and H. Joosten (2009). Greenhouse gas fluxes from tropical peatlands in Southeast Asia. Institute of Botany and Landscape Ecology, University of Greifswald (Germany).
- [7] Damen and Faaij (2007). Greenhouse gas balances of biomass import chains for green electricity production in the Netherlands. Report in the framework of IEA Bio-energy Task 38.
- [8] Damen and Faaij (2006). A greenhouse gas balance of two existing international biomass import chains. *Mitigation and adaptation strategies for global change* (2006), 11.
- [9] Delft Hydraulics, Wetlands International and Alterra (2006). Assessment of CO₂EQ-emissions from drained peatlands in South-East Asia. Wageningen (the Netherlands), November 2006.
- [10] Ecofys (2007). Technical specification: greenhouse gas calculator for biofuels. Utrecht (the Netherlands), December 2007.
- [11] ERIA (2007). Investigation on sustainable biomass utilization vision in East Asia: life cycle assessment for biomass derived fuel in Malaysia. ERIA Joint Research Project Series 2007, No. 39.
- [12] Directive 2009/28 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Brussels (Belgium), 23 April 2009.
- [13] Fargioni J, Hill J, Tilman D, Polasky S, Hawthorne P (2008). Land clearing and the biofuel carbon debt. *Science*, doi: 10.1126/science.1152747.

- [14] Field, R.D., G.R. van der Werf and S.S.P. Shen (2009). Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geoscience*, Vol 2, March 2009.
- [15] Germer J. and J. Sauerborn (2007). Estimation of the impact of oil palm plantation establishment on greenhouse gas balance. Springer Science+ Business Media BV, 2007.
- [16] Gibbs, H.K., M. Johnston, J.A. Foley, T. Holloway, C. Monfreda, N. Ramankutty, D. Zaks (2008). Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology. *Environmental Research Letters* 3 (2008).
- [17] Gibbs, H.K., S. Brown, J. O. Niles and J.A. Foley (2007). Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letters* 2 (2007).
- [18] Global Environment Centre and Wetlands International (2008). Assessment of peatlands, biodiversity and climate change – main report. Kuala Lumpur, May 2008 (ISBN 978-983-43751-0-2).
- [19] Goetz S.J. et al. (2009). Mapping and monitoring carbon stocks with satellite observations: a comparison of models. *Carbon Balance and Management* 2009, 4:2.
- [20] Hansen, M.C. Humid tropical forest clearing from 2000 to 2005 quantified using multi-temporal and multi-resolution remotely sensed data. (publication date and source unknown).
- [21] Henson, I.E. (2005). An assessment of changes in biomass carbon stocks in tree crops and forests in Malaysia. *Journal of Tropical Forest Science* 17 (2): 279-296 (2005).
- [22] Henson, I.E. (2008). The carbon cost of palm oil production in Malaysia. *The Planter* 84, (988).
- [23] Henson, I.E. and K.C. Chang (2009). Evaluating the global warming impact of palm oil production I. A field model. (not yet published).
- [24] Henson, I.E. and K.C. Chang (2009). Evaluating the global warming impact of palm oil production II. An estate model. (not yet published)
- [25] Henson, I.E. (2009). Modelling carbon sequestration and greenhouse gas emissions associated with oil palm cultivation and land-use change in Malaysia – a re-evaluation and a computer model. *MPOB Technology* – No 31, May 2009.
- [26] IFEU (2007). Conclusive evaluation of studies assessing the environmental impact of the use of palm oil as a bioenergy carrier. Heidelberg (Germany), September 2007.
- [27] IFEU (2006). An assessment of energy and greenhouse gases of NExBTL. Heidelberg (Germany), June 2006.
- [28] IFEU (2004) CO₂EQ mitigation through biofuels in the transport sector. Heidelberg (Germany), August 2004.
- [29] IPCC (2006). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. Chapter 5 Land-use change & Forestry.
- [30] IPCC (2003). Good practice guidelines for land use, land use change and forestry.

