Greenhouse Gas Emissions from Palm Oil Production

Literature review and proposals from the RSPO Working Group on Greenhouse Gases

Final report

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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, there is an increasing demand for GHG emission information of products placed on the market. For example, European governments under the Renewable Energy Directive request GHG emission information of biofuels placed on the market, while international retailers are increasingly studying the 'carbon footprint' of the ingredients they use in food and cosmetics. In 2005, these developments were just about to start.

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, RSPO has concluded 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 (WG-GHG), for which Brinkmann Consultancy was appointed as independent facilitator. The Terms of Reference of the Working Group have been included in Appendix I. The composition of the Working Group has been detailed in Appendix II.

Procedure followed by the GHG-WG

Between March and May 2009, Brinkmann Consultancy executed an extensive literature study on GHG emissions from palm oil production. Working Group members from all RSPO constituencies provided input to this study. The results of this study have formed the basis for further discussions in the GHG-WG.

In May 2009, the GHG-WG held its first meeting. The GHG-WG's preliminary proposals arising from this meeting, were summarized in the report 'Greenhouse gas emissions from palm oil production – literature review and recommendations for amendment of RSPO Principles & Criteria', dated 6 July 2009. This document was then published on the RSPO website for a consultation period of 60 days (10 July – 10 September 2009), although there were some objections particularly from producers' representatives in the GHG-WG.

During the 60 days consultation period, some 25 stakeholders –both RSPO members and non-RSPO members- presented their views through written submissions (available on www.rspo.org). In addition, two well-attended stakeholder meetings were held in Jakarta (7 September 2009) and Sibu, Sarawak (9 September 2009). The inputs received during the public consultation were reviewed by the GHG-WG during its second meeting on 10 and 11 May 2009.

During its second meeting, the Working Group again discussed the literature review. Most GHG-WG members felt that the literature was comprehensive and provided an objective overview of the issues pertaining to GHG emissions from the production and processing of palm oil. However, a group of stakeholders led by GAPKI and MPOA expressed their opinion that further work was needed.
Also during the second meeting, the GHG-WG discussed several proposals to the Executive Board, which have been summarized in this report. These proposals supersede the (preliminary) proposals summarized in the public consultation document of 6 July 2009.

After the public consultation meeting in Jakarta, Indonesian producers felt that their ability to respond to the public consultation document had been seriously hindered by the absence of a translated version, and also because translation had not been available during (the first part of) the consultation meeting.
The president of the Executive Board then decided to extend the consultation period with a period of 20 days, until 30 September 2009. Due to time constraints, views submitted during the extended period of public consultation were not reviewed by the GHG-WG within its current mandate, but were directly submitted to the Executive Board. The Executive Board, on the basis of the GHG-WG's proposals and the additional input to the public consultation, will in October/November 2009 decide on further steps.

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, executed by Brinkmann Consultancy with inputs from the GHG-WG. Chapter 3 includes the GHG-WG's proposals to the RSPO Executive Board.

N.B. As stated above, the proposals outlined in this document supersede the draft proposals outlined in the document 'Greenhouse gas emissions from palm oil production – literature review and proposals for amendment of RSPO Principles & Criteria', dated 6 July 2009.

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 'Reference list').

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 submitted publications which they thought would be relevant in the framework of the literature review. Additional literature has been collected by Brinkmann Consultancy through internet search and via scientific libraries.

The literature collected and reviewed does not provide full coverage of all existing, potentially relevant, publications. However, the author believes 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 on the subject.
As stated in Chapter 1, most GHG-WG members felt that the literature was comprehensive and provided an objective overview of the issues pertaining to GHG emissions from the production of palm oil. However, a group of stakeholders led by GAPKI and MPOA expressed their opinion that further work was needed.

The main findings of the literature review have been summarized in this Chapter.

2.2 Results -qualitatively

2.2.1 Type of documents

The documents reviewed vary considerably in scope and size, and can 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 [33]). This includes also studies which have been carried out for the development of 'CO_2-tools' by various European governments (Refer e.g. to [8], [27], [59], [41]);
- Studies which focus primarily on changes in carbon stocks, when palm oil plantations replace other land uses (Refer e.g. to [9], [22] and [33]);
- Studies which focus on environmental impacts, including GHG emissions, of operations at oil palm plantations and palm oil mills (Refer e.g. to [64]);
- 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], [41], [44]:

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 [41] has estimated diesel consumption at 58-70 liters per hectare per year, and CO_2-eq emissions at 3.1 kg CO_2-eq per liter diesel, equaling 180-217 kg CO_2-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 CO_2-eq/TJ diesel). At their assumed FFB yield of 20 tonnes/ha this leads to a CO_2-eq emission of 36 kg CO_2-eq/ha*yr. This figure only covers FFB transport from harvest to mill.

Wood and Corley [61] have estimated energy use for vehicles and machinery at 4.7 GJ/ha*yr. Assuming a specific emission of 0.086 kg CO_2-eq/MJ diesel, this would however result in an annual emission of 404 kg CO_2-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 CO_2-eq/ton diesel, resulting in an emission of 225 kg CO_2-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 CO_2-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 CO_2.

