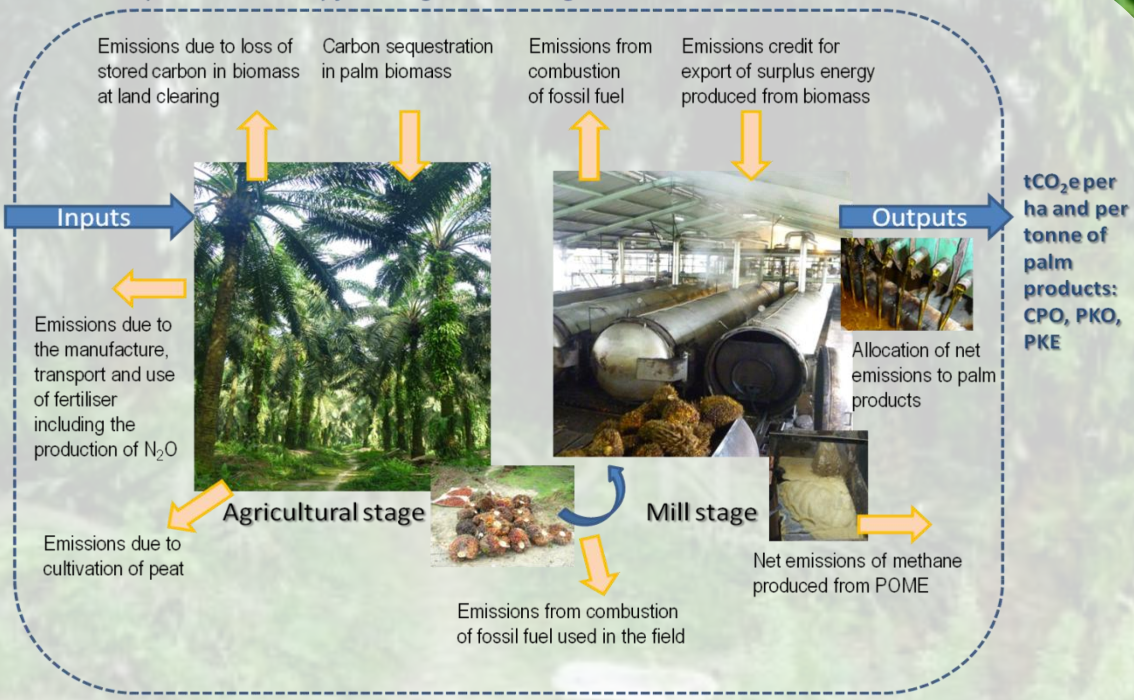
PalmGHG

A Greenhouse Gas Accounting Tool for Palm Products

Accompanying documentation

System boundary for the greenhouse gas calculation in PalmGHG



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RSPO
Roundtable on Sustainable Palm Oil
An International Multi Stakeholder Organization and Certification Scheme for Sustainable Palm Oil

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2

November 2012

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The expert panel conducting the critical review of this tool and report made significant comments and identified important issues that helped improve the accuracy, relevance, clarity and usefulness of PalmGHG.

Last but not least we are most grateful to members of the RSPO Executive Board for their continuing support. Particular thanks are due to Dr Simon Lord for proposing the adoption of the GWAPP model as a basis for developing PalmGHG and to Dr Timothy Killeen for guiding the development of the tool.

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Acronyms

CONCAWE	Oil companies' European association for environment, health and safety in refining and distribution
CPO	Crude Palm Oil
EC	European Commission
EUCAR	European Council for Automotive Research and Development
EFB	Empty Fruit Bunch
EU	European Union
FFB	Fresh Fruit Bunch
GHG	Greenhouse gas
GWAPP	Global Warming Assessment of Palm Oil Production
IPCC	Intergovernmental Panel for Climate Change
ISO	International Standard Organization
JRC	Joint Research Center of the EU Commission
LCA	Life Cycle Assessment
OPCABSIM	Oil Palm Carbon Budget Simulator
OPRODSIM	Oil Palm Production Simulator
PKE	Palm Kernel Expeller
PKO	Palm Kernel Oil
PME	Palm oil Methyl Ester
POME	Palm Oil Mill Effluent
RED	European Directive on Renewable Energy
RSPO	Roundtable on Sustainable Palm Oil
WG	Working Group
WS	Workstream

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Foreword

The PalmGHG Calculator has been developed by the Greenhouse Gas Working group 2 of the Roundtable on Sustainable Palm Oil (RSPO), with funding from RSPO. It has been developed so that palm oil producers can estimate the net greenhouse gas emissions of palm oil products throughout the production chain. This report describes the structure and presents guidelines for operating the PalmGHG *Beta* version 1.0. This version is being made freely available to interested parties on the understanding that any use of it is appropriately acknowledged in all forms of publication. We would appreciate if reprints of articles citing the use of the Calculator be sent to the Secretary-General of RSPO at:

RSPO Secretariat Sdn Bhd, Unit A-33A-2, Level 33A, Tower A, Menara UOA Bangsar, No. 5, Jalan Bangsar Utama 1, 59000 Kuala Lumpur, Malaysia

RSPO would also appreciate being informed of any problems with using the Calculator, and would welcome these and any other comments so that they may be considered for improving subsequent versions. Comments should be sent to rspo@rspo.org.