- [31] Khalil, M.I., A.B. Rosenani, O. Van Cleemput, C.I. Fauziah and J. Shamshuddin (2002). Nitrous oxide emissions from an ultisol of the humid tropics under maize-groundnut rotation. *Journal of Environmental Quality* 31: 1071-1078.
- [32] Lamade E. and J.P. Bouillet (2005). Carbon storage and global change: the role of oil palm. *OCL*, Volume 12 no2, March-April 2005.
- [33] Larson, E.D. (2006). A review of life-cycle analysis studies on liquid biofuel systems for the transport sector. *Energy for Sustainable Development*. Volume X No 2, June 2006.
- [34] Lord, S., M.K. Hoare and N.M. Thompson (2002) Composting for zero discharge_ NBPOL's solution. International Oil Palm Conference and Exhibition, Bali, Indonesia 8-12 July 2002
- [35] Melling L, Goh KJ, Beauvais C, Hatono R (2007). Carbon flow and budget in a young mature oil palm agroecosystem on deep tropical peat. In: *Carbon climate human interaction on tropical peatland. Proceedings of the International Symposium and Workshop on Tropical Peatland, Yogyakarta, 27-29 August 2007* (eds. Rieley JO, Banks CJ, RAdjagukguk B).
- [36] Melling L, Hatano R, Goh KJ (2005). Soil CO₂ flux from three ecosystems in tropical peatland of Sarawak, Malaysia. *Tellus*, 57B, 1-11.
- [37] M. Mohamed, E. Padmanabhan, B.L.H. Mie and W.B. Siong (2002). The peat soils of Sarawak. *University Malaysia Sarawak* March 2002.
- [38] Muruyama S, Bakar ZA (1996). Decomposition of tropical peat soils. Estimation of in situ decomposition by measurement of CO₂-flux. *Japan Agricultural Research Quarterly*, 30, 153-158.
- [39] Nikander, S. Greenhouse gas and energy intensity of product chain: case transport biofuel. MSc Thesis, Helsinki University of Technology. Helsinki (Finland), May 2008.
- [40] Noormahayu, M.N., A.R. Khalid and M.A. Elsadig (2009). Financial assessment of oil palm cultivation on peatland in Selangor, Malaysia. In: *Mires and Peat*, Volume 5 (2009), Article 2.
- [41] Reijnders L., Huijbregts MAJ (2008). Palm oil and the emission of carbon-based greenhouse gases. *Journal of Cleaner Production*, 16, 477-482.
- [42] Renewable Fuels Agency (2008). Carbon and sustainability reporting within the renewable transport fuel obligation – Technical guidance part one & part two. Office of the Renewable Fuels Agency (UK), August 2008.
- [43] RSPO – PNG National Implementation Working Group (2007). Indicators and guidance required to establish the RSPO Principles and Criteria. November 2007.
- [44] RSPO – Indonesian National Interpretation Working Group (2008). National interpretation of RSPO Principles & Criteria for Sustainable Palm Oil Production – Republic of Indonesia. May 2008.
- [45] RSPO – Malaysian National Interpretation Working Group (2008). Indicators and guidance to establish the RSPO Principles & Criteria. April 2008.