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 (P_2O_5), potassium chloride (K_2O) 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 [41]	ERIA [11]
Ammonium nitrate (kg N/ha/yr)	100	-	96-100	93
Ammonium sulphate (kg N/ha/yr)	--	88.2	-	-
Phosphate rock (kg P_2O_5/ha/yr)	45	34.6	28-45	114
Potassium chloride (kg K_2O/ha/yr)	205	252.0	172-205	200
Kieserite (kg MgO/ha/yr)	50	39.2	33-48	27

In the framework of a LCA study [4], Chen has 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] [41], [44]:

- 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;
- N_2O emissions which occur during the application of nitrogen fertilizer. According to IPCC guidelines [27] 1% N_2O-N of total N applied is emitted during fertilizer application. The Global Warming Potential of N_2O is 296 times stronger than CO_2.

Nikander [41] has estimated overall greenhouse gas emissions from fertilizer and pesticide use between 1,086 and 1,500 kg CO_2-eq/ha*yr. N_2O emissions during application of nitrogen fertilizer have been calculated at 616 kg CO_2-eq/ha*yr, which amounts to 40-60% of total fertilizer related GHG emissions.

Wijbrans and Van Zutphen [59] have estimated total GHG emissions related to the use of chemical fertilizers at 1,409 kg CO_2-eq/ha*yr.

The default value of the greenhouse gas calculator of the UK Renewable Fuels Agency [44] is also in the range of 1,000 - 1,500 kg CO_2-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 CO_2-eq emissions related to the use of the fertilizer mix equal 17.3 kg CO_2-eq/tonne FFB or, at 19 tonnes FFB/ha*yr, 330 kg CO_2-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. [56] 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. [38]).

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 CO_2-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 CO_2-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 CO_2 are considered negligible, the energy generation process is CO_2-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], [41], [51]) 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 [43].

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 the useful 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 (CH_4), which represents a substantial GHG emission source. Most studies indicate a typical methane content in biogas of 65% (e.g. [56], [8], [44]). Yacob et al. ([63] and [64]), 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 and Van Zutphen [59] have calculated that the POME methane release equals 9 kg/tonne FFB (at 0.7 m^3 POME/tonne FFB, 28 m^3 biogas/m^3 POME and 65% CH_4 in the biogas). This results in considerable extra GHG emissions of 190 kg CO_2-eq per tonne FFB. The figure of 28 m^3 CH_4/ m^3 POME has also been mentioned by others as a ‘common practice’ figure (e.g.[8] and [44]).

Nikander [41] has used a POME emissions range of 2,500 - 3,800 kg CO_2-eq/ha*yr.

ERIA [11] has specified a POME generation rate of 0.7m^3/tonne FFB, 28 m^3 of biogas/tonne of POME (with 65% CH_4), and 19 tonne FFB/ha/yr.

Yacob et al. ([63] and [64]) have calculated a methane emission of 5.5 kg CH_4/tonne POME discharged, equaling, some 9 m^3 CH_4/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 CO_2, 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 ([63] and [64]).

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. ([48] and [50]) have demonstrated that this technology has the potentially to significantly reduce POME quantities, while Lord et al. [35] 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 CO_2-eq per ha*yr, or 625 – 1,467 kg CO_2-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). Finally, literature data on carbon stocks from other landscapes have been summarized (Section 2.4.2.5).

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 IPPC [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 IPPC 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 CO_2. 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 in included in the IPCC methodology [29].

The CO_2 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 CO_2-eq/ha grassland, and 627 +/-326.3 tonnes CO_2-eq/ha of primary 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 primary 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 CO_2-eq per hectare of grassland, and 648.0 +/- 337.2 tonnes CO_2-eq per hectare of primary 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 primary 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 CO_2-eq/ha. GHG emissions from removal of aboveground and underground biomass in tropical grasslands are in the order of 43 +/-28 tonne CO_2-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.

2.4.2.5 Carbon stocks on other forest landscapes

Morel [39] has summarized data of above ground carbon stocks of different forested land covers in Sabah. She found aboveground carbon stocks of unlogged forest to be around 278 tonnes C/ha, and aboveground carbon stocks of logged forest in the range of 101 – 158 tonnes C/ha, depending on the year of logging. The Sabah Forest Research Centre measured aboveground carbon values ranging from 51 to 84 tonnes C/ha, for high to low disturbed forests.

Morel [39] has also quoted a range of biomass values reported in literature for a number of forested land cover types across Malaysia and Indonesia. These have been summarized in Table 2.2 below.

Table 2.2 Carbon values reported for a number of forested land cover types [39].

Forest Type	**Tonnes carbon/ha**
Peninsular Malaysia	
Logged hill	90
Forest fallow	70
Freshwater swamp	110
Disturbed freshwater swamp	142.5
Borneo – Sarawak	
Mixed diterocarps-dense stocking (flat to undulating)	162.5-192.5
Mixed dipterocarps –dense stocking (mountainous)	330-405
Borneo – Sabah	
Lowland Dipterocarp (logged and unlogged)	32-323.9
Borneo – Kalimantan	
Fallows (range of years since cleared)	13-25.5

Conclusion: The carbon stocks of logged over forests, and forests with various levels of disturbance, show large variations and generally appear to be in between the 'extreme' values of undisturbed primary forests and grasslands, as highlighted in the previous sections.