Tim Killeen and Jeremy Goon

Co-chairs, Greenhouse Gas Working Group 2, RSPO

Introduction

Agriculture contributes to roughly 13.5 percent of global GHG emissions (IPCC, 2007c). In particular, agriculture is the first source of global anthropogenic emissions of methane (52%) and nitrous oxide (84%) (Smith et al., 2008). Moreover, part of GHG emissions associated with the land use change and forestry sector, that represent 17.4 percent of global GHG emissions, are related to agricultural activities. There is hence a growing attention to GHG from agriculture due to this significant share, indicating agriculture's potential role in mitigating part of the GHG emissions. There are, indeed, significant opportunities for GHG mitigation in agriculture, but numerous barriers need to be overcome (Smith et al., 2008). Tools to quantify agricultural GHG emission 'hot spots' and thus assess the potential for mitigation, are needed.

Nowadays, palm oil is the most used vegetable oil worldwide, representing more than 30% of total produced vegetable oils by volume (Omont, 2010). About 14% of global production is certified by RSPO, the Roundtable on Sustainable Palm Oil (RSPO, 2012). Palm oil has received increasing attention due to it being the main vegetable oil source, and also because of the role of deforestation linked to oil palm plantation expansion.

RSPO recognises the importance of addressing GHG emissions from palm oil production and requires in its current Criterion 5.6 that members monitor their sources of GHG and implement measures to reduce them. In addition, RSPO organised two working groups on GHG emissions between 2009 and 2011, with the mandate to recommend ways of reducing GHG emissions across the palm oil supply chain. As part of this mandate, the second working group on GHG developed a GHG calculator named PalmGHG to quantify the sources and sinks of GHG from the plantation to the mill.

Other GHG calculators have been proposed to quantify GHG emissions at the farm level and identify mitigation opportunities, both crop-generic (e.g. the Cool Farm Tool; Hillier et al., 2011) and crop-specific (e.g. the Bonsucro certification scheme for sugar cane[1]). Given the particular modelling needs of oil palm (i.e. a perennial crop with significant carbon fixation during its growth that undergoes continuous replanting), a specific calculator was designed named PalmGHG; PalmGHG is based on an existing GHG balance calculator, GWAPP (Chase and Henson, 2010).

This report describes the assumptions behind the model in section A, and in section B presents the results of a pilot study undertaken in 2011 to test its user-friendliness and flexibility. Section C provides some conclusions and suggests future development needs.

[1] http://www.bonsucro.com/standard/appendicies.html consulted on-line [31-05-2012]

A. PalmGHG, A Greenhouse Gas Accounting Tool for Palm Products

A.1 PalmGHG: goals and scope

Prior to the establishment of Work stream 1 (WS1), Chase and Henson (2010) developed the GWAPP[2] model for evaluating the GHG balance of palm oil production that fulfilled many of the requirements for carbon accounting identified by WS1. GWAPP was subsequently modified to facilitate the direct use of producer data and to give balances for individual operating units (mills and the plantations served by them). GWAPP shares certain features with OPCABSIM[3] (Henson, 2009), a model that operates on a Windows platform and that has three levels of accounting (field, estate and region).

The PalmGHG calculator was thus commissioned by RSPO; it is a significant development of GWAPP which, while straightforward to use, has a number of limitations in that palms are assumed to have an even age distribution, no allowance is made for variations in inputs and outputs within the palm area, and several aspects involve elaborate modelling rather than being based on real data. These limitations were addressed and the model simplified, by assessing only the main sources of emissions and sequestration, and by using as much real data as possible, resulting in a smaller, more flexible, and more site-specific calculator. In the future, the scope of the tool will be expanded to include biodiesel production and to give output conforming to the requirements of the European Directive on Renewable Energy (RED). Successive versions of PalmGHG have been produced during which process the tool has been progressively refined. The following description of PalmGHG content is relevant for the PalmGHG *Beta* version 1.0, which followed the v1.8 version presented at RT9 in November 2011[4].