- [46] Schuchardt F., K. Wulfert, D. Darnoko and T. Herawan (2008). Effect of new palm oil mill processes on the EFB and POME utilization. *Journal of Oil Palm Research – Special Issue*, October 2008.
- [47] Schuchardt F., D. Darnoko and P. Guritno (2002). Composting of empty oil palm fruit bunch (EFB) with simultaneous evaporation of oil mill waste water (POME). *International Oil Palm Conference*, Nusa Dua, Bali, July 8-12, 2002.
- [48] Searchinger T. et al. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change. *Scienceexpress*, 7 February 2008.
- [49] SenterNovem (2005). Participative LCA on biofuels. Utrecht (the Netherlands), 2005. (Report 2GAVE-05.08)
- [50] SIRIM Berhad (2007). Development of LCI for biofuel production from palm oil (Presentation, exact date and author unknown).
- [51] Vasander H., Jauhiainen J. (2008) Uncertainties, deficiencies and unknowns in greenhouse gas emissions from tropical peatlands. *Tropical Peatland*, ...
- [52] Vries de, S.C. (2008) The biofuel debate and fossil energy use in palm oil production: a critique of Reijnders and Huijbregts 2007. *Journal of Cleaner Production* 16 (2008) 1927-1927.
- [53] Wahid Mohd Basri, Chan Kook Weng, Choo Yuen May, Chow Mee Chin (2006). The need to reduce national greenhouse gases emissions: oil palm industry's role. *Journal of oil palm research*, April 2006.
- [54] Wahid Mod Basri, Siti Nor Akmar Abdullah and I.E. Henson (2004). Oil palm – achievements and potential. 4th International Crop Science Congress, October 2004 (Brisbane, Australia).
- [55] Wicke B, Dornburg V, Junginger M, Faaij M (2008). Different palm oil production systems for energy purposes and their greenhouse gas implications. *Biomass and Bioenergy*, 32, 1322-1337.
- [56] Wijbrans and Van Zutphen (2005). Environmental impact study for the combustion of palm fatty acid distillate in a power plant. Zwolle (the Netherlands), May 2005.
- [57] Wilson D., Alm J., Liane J., Byrne K.A., Farrel E.P., Tuitila E-S (2008). Rewetting of cutaway peatlands: are we re-creating hot spots of methane emissions? *Restoration ecology*, doi: 10.1111/j.1526-100X.2008.00416.x.
- [58] Wood B.J. and R.H.V. Corley (1993). The energy balance of oil palm cultivation. In: *Proceedings 1991 PORIM International Palm oil Conference- Agriculture*. Palm Oil Research Institute Malaysia, Kuala Lumpur, pp 130-143.
- [59] Wösten J.H.M., A.B. Ismail and A.L.M van Wijk (1997). Peat subsidence and its practical implications: a case study in Malaysia. *Geoderma*, 78, 25-36.
- [60] Yacob S., M.A. Hassan, Y. Shirai, M. Wakisaka, S. Subash (2006). Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. *Science of the Total Environment* 366 (2006), 187 – 196.

[61] Yacob S., M.A. Hassan, Y. Shirai, M. Wakisaka, S. Subash (2005). Baseline study of methane emission from open digesting tanks of palm oil mill effluent treatment. *Chemosphere* 59 (2005), 1575-1581.

[62] Yusoff, S. (2006) Renewable energy from palm oil – innovation on effective utilization of waste. *Journal of cleaner production* 14 (2006) 87-93.

[63] Yusoff, S. and S Hansen (2005). Feasibility study of performing a life cycle assessment on crude palm oil production in Malaysia. *International Journal on LCA*, 2005.

[64] Zah, R., H. Böni, M. Gauch, R. Hischer, M. Lehmann and P. Wäger. Life cycle assessment of energy products: environmental assessment of biofuels. Empa, St. Gallen (Switzerland), May 2007.