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 (Syahrinudin, 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 CO_2-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

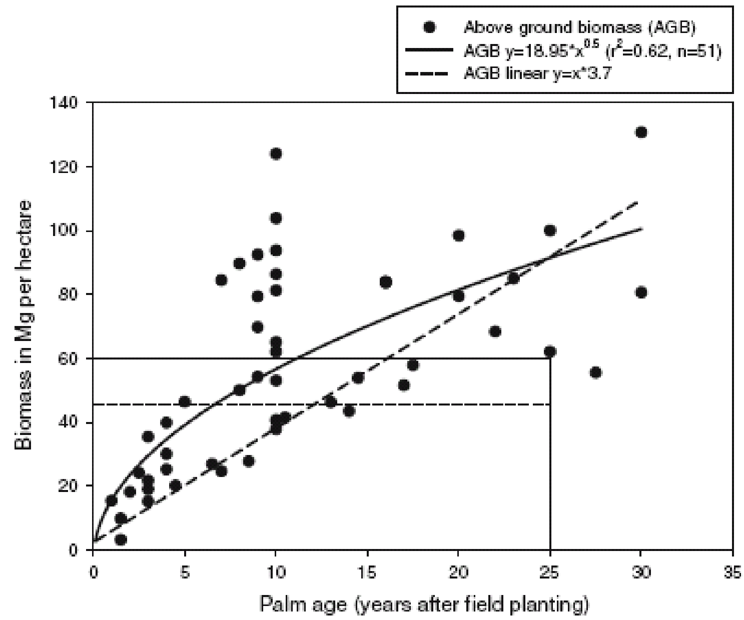

Figure 1. Increase in biomass (tonnes/ha) as a function of palm age [13].

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 CO_2-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).

Morel [39], on the basis of field measurements at oil palm plantings in Sabah, calculated a weighed averaged value of 24.2 tonnes carbon/ha for aboveground biomass, assuming a 25 year planting period.

Syahranudin [49] found a value of 84.6 tonnes carbon/ha for 30 years palm oil plantings, of which 62.8 tonnes C/ha was aboveground biomass, and 21.8 tonnes C/ha was underground biomass. Jiwan and Saharjo [31] found an aboveground carbon stock of approximately 40 tonnes/ha, for a 25 year oil palm plantings in East Kalimantan. Both studies have not calculated time averaged carbon stocks on oil palm plantings.

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 appears to be in the order of 35 tonnes carbon/ha, calculated over a 25-30 years standing period. Some literature sources quote higher time averaged figures, while others quote lower figures. 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, CO_2 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. [38] 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 Histosoils. 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.peatsociety.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 [54]). 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.

CO_2-emissions increase with drainage depth, with a figure of 9 tonnes of additional CO_2 emission for every extra 10 cm drainage depth quoted by various authors (e.g. [61]). 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. CO_2-emissions increase with drainage depth.

The database of CO_2-emission values from drainage and fire is still poor. Most published CO_2 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 [54] and Melling et al. [36], 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 CO_2 emission from peat soils, these studies are inadequate for determining net emissions from peat oxidation.

Melling et al. [36] 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 CO_2/m^2*yr. The measurement method (chamber design and sampling method) tends to underestimate CO_2 fluxes by 15-20% [36] or more, however, which means that the actual flux may amount to more than 4.9 kg CO_2/m^2*yr.

Other, longer term lifecycle analyses also all arrive at clearly negative values for CO_2 emissions from peat degradation, e.g. 1.8 kg CO_2/m^2*yr [15], 3.7-5.5 kg CO_2/m^2*annum [43], 3.9 kg CO_2/m^2*yr [58], and 5.5-7.3 kg CO_2/m^2*yr [13]. Muruyama and Bakar [44] have estimated a CO_2-emissions of oil palm plantations on peat of 54 tonnes CO_2-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 [61] and 9.17 tonnes carbon/ha/yr [36]. This equals emissions of approximately 25 to 35 tonnes CO_2-eq/ha*yr.

Conclusion: There is a large variety of quantitative data on CO_2-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 CO_2/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 CO_2/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 N_2O and methane, the following appears from literature:

- Nitrous oxide emissions from primary and secondary forest sites vary between -63 µg N_2O/m^2*hour, and 916 µg N_2O/m^2*hour, with 90% of the measured values below 125 µg N_2O/m^2*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 CO_2 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 N_2O emissions from both natural peatlands and from oil palm plantations on peat, are limited.

Vasander and Jauhiainen [54], 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 2.3.

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 2.3 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:
[1]A positive sign indicates a net increase in carbon stock
[2]Peat 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 none-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 CO_2-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 CO_2-eq/ha/yr from oxidative peat decomposition'….'Peatland of average depth (3m) could release peat-derived CO_2-eq for about 120 years. Total net carbon released would be approximately 6,000 tonne/ha of CO_2-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 2.4 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	Frond 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 2.5 GHG emissions from palm oil production, including emissions from carbon stock changes (all emissions on a kg CO_2-eq/ha and kg CO_2-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	-
Total operations	*+4,180 to +6,225*	*+920 to + 2,007*	-
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	-
Total emissions related to carbon stock change	*+12,040 to +90,340*	*+3,010 to + 28,233*	-
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. [67], 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 CO_2 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 [41] 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 CO_2-eq/tonne palm oil.