PalmGHG is based on the life-cycle assessment (LCA) approach (ISO 14044 and series) and PAS2050 (BSI, 2011) recommendations, although it does not claim strict compliance with these standards. As a GHG calculator, PalmGHG does not encompass the comprehensive calculations of a LCA, *i.e.* calculations of other environmental impacts other than global warming such as, e.g. eutrophication, health impacts, or biodiversity; therefore, the results of PalmGHG should not be considered as an indicator of global environmental impacts, but only of global warming. The ISO hierarchy on allocation approaches is not followed either in PalmGHG, and this report does not contain all aspects of the interpretation phase required by ISO 14044 (e.g. consistency, sensitivity and completeness analyses), although PalmGHG allows the user to fulfil such analyses. Nevertheless, each step of the LCA methodology, where relevant to PalmGHG construction and GHG calculations, is carried out according to state of the art methodological development and knowledge of the palm oil supply chain. These steps cover the *goal and scope definition*, *life cycle inventory*, *impact characterisation* and *interpretation of results.* The non inclusion of embedded emissions in capital goods and the timeframe for biogenic carbon sequestration are in accordance with PAS2050 recommendations (BSI, 2011). It is also important to highlight that in spite of using robust sources of information, the main GHG hotspots in palm oil production (land clearing; POME emissions; peat emissions; field emissions) are associated with large uncertainties, and thus the accuracy of the results inevitably depends on the input values used.

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[2] GWAPP : Global Warming Assessment of Palm Oil Production

[3] OPCABSIM : Oil Palm Carbon Budget Simulator

[4] Chase L., Bessou C. (2011). Introduction to PalmGHG The RSPO greenhouse gas calculator for oil palm products. RSPO Roundtable 9, 22nd to 24th November 2011, Borneo, Malaysia.

Goals of PalmGHG

The PalmGHG calculator provides an estimate of the net GHG emissions produced during the palm oil and palm biodiesel production chains. The emissions are presented as t CO_2 equivalents (CO_2e), per hectare and per unit of product: i.e. per tonne of Crude Palm Oil (CPO) and per tonne of Crude Palm Kernel Oil (CPKO). The main purposes of the tool are:

- Identification of hotspots in the life cycle of palm oil products, with the aim of guiding GHG reduction opportunities;
- Internal monitoring of GHG emissions;
- Reporting to RSPO of progress towards GHG reduction plans;

PalmGHG could be useful to explore the relationship between resource use (e.g., fertilizer) efficiency and carbon emissions, as all the relevant information is provided. For the time being such performance / efficiency indicators are not integrated in the tool, but may be derived from it to inform plantation management.

Scope, functional unit, system boundaries and cut-off criteria

Net GHG emissions are calculated by adding the emissions released during land clearing, crop production and crop processing, and subtracting from these emissions the sequestration of carbon in the standing crop and in any conservation areas[5]. The system boundary is shown in Figure 1. The function of the system is to produce several palm oil products (palm oil; palm kernel oil). Thus, net emissions are calculated in relation to the diverse final products. In the first step, net emissions are calculated as tonnes of CO_2e per hectare and per tonne of Fresh Fruit Bunches (FFB). From the yield of FFB and the extraction rates in the mill, values are obtained per tonne of Crude Palm Oil (CPO) and per tonne of Palm Kernel (PK); the latter is an intermediate product sent to kernel crushers for the extraction of Palm Kernel Oil (CPKO).

[5] Specific conditions apply for conservation areas. See specific section under A.2.