Appendix 1

Methodology followed to carry out the Feasibility
Study

Appendix 1

Composition of RSPO Working Group on GHG

RSPO Category	Name of expert	Organisation
Oil palm growers	Purboyo Guritno	PT Makin Group
	Ong Kim Pin	Kulim Berhad
	Mamat Salleh	MPOA / RSPO EB
	Chew Jit Seng	MPOA (alternate) /RSPO EB
	Jean-Charles Jacquemard	PT Socfindo
Palm oil processors/traders	Dr Klimes	ADM
	UR Unnithan	Carotina Sdn Bhd
	Kaisa Hietala	Neste Oil
	Riitta Lempiainen	Neste Oil (alternate)
NGOs	Faizal Parish	Global Environment Center
	Suzana Mokheri	Global Environment Center (alternate)
	Sander van Bennekom	OxfamNovib
	Norman Jiwan	Sawit Watch/RSPO EB
	Bambang H. Saharjo	Sawit Watch (alternate)
	Marcel Silvius	Wetlands International
	Tim Killeen	Conservation International/ RSPO EB
Consumer goods/retailers	Jonathan Fursland	Royal Dutch Shell
	Amir Abdul Manan	Royal Dutch Shell (alternate)
	Sarah Sim	Unilever
	Llorenc Mila-i-Canals	Unilever (alternate)
Banks & Investors	Ken MacDicken	IFC
Technical experts	Niels Wielaard	Sarvision
	Simon Lord	Global Sustainability Associates
	Petra Meekers	Global Sustainability Associates (alternate)
	Dr Puah Chew Wei	MPOB
	Dr Chen Sau Soon	SIRIM
	B.G. Yeoh	Eco Securities Malaysia Sdn Bhd
	Robert Cheong	TUV Nord
	Yohannes Samosir	Indonesian Palm Oil Research Institute
	Ian Henson	Independent consultant

Observers at first Working Group meeting

Name	Organisation/Affiliation
Dr. Vengeta Rao	RSPO Secretary General
Ms. Jutta Poetz	RSPO Secretariat Biodiversity Coordinator/New Plantings Working Group
Darrel Webber	WWF Malaysia

GHG Working Group chairman & facilitator: Arjen Brinkmann (Brinkmann Consultancy)

Appendix 2

Glossary

Above-ground biomass: All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.

Afforestation: planting of new forests on lands that historically have not contained forests.

Below-ground biomass: All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter.

Biomass: the biodegradable fraction of products, waste and residues from biological origin from agriculture, forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.

Canopy cover: The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants. Cannot exceed 100%. (Also called crown closure).

Carbon compensation project: a project dedicated to 'offset' greenhouse gases emissions from another organisation's project, which overall results in less carbon dioxide or other greenhouse gases in the atmosphere than would otherwise occur.

Carbon sequestration: The process of removing carbon from the atmosphere and depositing it in a reservoir.

Carbon stock: The quantity of carbon in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon. Examples of carbon pools are living biomass (including above and below-ground biomass), dead organic matter (including dead wood and litter) and peat soils.

Carbon dioxide equivalent: a measure used to compare different greenhouse gases based on their global warming potentials (GWPs). The GWPs are calculated as the ratio of the radiative forcing of one kilogram greenhouse gas emitted to the atmosphere to that from one kilogramme CO₂ over a period of time (usually 100 years).

Clean Development Mechanism (CDM): A mechanism under the Kyoto Protocol through which developed countries may finance greenhouse-gas emission reduction or removal projects in developing countries, and receive credits for doing so which they may apply towards meeting mandatory limits on their own emissions.

Degraded forest: forest that has lost biomass after logging, fire, or some combination of the two.

Greenhouse gases (GHGs): The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Less prevalent --but very powerful -- greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆).

Peat soils: soils that have 50 cm or more organic soil matter within 100.

Reforestation: Replanting of forests on lands that have previously contained forests but that have been converted to some other use.

Remote sensing: practice of acquiring and using data from satellites and aerial photography to infer or measure land cover/use. May be used in combination with ground surveys to check the accuracy of interpretation.

Secondary forest: Forest regenerated largely through natural processes after significant human ('slash and burn') or natural disturbance of the original forest vegetation.

Sequestration: a process, activity or mechanism which removes a greenhouse gas from the atmosphere.