The (conservative) default values in the RFA CO_2-calculation tool [44], for over land transport of palm oil (mill to port) and overseas transport, have been summarized below:

Table 2.6 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 CO_2-calculation tool [44] specifies conservative default values for refinery of CPO in Asia, which have been summarized below:

Table 2.7 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
		Total	*156-242 kg CO_2-eq/tonne*

Based on the data mentioned in [58], a refinery related GHG emission of 75 kg CO_2-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. Based on the literature data reviewed, 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 Proposals by the GHG Working Group

3.1 Introduction

This chapter summarises the proposals from the GHG-WG. The following proposals were discussed, however there was no broad consensus within the GHG-WG on all items discussed, i.e.:

1. Develop a framework for reducing GHG emissions from RSPO certified palm oil (Section 3.2);
2. Amend a number of RSPO Criteria and/or related Indicators and/or Guidance, to better include various aspects of GHG emission (reduction) (Section 3.3);
3. Further study a number of other aspects which impact upon (standards for) GHG emissions from palm oil production, such as indirect land use change and yield increases (Section 3.4);
4. Extend the mandate of the GHG-WG and establish an Expert Group (Section 3.5) to deliberate on the unresolved issues some of which are outlined above, in order to reach a consensus.

3.2 Developing a framework to reduce GHG emissions from palm oil production

The literature review summarized in the public consultation document of 6 July 2009, has categorised GHG emissions from palm oil production as follows:

1. GHG emissions arising from operations during palm oil 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 fertilisers;
   - 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. GHG emissions arising from changes in carbon stock during the development of new plantings;
3. GHG emissions from peat (only when plantings are on peat).

The GHG-WG has noted the literature findings in relation to GHG emissions from operations (category 1), but has not unanimously agreed with the literature study findings in relation to carbon stocks and peat (category 2 and 3). In short, producers' representatives felt that more data collection is required before (quantitative) standards can be set, while non-producers' representatives felt that sufficient evidence was available for the development of (quantitative) standards.

The literature study findings on carbon stocks and peat, as well as views from the stakeholder groups in the GHG-WG, have been summarised below.

3.2.1 Literature study findings on carbon stocks (excluding peat)

The literature review has indicated that the development of new plantings will lead to a change in carbon stocks, depending on the previous land cover. Development of oil palm on grasslands (with mineral soils) will generally lead to an increase of carbon stock (i.e. net CO_2 sequestration) whereas conversion of primary forests to oil palm will lead to a reduction of carbon stock (i.e. a net CO_2 emission). Whether conversion of secondary or degraded forests to oil palm will lead to an increase or a decrease in carbon stocks, depends on the exact carbon stocks of those forests, and the assumed carbon stocks in the oil palm planting.

The scientific literature reported estimated values for aboveground carbon stocks that varied between 25 and 40 tonnes C/ha.
The GHG-WG has not come to a unanimous conclusion as regards the literature review findings on carbon stocks, and potentially necessary amendments of the RSPO P&C.

The non-producers' representatives in the GHG-WG have concluded that the development of new plantings shall not lead to a reduction in carbon stocks. They have suggested that new plantings shall only be developed on land which has a time averaged carbon stock in the order of 35 tonnes/ha (exact figure to be determined accounting for inclusion of underground biomass, precautionary principle, compensation mechanisms etc.).

The producers' representatives in the GHG-WG have doubted the time average carbon stock figure of 35 tonnes/ha, and argued that the time averaged carbon stock of oil palm plantings is highly variable and may strongly depend on local conditions. A thesis by Syahrinudin [49] has been submitted to illustrate the variation. The producers' representatives in the GHG-WG strongly felt that more data need to be collected before a threshold for carbon stocks can be defined.

3.2.2 Literature study findings on peat

In relation to peat, the literature review has concluded the following:

a. In their natural state, tropical peatlands sequester carbon by accumulation in peat and biomass. Drainage and degradation of 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. CO_2-emissions increase with drainage depth;
b. There is a large variety of quantitative data on CO_2-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 CO_2/ha*yr;
c. 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 N_2O emissions from both natural peatlands and from oil palm plantations on peat, are limited;
d. 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 conclusions a-c above, but rather refine and narrow down the data ranges.

The GHG-WG has not come to a unanimous conclusion as regards the literature study findings on GHG emissions from peat, and potentially necessary amendments to the RSPO P&C. One group, including primarily producers' representatives, considered that five years would be needed to organize and execute a further study of peat emissions, while the other group believes that enough information exists to establish that converted peat forests are the source of significant CO_2 emissions and that steps should be taken immediately to reduce those emissions and to avoid new emissions due to the conversion and drainage of peat.

3.2.3 Developing a standard for the carbon intensity of palm oil

Once it appeared that there were strongly divided views on both the quality of available quantitative data and on potential decisions on carbon stocks and peat, the GHG-WG has taken a more qualitative approach. It has concentrated on developing (qualitative) principles for setting carbon standards. Conclusions and recommendations have been summarized below.

The GHG-WG recommends that RSPO develops a framework for reducing GHG emissions caused by the production of palm oil. This framework shall take account of all (potentially) relevant sources of GHG emissions, including in particular emissions from land use change, emissions from peat degradation (if applicable), emissions from POME, etc.