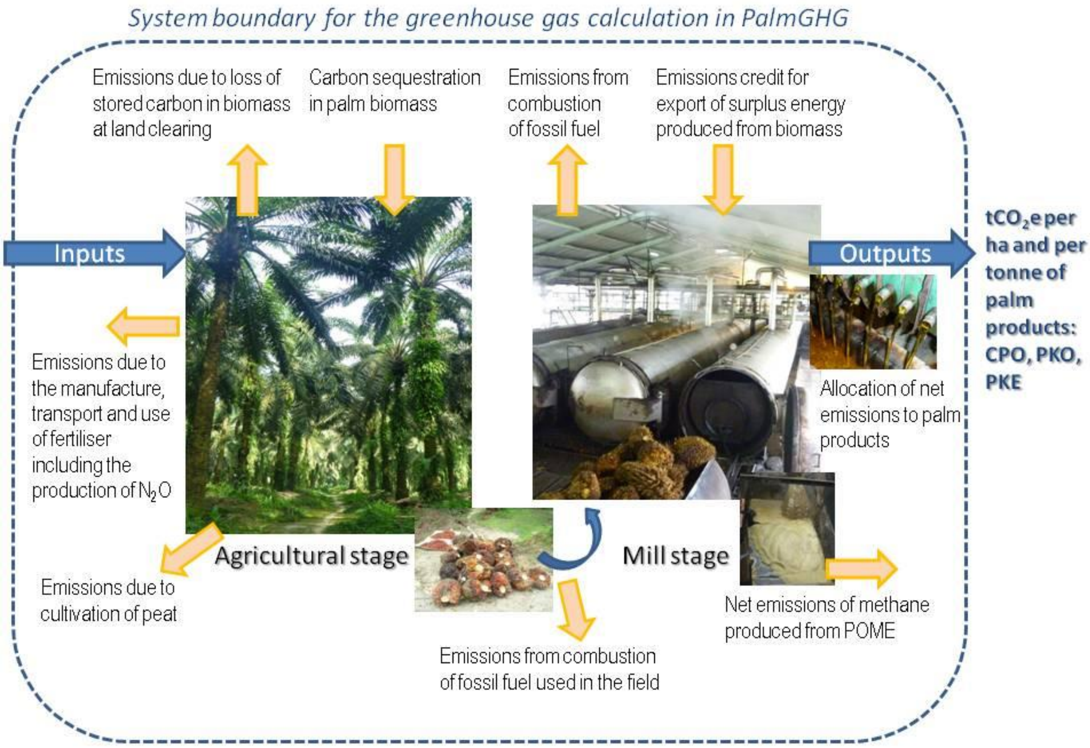

Figure 1: System boundary of PalmGHG

The emission sources included in the calculator are:

i) Land clearing;

ii) Manufacture of fertilisers and transport to the plantation;

iii) Nitrous oxide and carbon dioxide resulting from the field application of fertilisers and mill by-products and other organic sources such as palm litter;

iv) Fossil fuel used in the field (mainly for harvesting and collection of FFB);

v) Fossil fuel used at the mill;

vi) Methane produced from palm oil mill effluent (POME); and

vii) Carbon dioxide and nitrous oxide generated by the cultivation of peat soils.

In addition, the following GHG fixation and credits are considered:

i) Carbon dioxide fixed by oil palm trees, ground cover and carbon sequestered in plantation litter (see crop sequestration, below);

ii) Carbon dioxide fixed by biomass in conservation areas;

iii) GHG emissions avoided by the selling of mill energy by-products (e.g. electricity sold to the grid; palm kernel shell sold to industrial furnaces).

These elements account for the bulk of the GHG emissions and fixation occurring during the oil palm crop cycle (99% according to Chase and Henson, 2010). Items that are not included in the budget are the nursery stage, pesticide treatments, fuel used for land clearing, emissions embedded in infrastructures and machines, and the sequestration of carbon in palm products and by-products. These items are generally negligible GHG sources or sinks (Schmidt, 2007; European Commission, 2009). Carbon sequestered in palm products and by-products is short-lived, while the other emissions are small when annualized over the crop cycle. Changes in soil organic matter in mineral soils might be significant in the long term but were not considered as the evidence concerning them is limited and contradictory. Direct land use changes caused by the production unit (mill) under study are considered in PalmGHG, but indirect land use change due to market compensation of increased / reduced supply of palm oil are outside the scope of PalmGHG.

Provision is made for separate budgets for a mill's own crop (usually produced on estates) and an out-grower crop (such as produced by smallholders). PalmGHG uses the annualized emission and sequestration data to estimate the net GHG balance for the palm products from both own and out-grower crops at an individual mill. Emissions from the biomass cleared at the beginning of the crop cycle are averaged over the cycle. Emissions from the other sources are averaged over the three years up to and including the reporting date, thus simplifying data collection and smoothing out short-term annual fluctuations. The estimates can be updated on a yearly basis to reflect changes in operating conditions and the growth of palms.

Allocation

Allocation of the net emissions of CO_2e between CPO and PK, then subsequently between Palm Kernel Oil (PKO) and Palm Kernel Expeller (PKE), is carried out according to the relative masses of these co-products. Allocation by mass is only the second option according to the ISO standards (ISO 14044, 2006); however, allocation by mass has been used in PalmGHG in order to provide stable results for all co-products as they leave the product system (mill). System expansion is used for other by-products (electricity; kernel shells exported for energy).

Impact assessment methodology and limitations

Following the IPCC guidelines (2006), the GHGs considered are CO_2, N_2O, and CH_4. Conversion factors of N_2O and CH_4 into CO_2e are as given by IPCC (2007), and correspond to a 100 year timeframe. The conversion factor for biogenic CH_4, needed to account for the released CO_2 originating from photosynthesis, is calculated from the ratio of the molecular weights of CO_2 and CH_4 (Wicke et al., 2008); this is further described in Muñoz et al. (2012). In summary, a GWP factor of 0 is used for CO_2 fixed in (or emitted from) short-lived biomass (such as the palm fruit, FFB, or the emissions derived from it when palm oil is consumed); a factor of -1 is used for CO_2 fixed in biomass for a longer period (e.g. in palm trunks); a factor of 298 is used for N_2O emitted from field application of fertilisers, POME and EFB and a factor of 22.25 is used for CH_4 emissions arising from biogenic carbon not previously accounted for as fixation (e.g. emissions from POME, arising from C in the FFB).