Appendix 3

Measuring carbon stocks

Background carbon stock and canopy cover measurements GHG emission WG
Draft version 18-06-2009. Niels Wielaard, SarVision

Applicable measurement approaches

As noted in the paper of Goetz et al that I contributed “attempts to map above ground biomass without satellite imagery are insufficient”. In my opinion, *solely* relying on ground assessments should not be recommended for assessing compliance with sustainable oil palm production:

1. The number of locations that can be assessed within in the framework of a social and environmental impact assessment will likely be insufficient and its spatial coverage limited. For relevant and accurate biomass indications, vegetation stratification is required first to do field measurements in representative areas. Such stratification is commonly based on... satellite data.
2. Stocks which are easiest to measure, i.e. forest carbon stocks using tree measurements of diameter at breast height (DBH) are NOT the primary focus of measurements. The focus of measurements should be lands with carbon stocks below 35 to 70 tonnes carbon/ha. Such areas will mostly be shrublands with an excessive number of stems with (very) small DBH or grassland that can not be surveyed using DBH measurements.
3. It is not possible to do field measurements in the past, would it be required. It is not possible to perform measurements in all places that will be converted to plantations just before or after the cut-off dates such as January 2008, 2010 or any other proposed by country systems (e.g. UK, Netherlands), EU RED, or the revised RSPO P&C.

Leading scientists have developed recommendations for credible carbon measurements using a combination of field measurements and satellite/airborne sensor data. Guidance is documented in the GOFC GOLD source book (<http://www.gofc-gold.uni-jena.de/redd/index.php>), developed to complement the IPCC Good Practice Guidance (IPCC, 2003) and IPCC Guidelines (IPCC, 2006) by providing additional explanation, clarification and enhanced methodologies for obtaining and analyzing key data. GOFC GOLD is a platform of leading forest monitoring experts (space agencies, institutes, industry). Australia has already developed an operational National Carbon Accounting System, in which satellite-based land cover maps are playing a key role (AGO, 2009). This approach is currently adapted and transferred to tropical regions, including Indonesia. This work is coordinated within the framework of a new initiative of the Group on Earth Observation (GEO). GEO is an international collaborative effort of over 78 countries, institutes and space agencies, initiated by the G8. GEO has defined a ‘Forest Carbon Tracking task’ (<http://geo-fct.org/>), aiming to establish an operational independent global carbon information system, integrating national level systems. Its objectives are:

- (i) to demonstrate that coordinated Earth observations can provide reliable information of suitable consistency, accuracy and continuity to support forest carbon monitoring, reporting and verification;
- (ii) to define a set of standards and requirements that any methodology should adopt to provide the most accurate results relying on the full potential of existing observational and processing capabilities.

Obviously, the oil palm sector could benefit much from carbon stock information resulting from the GEO Forest Carbon Tracking task, and technical guidance by GOFC GOLD.

Mapping carbon stocks

Of the credible, internationally accepted wide area carbon stock assessment approaches that exist, the following are most applicable (GOFC GOLD, 2008, CIFOR, 2008):

1. indirect measurement: using field measurement data in combination with land cover/vegetation type data derived from satellite imagery;
2. indirect measurement: using field measurement data in combination with land cover/vegetation type data derived from satellite imagery and other spatial data for spatially explicit modeling of carbon stocks;
3. direct measurement: using biomass information detected more directly from the (radar) satellite signal (i.e. without the requirement to use land cover/vegetation type maps as a proxy by assigning biomass values to each thematic type class).

Appendix 3 (Continuation 50)

Indirect measurement

The lack of clear and agreed definitions of land cover vegetation types currently leads to much confusion. For example, there is a lot of debate and dispute as to whether forest earmarked for conversion to plantation is 'degraded' or not.

This problem might be addressed by adhering to the classes proposed by IPCC. IPCC has identified six broad 'high-level' categories of land use consistent with the IPCC Guidelines, to be reported at the national level. These include forest land, cropland, grassland, wetlands, settlements, and other land. According to IPCC it is good practice to specify national definitions for all categories used in the inventory and report any threshold or parameter values used in the definitions. Furthermore, it is good practice to make locally relevant additional classes subcategories of the suggested high-level categories. This could include well described and therefore objectively measurable shrubland or 'degraded' forest classes. The 30% canopy cover threshold as defined by the EU RED is also useful to distinguish forest from 'degraded' forest.

The oil palm sector could use such IPCC maps when made available by national governments in compliance with UN climate convention requirements.