The GHG-WG has agreed that a framework to reduce GHG emissions should be organized around a 'baseline' that is formulated using the ISO 14064 standards for reducing GHG emissions. The unit of measurement for the baseline shall be the holding level of the company. Furthermore, the GHG-WG has agreed that this baseline should be accompanied by a time bound plan (to be specified by the company), which allows companies flexibility in making GHG emission reductions over time, and also the possibility to link emission reductions to trading mechanisms to compensate for lost opportunities and costs associated with making GHG emission reductions.

a. A group of GHG-WG members, led by MPOA and GAPKI representatives, have proposed that the baseline should be based on a company's existing land banks, such that GHG emissions from past, present and future land use change are used to estimate what would occur in a business-as-usual scenario;
b. A group of GHG-WG members, led by Conservation International and Wetlands International representatives, have proposed that the baseline should be based on historical emissions (including those that occurred on high carbon landscapes) so that future emission reductions can be verified objectively;
c. A group of GHG-WG members, led by the Unilever representative, proposed that whatever baseline is selected (either A or B) this should be compared to a standard based on a value that would approximate the emissions of other major vegetable oils. The last suggestion assumes companies would incorporate within their time bound plan a commitment to reduce emissions from their baseline level to this (as yet to be determined) industry-wide carbon intensity standard (tonnes CO_2/tonne CPO).

The GHG-WG recommends that methodological issues in relation to the development of the framework, and issues for which additional data collection is required, shall be solved as a matter of high priority.

The GHG-WG recommends that RSPO studies the feasibility of a mechanism for RSPO internal carbon trading. The Working Group believes that such a mechanism will contribute to the cost effective reduction of overall GHG emissions from RSPO certified producers.
In addition, the GHG-WG recommends that mechanisms be developed which provide incentives/compensation for producers to move away from high carbon stock areas.

The Working Group has discussed the possibility to set a moratorium for certification of new developments on peat, until the required additional data collection and detailing of methodological issues have been executed. One group supported the moratorium option as a means to put pressure on the development of a carbon intensity standard but the producers' representatives opposed the idea as being too restrictive, moreover they felt that the GHG-WG needs to consider the socio-economic implications of the proposed moratorium on the livelihood of the local people who rely on oil palm.

3.3 Proposals for amendments of RSPO Principles & Criteria

In addition to the proposal by one group in the GHG-WG related to the development of a carbon intensity standard (Refer to Section 2.) the Working Group has discussed a number of recommendations for specific amendments to a number of RSPO Criteria, Indicators and related Guidance. In this Chapter, each of the proposed amendments is outlined in detail, i.e.:

- Plans to reduce GHG emissions (3.3.1);
- Fossil fuel use (3.3.2);
- Fertiliser use (3.3.3);
- Palm oil mill residues (3.3.4);
- POME (3.3.5);
- Water management on plantations on peat (3.3.6).

3.3.1 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 resulting from carbon stock changes, treatment/re-use of mill residues (POME, EFB), fertilizers and fossil fuels. A system for the assessment, monitoring and reduction of GHG emissions should be developed based on ISO 14064'

Furthermore, the GHG-WG recommends to add to this Criterion specific Indicators in relation to the ISO 14064 based framework methodology for reducing GHG emissions (refer to Chapter 2).

3.3.2 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 Indicators in the respective national interpretations. The GHG-WG recommends to add to the guidance under Criterion 5.4 that '*Use of sustainable biofuel on plantations should be considered as an alternative to the use of fossil fuel'*

3.3.3 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'.

3.3.4 Palm oil mill residues

<u>Relevant references in current set of P&Cs</u>
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'*.

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 that 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.

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'.

3.3.5 POME

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, in particular methane. 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).

b. Not prescribing a single technology, but instead defining a methane reduction target (% from a certain baseline) or setting a maximum emission (m^3 CH_4/tonne POME).
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.

The GHG-WG has not come to a conclusion as regards the preferred option. Instead, the GHG-WG has concluded that emission reduction from POME shall be dealt with under the umbrella of the ISO 14064 based framework methodology for reducing GHG emissions. Specific indicators on POME might then be included under proposed new Criterion 5.7 ('Plans to reduce GHG emissions').

3.3.6 Water management on plantations on peat

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

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

The National Interpretations specify the following Indicator 4.3.4: '*Subsidence of peat soils should be minimized through an effective and documented water management programme*', 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 Interpretations for Malaysia and Indonesia, this indicator has the status of 'minor compliance issue', where as in the National Interpretation for PNG it has the status of 'major compliance issue'.

In relation to existing plantings on peat, the GHG-WG recommends that in the National Interpretations for Malaysia and Indonesia, the status of this Indicator is amended from 'minor compliance issue' to 'major compliance issue', such as to strengthen the importance of this requirement;

3.4 Other conclusions recommendations

Further to the (specific) recommendations outlined in Chapter 2 and 3, the GHG-WG has formulated a number of more generic conclusions and recommendations in relation to indirect land use change, yield increases, reduction of fires, development of a CSPO market, and biofuel standards in the EU. These recommendations have been summarised in this Chapter.

GHG emissions from indirect land use change

The members of the GHG-WG have discussed the issue of indirect land use change, but have been unable to come to agreement on its significance regarding the palm oil industry. However, they did agree that it would be difficult to address within the current framework of the RSPO P&C, because the system is based on measures taken by individual companies within the context of their operations, whereas indirect land use change, by definition, occurs outside of those operations and are beyond their control. Nonetheless, because this issue has been highlighted by several academic studies and is relevant in current policy discussion in international forums, the members of the GHG-WG have flagged this as an issue in need of further study.