Critical review

An external peer-review was carried out by an expert panel including LCA and palm oil experts in order to verify the robustness of the assumptions, while the choice of emission factors and allocation coefficients was justified and tested through a sensitivity analysis. The critical review panel was coordinated by Ms. Monica Skeldon (Deloitte Consulting LLP, USA), and consisted of Dr Thomas Fairhurst (Tropical Crop Consultants Ltd., UK); Prof Jannick Schmidt (2.0 LCA Consultants, Denmark), and Mr. Jacob Madsen (Deloitte Consulting LLP, USA). The critical review report, including the responses to the review comments, is attached in the Appendix. It must be noted that the peer review was carried out in a version of PalmGHG including calculations up to palm biodiesel refining according to the BioGrace model (BioGrace, 2010). Eventually, that section in PalmGHG had to be removed as requirement by the BioGrace project; this does not affect the conclusions of the peer review, but some of the comments found in the Appendix are no longer relevant. RSPO is currently working on a new model for palm biodiesel to be incorporated in a future version of PalmGHG.

A.2 Life Cycle Inventory

Land clearing

The approach used to evaluate the contribution of land clearing to GHG emissions in PalmGHG is to average the emissions over a full crop cycle. The calculator estimates the total emissions occurring each year by new plantings, adds them up, and finally divides by the number of years in the average crop cycle (the default is 25) to obtain an average emission per ha per year. The crop cycle length is defined by users and can differ between "own crops" and "out-growers". It can differ also between crops on mineral soils and those on peat soil, which are often shorter due to ground subsidence, palm leaning and accentuated sensitivity to pest and diseases (RSPO, 2012). It must be noted that allocation of land clearing emissions is still an unresolved issue; the PAS2050 (BSI 2011) suggests allocating them over 20 years or a single harvest period (whichever is the longest). In PalmGHG a slightly longer period corresponding to the plantation cycle is used as default, as this allows including consistently the changes in land cover without providing a bias for younger or more mature plantations. In addition, it is worth highlighting that PalmGHG only considers direct land use change; other approaches suggest e.g. assessing indirect land use change and / or allocating direct land use change to the first production year only. These potential different considerations are thus an additional source of decision rule uncertainty. Indirect land use change is not considered in PalmGHG due to the non consensual methods used to assess consequential impacts of land use change.

Previous land uses and their respective carbon stocks were defined in consultation with the scientific panel of RSPO GHG WG2 (WS3) who performed a thorough review of literature data and satellite images to identify land use changes associated with oil palm plantations in Indonesia and Malaysia (Agus et al. in preparation). Values for ten previous land uses are currently available in PalmGHG. These are: logged forest, secondary re-growth (average of logged forest and food crops), primary forest, grassland, rubber, cocoa under shade, coconut, food crops (average of annual and perennial crops in Papua New Guinea), shrubland and oil palm. The values for carbon stocks in these land uses are provided in Table 1, and will be updated with the values provided by WS3 once these are peer reviewed and published (Agus et al. in preparation). Definitions for these types of land cover are not clear, especially the term 'logged' which can cover a variety of situations. The values are provided as guidance in the absence of more specific measurements, which will generally not be available. Further guidance will be required for the audit of PalmGHG input data, on how to link evidence for previous land uses (such as aerial photographs or maps) to specific land use classes and carbon stocks. Further options can easily be incorporated. In the case of plantations on peat soils, only logged forest, food crops, secondary re-growth, and oil palm were identified as relevant. Clearing of primary forest is not accepted within the framework of RSPO Principles and Criteria; however, this option for previous land use has been included in case growers want to assess the effects of areas cleared prior to RSPO certification. In all cases, for land clearing as well as crop sequestration, data should always be taken from the best available source. On-site field measurements should provide the most relevant data, should they be available. In the absence of field measurements, the carbon stock for oil palm can be calculated from models as described in the next section.

Emissions arising from land clearing are calculated based on a 45% C content of the biomass (above- and below-ground) in the previous vegetation; biomass is always expressed as dry weight. The emitted carbon is converted to CO_2 by multiplying by 44/12. In PalmGHG changes in soil organic carbon due to land use changes in mineral soils were not accounted for due to a lack of consensual and reliable data on soil organic carbon stocks prior to and after oil palm establishment.