To further address the definition problem, the FAO has developed a classification 'language' to operationalize the definition of thematic map class descriptions in terms of objectively measurable parameters; e.g. canopy cover, number of months flooded, etc. This so-called FAO Land Cover Classification System (LCCS - <http://www.glcnlccs.org/>) is applicable to all climatic zones and environmental conditions and compatible with existing classification systems developed by countries. LCCS has been submitted to become an international standard through the TC 211 technical committee of the International Organization for Standardization (ISO).

Direct measurement

Traditionally used satellite sensors (e.g. landsat) can not be used for accurate direct measurement of biomass. The direct relationship between radar sensors and biomass has been investigated since the early 90's (LeToan et al, 1992; Beaudoin et al 1994; Imhoff, 1995; LeToan et al 2004). Studies from Malaysia also indicate that radar data can be used as an indicator for biomass (Hazim and Kadir, 1999). Currently operational satellite radar can be used to measure biomass up to 50-100 ton/ha. *Forest* biomass can not be reliably measured directly as the satellite signal saturates beyond 100 ton/ha. The proposed time averaged carbon stock of oil palm, as well as bare areas, grassland and shrublands however, is within the range that can be measured. Measurement error is typically in the order of 20 tons/ha (e.g. Pierce *et al.* 2002), which is relatively large. Nevertheless, if only a simple scheme is used identifying bare areas, grassland, shrubland, mature plantations and forest it should be acceptable as a proxy.

Satellite lidar (laser) is very promising, but will not be operationally available in the next few years. Airborne radar (Hoekman and Quiñones, 2002; Santos et al, 2003) and airborne lidar (Lucas et al, 2006; Boudreau et al, 2008) are readily available and will provide much more accurate results, but at high cost.

Mapping canopy cover

The mapping of canopy cover (required to demonstrate compliance with the EU RED 30% threshold for continuously forested areas) is relatively straightforward. Very high resolution satellite data or aerial photography (at 0.10 – 2.5m spatial resolution) can be used to identify individual trees. Using visual analysis or computer classification, tree crown cover can be classified at full resolution and results aggregated to canopy cover percentages over larger spatial units required (e.g. per hectare). This is common practice in Australia (AGO, 2009) and Malaysia (e.g. Ming, 2003). Other studies have demonstrated it is also well possible to extrapolate local very high resolution canopy cover mapping results to regional and even global scale with acceptable accuracy (Hansen et al, 2002).

In addition, techniques have been developed to classify canopy cover using widely used satellite sensors such as 30m spatial resolution Landsat-type data (Joshi et al, 2005). The development of one of such freely available techniques, Forest Canopy Density mapping (Rikimaru et al, 2002), has been funded by ITTO and applied by government agencies in Sabah and Indonesia. A consistent, yet approximate, application should suffice.

Accuracy of measurements

Appendix 3 (Continuation 51)

Carbon stock measurement can and does not have to be perfect from the start, as long as commitment to continuous improvement is assured. Despite known uncertainties, experts agree that well documented techniques and satellite data are available for reliable mapping of carbon stocks over large areas. Applicable techniques and data have been published in refereed scientific literature and are progressing rapidly (Goetz et al, 2008).

The Voluntary Carbon Standard for credible carbon offset trading recommends that “*When highly uncertain data and information are relied upon, the project proponent shall select assumptions and values that ensure that the quantification does not lead to an overestimation of GHG emission reductions or removal enhancements.*” The IPCC good practice guidance supports the development of inventories that are “transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and assurance, efficient in the use of resources available to inventory agencies,” and last but not least, “*in which uncertainties are reduced as better information becomes available*”.

The situation with respect to accuracy will improve further as new satellite missions and approaches come online in the next few years, several of which are designed specifically with the intent of improving estimates of the standing stock of carbon in biomass, and changes in those stocks through time (Houghton and Goetz, 2008).