Yield increases
The GHG-WG has concluded that increasing yields has the potential to significantly reduce the overall carbon footprint of palm oil production, as it reduces the need for expansion and carbon stock conversion, and lowers the average GHG emissions per tonne CPO/FFB produced. This relates in particular to smallholders, who on average have a much lower yield than large scale producers.
The GHG-WG recommends that RSPO studies and implements mechanisms which facilitate significant yield increases, in particular from smallholders.

Fires
Intended and accidental fires related to the clearance of land for palm oil, are a significant source of GHG emissions, in particular when occurring on drained peatlands. The GHG-WG recommends that RSPO studies which further measures are required, within or outside the framework of RSPO, to reduce occurrence of fires.

Development of CSPO market
The GHG-WG has concluded that the development of a significant and fair CSPO market is a financial incentive for further steps towards decreasing the carbon intensity of palm oil production. The GHG-WG calls upon RSPO members buying palm oil to contribute to the development of this market.

Qualification of CSPO on EU biofuel market
The GHG-WG has concluded that its agreed recommendations are insufficient to allow CSPO to meet the sustainability requirements of the EU Renewable Energy Directive, as summarised in Box 2 below.

Note: Producers' representatives in the GHG-WG feel that the EU sustainability requirements as outlined in Box 2 have not been discussed in detail, and should therefore not have been included in this report with the intention to inform the Executive Board and others of relevant issues pertaining to biofuels.

Box 2 Summary of relevant sustainability requirements in EU Renewable Energy Directive

Art. 17.2 The greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes shall be at least 35% (and target increases step-wise)

Art. 17.4 Biofuels and bioliquids shall not be made from raw material obtained from land with high carbon stock, namely land that had one of the following statuses in January 2008 and no longer has that status
(a) wetlands, namely land that is covered with or saturated by water permanently or for a significant part of the year
(b) continuously forested areas, namely land spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30%, or trees able to reach those thresholds in situ
© land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10% and 30%, or trees able to reach those thresholds in situ, unless evidence is provided that the carbon stock of the area is such that, when the methodology laid down in part C of Annex V is applied, the emission saving reductions are fulfilled

Art. 17.5 Biofuels and bioliquids shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil

Art. 19.6 The European Commission shall, by 31 december 2010, submit a report reviewing the impact of indirect land-use change on greenhouse gas emissions and addressing ways to minimise that impact

3.5 Procedural aspects

To allow an effective follow-up of the recommendations outlined in the previous sections, the GHG-WG proposes the following:

1. That the mandate of this Working Group will be extended until 31 December 2009. This will allow the Working Group to review the input from the extended public consultation period and – on the basis of Executive Board and/or General Assembly decisions – to detail the Terms of Reference to develop the framework for a voluntary incentive system to reduce GHG emissions within the RSPO.
2. Establish an expert group to develop the information resources that are sufficiently accurate to inform the implementation of a voluntary framework to reduce GHG emissions, particularly the definition of what type of baseline will be adopted within that voluntary system and the designation of default (average) values regarding carbon stocks on oil palm plantations and the different types of landscapes that are being converted to oil palm plantations, as well as the GHG emissions from intact peat forest, drained peatlands currently planted with oil palm, and peatlands that were previously planted to oil palm, but which are now undergoing restoration to a natural forest ecosystem.

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] Jiwan, N. and B.H. Saharjo (2009). The Above Ground Carbon Stock of 25 years Oil Palm Planted in the Mineral Soil "Case Study in Tanah Grogot, East Kalimantan, Indonesia". July 2009.

[32] 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.

[33] Lamade E. and J.P. Bouillet (2005). Carbon storage and global change: the role of oil palm. OCL, Volume 12 no2, March-April 2005.

[34] 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.

[35] 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

[36] 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).

[37] Melling L, Hatano R, Goh KJ (2005). Soil CO2 flux from three ecosystems in tropical peatland of Sarwawak, Malaysia .Tellus, 57B, 1-11.

[38] M. Mohamed, E. Padmanabhan, B.L.H. Mie and W.B. Siong (2002). The peat soils of Sarawak. University Malaysia Sarawak March 2002.

[39] Morel, A. (2009) Estimates of Aboveground Biomass Forest and Oil Palm Values for Sabah, Malaysia. University of Oxford, Environmental Exchange Institute, September 2009

[40] 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.

[41] Nikander, S. Greenhouse gas and energy intensity of product chain: case transport biofuel. MSc Thesis, Helsinki University of Technology. Helsinki (Finland), May 2008.

[42] 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.

[43] Reijnders L., Huijbregts MAJ (2008). Palm oil and the emission of carbon-based greenhouse gases. Journal of Cleaner Production, 16, 477-482.

[44] 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.

[45] RSPO – PNG National Implementation Working Goup (2007). Indicators and guidance required to establish the RSPO Principles and Criteria. November 2007.

[46] RSPO – Indonesian National Interpretation Working Group (2008). National interpretation of RSPO Principles & Criteria for Sustainable Palm Oil Production – Republic of Indonesia. May 2008.

[47] RSPO – Malaysian National Interpretation Working Group (2008). Indicators and guidance to establish the RSPO Principles & Criteria. April 2008.

[48] 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.

[49] Syahrinudin (2005). The potential of oil palm and forest plantations for carbon sequestration on degraded lands in Indonesia. Ecology and Development Series No. 28, 2005.