Land uses	*Carbon stocks in tonne C/ha*	*Sources and notes*
Primary forest	225	Mean of 62 values with CV=26%, taken from LUC Database revised 18-9-2012 (Henson, in prep.)
Logged forest	87	Henson, 2009
Coconut	75	European Commission, 2009
Rubber	62	Henson, 2009
Cocoa under shade	70	Lasco et al., 2001 (increased by 20% to allow for roots as per Mokany et al., 2005)
Oil palm	≥ 50	Calculated with OPRODSIM and OPCABSIM models (Henson, 2005, 2009). Depends on the cycle length and growth type (vigorous or average)
Secondary regrowth	48	Average of logged forest and food crops
Shrubland	26	WINROCK data (Harris, pers. com. 2010) MODIS Data 2000 to 2007
Food crops	9	Average of annual and perennial crops in Papua New Guinea WINROCK data (Harris, pers. com. 2010) MODIS Data 2000 to 2007
Grassland	5	Henson, 2009

Table 1. Carbon stocks in below- and above-ground biomass for land uses included in PalmGHG

Crop sequestration

Data for carbon sequestration in the crop can be obtained from different sources. The preferred option is to base them on direct measurements, but where the resources for obtaining these are not available, modelled data may be used instead. In order to perform on-site measurements of carbon sequestration in the crop, the producer should carry out some basic on-site growth measurements of planting density, fronds and trunk for palms of different ages following the methods described by Corley et al. (1971) and Corley and Tinker (2003, p 93.). Guidance from an experienced agronomist is also required to analyse these data further before being used to generate sequestration values.

When on-site measurements are not possible, OPRODSIM and OPCABSIM (Henson, 2005; Henson, 2009) are examples of models specifically designed to estimate oil palm and associated biomass in the plantation (litter and ground cover) by generating growth curves based on climate and soil data, largely based on Malaysian conditions. Alternative models are provided by Indonesian studies of van Noordwijk et al., (2010), recently updated by Khasanah et al. (2012) and included as part of the Excel-based RSPO/ICRAF Carbon stock calculator (Harja et al., 2012). Data from these models may be included as options in PalmGHG.

OPRODSIM and OPCABSIM produce annual values of standing biomass for the oil palms (above and below-ground), ground cover, frond piles and other plantation litter (shed frond bases and male inflorescences) and provide estimates of the nitrogen recycled in litter and ground cover that can be used to calculate values for the N_2O emissions from these sources. The Indonesian studies also include measurements of understory, litter and other necromass in the plantation. In both cases the total biomass is converted to carbon using measured or assumed carbon contents, of 45 or 46%. Sequestration is then calculated as the difference in the total standing carbon between successive years. In the case of OPRODSIM the sequestration in the first year is taken as equal to the total carbon at the end of that year (this ignores the biomass at planting but this is small). The amount of carbon sequestered in the reporting year is calculated by multiplying the area of each year of planting (plot) by the amount of carbon sequestered in each plot, adding these together, and dividing by the total area to give t C/ha/yr. The sequestered carbon is again converted to CO_2 by multiplying by 44/12. Field observations reveal that biomass growth and yields are generally lower in the case of out-growers (Chase & Henson, 2010; Khasanah et al., 2012). To reflect this difference, contrasting simulation scenarios of crop sequestration are used as default estimates for mill own crops and out-growers. For OPRODSIM a 'vigorous growth' simulation is used for own crops (estates, see Figure 2), and an 'average growth' simulation is used for out-growers (Figure 3).