References

AGO, 2009. URL: <http://www.climatechange.gov.au/ncas/activities/landcover.html>

Beaudoin, A., Le Toan, T., Goze, S., Nezry, E., Lopes, A., Mougin, E., Hsu, C.C., Han, H.C., Kong, J.A., Shin, R.T., Retrieval of forest biomass from SAR data. *International Journal of Remote Sensing*, (14), 2777 – 2796, 1994.

Goetz, S., A. Baccini, N. Laporte, T. Johns, W. Walker, J. Kellndorfer, R. A. Houghton, 2008. Mapping and Monitoring Carbon Stocks with Satellite Observations: An Update

Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF), to support the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) URL: http://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf_contents.html

Hazim and Kadir, 1999. Comparison of JERS-1 and Radarsat Synthetic Aperture Radar Data for Mapping Mangrove and Its Biomass. URL <http://www.gisdevelopment.net/aars/acrs/1999/ps3/ps300e.asp>

Hoekman, D.H., Quiñones, M.J., Land Cover Type and Biomass Classification Using AirSAR Data for Evaluation of Monitoring Scenarios in the Colombian Amazon. *IEEE Transactions on Geoscience and Remote Sensing* 38 (2), 685 – 696, 2002.

Houghton, R.A. and S.J. Goetz, 2008. New satellites offer a better approach for determining sources and sinks of carbon. *Eos Transactions of the American Geophysical Union* (43): 417-418, 21 Oct 2008

Imhoff, M.L., Radar backscatter and biomass saturation: ramifications for global biomass inventory. *IEEE Transactions on Geoscience and Remote Sensing*, 33(2), 511-518, 1995.

IPCC. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF). Available at <http://www.ipcc-nggip.iges.or.jp/>

IPCC. 2006. Guidelines for National Greenhouse Gas Inventories – Volume 4: Agriculture, Land Use and Forestry (AFOLU). Available at <http://www.ipcc-nggip.iges.or.jp/>

Le Toan, T., Beaudoin, A., Riom, J., & Guyon, D., Relating forest biomass to SAR data. *IEEE Transactions on Geoscience and Remote Sensing*, 30(2), 403-411, 1992.

Appendix 3 (Continuation 52)

Le Toan T, Quegan S, Woodward I, Lomas M, Delbart N and Picard C 2004 Relating radar remote sensing of biomass to modeling of forest carbon budgets *Clim. Change* 76 379–402

Lucas, R.M., Cronin, N., Lee, A., Moghaddam, M., Witte, C. & Tickle, P. 2006. Empirical relationships between AIRSAR backscatter and LiDAR-derived forest biomass, Queensland, Australia. *Remote Sensing of Environment*, 100, 407-425.

Lucas, R.M., Cronin, N., Moghaddam, M., Lee, A., Armston, J., Bunting, P. and Witte, C., Integration of Radar and Landsat-derived Foliage Projected Cover for Woody Regrowth Mapping, Queensland, Australia, *Remote Sensing of Environment*, 100, 407-425, 2006.

Lucas, R.M., Mitchell, A.L., Rosenqvist, A., Proisy, C., Melius, A. and Ticehurst, C., 2007. The potential of L-band SAR for quantifying mangrove characteristics and change. Case studies from the tropics and subtropics. *Aquatic conservation: marine and freshwater ecosystems - Special Issue: Radar Applications for Wetlands Management*. 17, 245-264, 2007.

Pierce, L.; Pan Liang; Dobson, M.C., 2002. Regrowth biomass estimation in the amazon using JERS-1/RADARSAT SAR composites. *Geoscience and Remote Sensing Symposium, 2002. IGARSS apos;02. 2002 IEEE International Volume 4, Issue , 24-28 June 2002 Page(s): 2075 - 2077 vol.4*

Santos, J.R., Freitas, C.C., Araujo, L.S., Dutra, L., Mura, J.C., Gama, F.F., Soler, L.S., & Sant'Anna, S.J.S., Airborne P-band SAR applied to aboveground biomass studies in the Brazilian tropical rainforest. *Remote Sensing of Environment*, 87, 482-493, 2003.