[50] 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.

[51] Searchinger T. et al. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change. Sciencexpress, 7 February 2008.

[52] SenterNovem (2005). Participative LCA on biofuels. Utrecht (the Netherlands), 2005. (Report 2GAVE-05.08)

[53] SIRIM Berhad (2007). Development of LCI for biofuel production from palm oil (Presentation, exact date and author unknown).

[54] Vasander H., Jauhiainen J. (2008) Uncertainties, deficiencies and unknowns in greenhouse gas emissions from tropical peatlands. Tropical Peatland, …

[55] 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.

[56] 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.

[57] 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).

[58] 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.

[59] 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.

[60] 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.

[61] 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.

[62] 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.

[63] 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.

[64] 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.

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

[66] 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.

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

Appendix 1

Terms of Reference for the RSPO Working Group on Greenhouse Gases

Terms of Reference
RSPO Greenhouse Gas Working Group (GHGWG)

These Terms of Reference outline the scope of work, expected outputs and timeframe of the RSPO GHG Working Group.

- **Background**

There is rising worldwide concern about global climate change driven by increasing greenhouse gas (GHG) emissions. Climate change is now accepted as one of the top issues of the environment and sustainable development agenda with all sectors of society needing to identify ways to reduce GHG emissions. Biofuels offer the potential for reducing GHG emissions and palm oil provides one pathway to producing biofuels because of its high productivity and the high energy use ratio in its production and processing.[1] At the same time, the reduction of deforestation is considered to be one of the cost-effective GHG abatement measures available over the short term,[2] because it represents more than 20% of all GHG emission,[3] of which 80% of the global total are estimated to come from the Amazon and Southeast Asia,[4] two regions with the largest potential for expansion of oil palm cultivation. If the perceived conflicts between oil palm cultivation, deforestation, and GHG emissions are resolved, the future potential for palm oil as a biofuel feedstock will be significantly enhanced.

Although there are different views by diverse stakeholders as to the scale of emissions from palm oil production – it is generally agreed that emission sources from the palm oil sector include those from the clearance of forests and peatlands for plantation development, use of fossil fuels for operating, processing and transport, fertiliser use, and methane emissions from wastewater treatment ponds. Accepted mitigation measures include establishing new plantations on low biomass landscapes, increased energy efficiency, reforestation of degraded landscapes, maintenance of optimal water levels in peatlands, and methane capture and bio-energy production. A number of palm oil companies have addressed these issues are already generating revenues by certifying reductions in GHG emissions via the Clean Development Mechanism (CDM), but other companies have yet to access such resources.

The reduction of GHG emissions and the avoidance of deforestation in the establishment of new plantations are increasingly being recognized in the RSPO as an emerging and critical issue that requires further investigation and adjustments to the existing RSPO Principles and Criteria (P&C), which were adopted in November 2005. The issue was raised by a number of stakeholders in the review process, but the RSPO Criteria Working Group (CWG) was not able to finalize revised wording to incorporate GHG issues into the revised P&C presented to the GA4 in November 2007. In October 2007, the CWG therefore made an urgent recommendation to the RSPO Executive Board for the establishment of GHG Working Group. The Executive Board in

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1 Fargione J, Hill J, Tilman D, Polasky S and Hawthorne P (2008) Land clearing and the biofuel carbon debt. *Science* 319:1235-1238.

2 McKinsey & Company (2007) Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp (accessed 11/20/2008).

3 Intergovernmental Panel on Climate Change (2007) *Climate Change 2007 – The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press, Cambridge, UK.

4 Hansen MC, Stehman SV, Potapov PV, Loveland TR, Townshend JRG,. DeFries RS. Pittman1 KW, Stolle F, Steininger MK, Carroll, M, DiMiceli C (2008) Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data *Proc. Nat. Acad. Science* 105:9439–9444.

its meeting in November 2008 recognized the concern and called for the development of a draft Terms of Reference (ToR) to guide a decision on the establishment of the group.

The GHG Working Group is envisaged to be a short-term, multi-stakeholder expert panel established to review the current P&C 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 will incorporate key features into the existing P&C framework to provide credible proxy measures for GHG emissions,[5] including those originating from above and below-ground carbon pools from natural and anthropogenic land cover types that are converted to oil palm plantations.[6] 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.

2. Objectives

The proposed objectives of the GHG Working Group are to:

2.1 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,

2.2 Identify options for avoiding or mitigating GHG emissions at all stages of the production chain.

2.3 Provide technical guidance and recommendations on how to address GHG emissions from palm oil production and processing within the RSPO P&C.

2.4 Provide specific recommendations for modifying of the existing RSPO P&C terminology, in order to establish auditable and achievable indicators for units of certification

2.5 Coordination with similar certification schemes under development in forestry, agro forestry and biofuels industries.

2.6 Provide objective information from peer-reviewed sources to guide communication related to the sustainability of palm oil in the context of biofuels and bioenergy.

3. Proposed Activities

5 Note: Proxy measures for biomass estimates of land-cover types are typically based on changes in vegetation cover derived from remote sensing technologies.

6 Note: Oil palm plantations established in pasture or other low biomass vegetation types are very effective carbon sinks and can be used to offset GHG emissions from other components of an enterprises' activities or potentially be eligible for carbon-based subsidies in future voluntary or compliance markets.