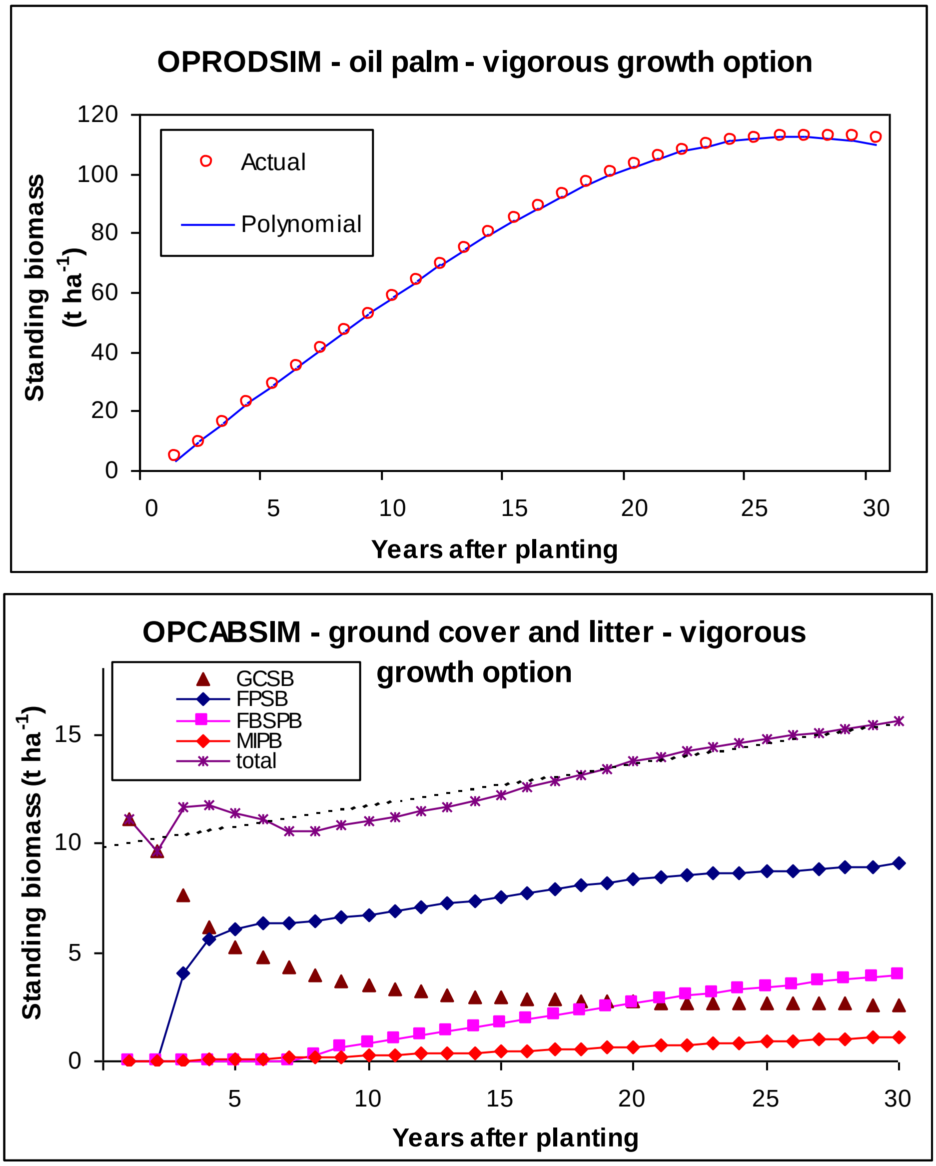

Figure 2: Changes in standing biomass with age as modelled by OPRODSIM and OPCABSIM assuming vigorous oil palm growth. Upper graph shows growth of oil palm; lower graph shows changes in other plantation components; GCSB: ground cover standing biomass; FPSB: frond pile standing biomass; FBSPB: frond base shed pile biomass; MIPB: male inflorescence pile biomass.