The initial timeframe of the GHG Working Group's timeframe is proposed to be 9 months starting in January 2009. Within this period the following activities are proposed:

3.1 Conduct a literature review of key issues regarding GHG emissions and the oil palm industry in order to inform future discussions pertaining to the evolution of the RSPO P&C framework:

3.1.1 Life Cycle Analyses for Oil Palm and other relevant information to identify the main sources of GHG emissions from palm oil production (including land development, drainage, fertilization, plantation operation, processing, and the transport of palm oil).

3.1.2 The social dimensions of carbon accounting including "leakage" (i.e. displacement of land use) and "permanence" (i.e. long term vs. short term land use impacts), market-driven crop displacement, impact on food prices and other social implications, as well as the potential role of smallholders in oil palm production.

3.1.3 The availability, accuracy, and cost of existing and new technologies that can be used to estimate carbon stocks on landscapes prior to and following the establishment of oil palm plantations (i.e., satellite and airborne platforms using L-band RADAR and LIDAR technologies).[7]

3.1.4 Existing methodologies and approaches for calculation of GHG emission from oil palm plantations and processing and options of use of proxy indicators (eg. energy, fertilizer use, previous land use). With a view to develop a "Carbon Score Card" that can aid reporting on the dimensions of total GHG emissions related to palm oil production.

3.2 Identify measures that will allow producers to avoid GHG emissions originating from the establishment of new plantations:

3.2.1 Site selection criteria that will avoid GHG emissions by ensuring that all new plantations are established on low biomass landscapes.

3.2.2 Special recommendations and measures that can assist smallholders to reduce GHG emissions (i.e., raising yields and reducing the use of pesticides), either individually, via producer cooperatives, or in partnership with processors.

3.3 Review the current RSPO P&C and recommend adjustments to incorporate GHG issues, if possible focussing on indicators and systems that are auditable and achievable in order to facilitate the certification process and which produce real and meaningful reduction in GHG emissions.

- Recommend further work required to refine guidance or assist in its implementation.

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7 Note: The most common remote sensing technologies are based on optical sensors (LANDSAT, SPOT, CBRS), which can be of limited use in high rainfall areas due to frequent cloud cover and infrequent data acquisition protocols; new RADAR satellites and LIDAR sensors (an infrared laser instrument) provide cost effective alternatives that not only document forest cover but provide direct measurements that can be used as proxies for above ground biomass..

4. Proposed Outputs

The GHG Working Group will develop:

4.1 A document that summarizes the scientific literature on GHG emissions and palm oil.

4.2 Clear standards on site selection to avoid GHG emissions on new oil palm plantations.

4.3 Auditable and achievable amendments to the current RSPO P&C guidance and indicators based on this review process.

4.4 Recommendations for coordinating mechanisms and communication strategies.

5. Proposed Operational Arrangements

GHG Working Group Participants

To ensure a representative mix of stakeholders and expertise, it is envisaged that the Working Group would comprise 12 members

Members:

It is proposed that members of the group come from the following sub-groups:

i. Representatives from the Criteria Working Group or Executive Board (to ensure a strong understanding of RSPO processes and the current P&C) - 4 members with a range of different backgrounds including palm oil/biofuel industry, environmental NGO, social NGO)

ii. Experts on Greenhouse Gases and climate change – 4 members with a range of different experiences including carbon stocks in forest and peatlands, palm oil life cycle analysis and GHG emission/mitigation options.

iii. Other members – 4 members from industry, NGOs, government or research institutes with practical experience in implementing measures to assess or mitigate GHG emissions from palm oil production and processing.

Chair:

The working group should be chaired by an independent expert in GHG emission, who will also be contracted to facilitate the work of the Working Group.

He/she will be responsible for leading the working group, organising and coordinating the contributions of the different members of the working group to ensure that the mandate is fulfilled, all the outputs are adequately addressed, and that the outcome is of high quality and correctly reflects the collective and individual positions of the working group members.

Consultant/Facilitator:

The working group should be supported by an independent consultant/facilitator with appropriate experience on GHG life cycle assessment from palm oil/ land use change and understanding of appropriate certification schemes. The consultant will prepare the meetings (agenda, invitations, distribution of documents, minutes) and Chair them, act as a moderator at stakeholder meetings, collate public comments and draft the inception, interim and final reports, coordinating and synthesising the inputs of the members of the group. The consultant will also carry out some appropriate desk research/analysis as may be required by the working group.

Proposed Timetable

The working group will meet two times during 2009 (two days per meeting), although the number of meetings can be adapted as necessary. One public consultation meeting should be organized before submitting the text for adoption by the Executive Board of the RSOP. Participants will need to assume responsibilities and commit time between meetings to deliver the objectives. Meetings are tentatively proposed in April/June 2009 with public consultation in May/June to enable a recommendation to be considered by the Executive Board in September 2009.

Appendix 2

Composition of RSPO Working Group on GHG

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)
	Adrian Suharto	Neste Oil (alternate)
NGOs	Faizal Parish	Global Environment Center
	Suzana Mokheri	Global Environment Center (alternate)
	Sander van Bennekom	OxfamNovib
	Johan Verburg	OxfamNovib (alternate)
	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/Affilliation
	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 3

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 CO_2 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 (N20). 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 4

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).

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.glcn-lccs.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

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/gpglulucf/gpglulucf_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.

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'Ánna, 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.