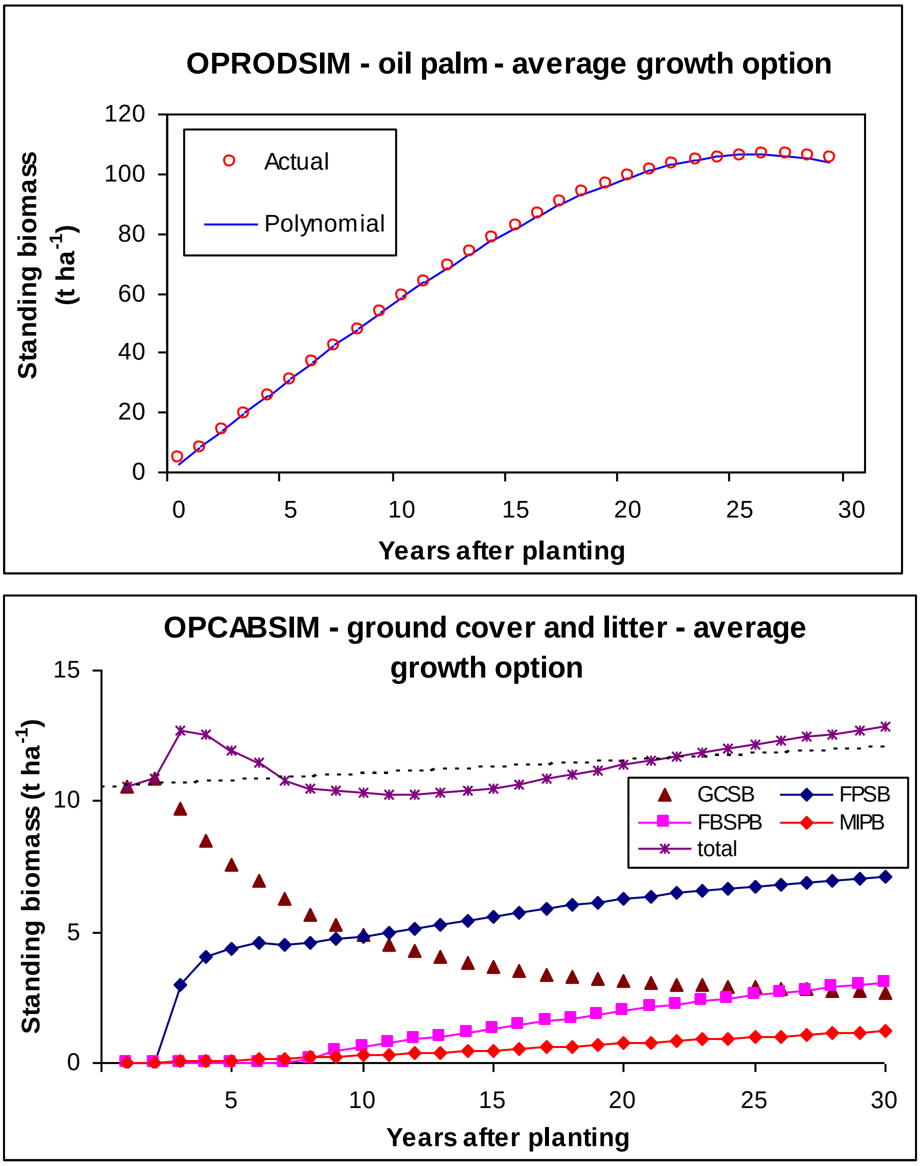

Figure 3: Changes in standing biomass with age as modelled by OPRODSIM and OPCABSIM assuming average oil palm growth. Upper graph shows growth of oil palm; lower graph shows changes in other plantation components; GCSB: ground cover standing biomass; FPSB: frond pile standing biomass; FBSPB: frond base shed pile biomass; MIPB: male inflorescence pile biomass.

Because the same data sources are used for the carbon stocks in oil palm plantations for the clearing and sequestration estimates, when a plot is replanted from old oil palm to a new cycle of oil palm, the carbon balance would be maintained over the whole crop cycle. However, this is seldom the case for the assessments done over the whole plantation / sourcing area, due to different age distributions of palms, and possibly variation in planting material. PalmGHG is designed so such differences are automatically captured, rather than assuming a neutral carbon balance when oil palms are replaced with new oil palms.

Conservation area sequestration

Sequestration of carbon in areas where vegetation is being conserved on land that would otherwise be used for oil palm is also considered in each year's carbon budget. No default values are provided for this, as the amount that is being sequestered will depend on the type and maturity of the vegetation, and on climatic, management and soil factors. Growers reporting sequestration in these conservation areas will need to carefully assess the annual sequestration, most likely supported by field measurements. This is an aspect that is still under consideration by RSPO in the light of international mechanisms such as UN's REDD (Reduction of Emissions from Deforestation and forest Degradation). The amount of sequestration in conservation areas should thus be reported separately from the palm oil balance, and the evidence carefully monitored in the audit process.

Field emissions

Emissions due to fertiliser production, transport and use

Emissions due to fertilisers contribute significantly to total agricultural GHG emissions and so affect the final GHG balance of palm oil (Yusoff and Hanson, 2007; Vijaya et al. 2008b; Pleanjai et al., 2009; Arvidsson et al., 2010; Choo et al., 2011). Therefore, they have been accorded special attention in PalmGHG. Provision is given for nine widely used synthetic fertilisers and two organic ones (EFB and POME) but additional fertiliser types can be included by the user if required.

For synthetic fertilisers, emissions consist of i) upstream emissions due to their manufacture (Table 2), ii) transport from production sites to the field; iii) direct field emissions linked to physical and microbial processes in the soil, and iv) indirect field emissions following re-deposition of previous direct field emissions. Emissions during fertiliser production vary widely with the type of product from 44 to 2,380 kg CO_2e/t fertiliser (Jensson and Kongshau, 2003). Direct and indirect field emissions are calculated according to IPCC Tier 1 (IPCC, 2006); there is a large uncertainty associated with these emission factors, as discussed in IPCC (2006). Nitrogen fertiliser emissions are converted to N_2O my multiplying by 44/28.

Emissions due to production of EFB and POME are already accounted for intrinsically within the supply chain assessment. The amounts of EFB and POME are calculated using the following factors: 0.5 t POME/t FFB (Yacob et al. 2006), and 0.22 t EFB/t FFB (Gurmit, 1995). PalmGHG assumes by default that the whole amounts of EFB and POME generated in the mill are used as fertilisers in the plantation. Direct and indirect field emissions of N_2O are calculated according to IPCC Tier 1 based on their N content of 0.32% for EFB and 0.045 % for POME (Gurmit, 1995); note that these N contents are also highly variable and should be replaced by the user with own measurements if available, although the overall effect in the final results is not dominant. The amounts of EFB and POME, as well as their N contents can be substituted using on-site measurements if these are available. Methane emissions due to POME are accounted for at the mill stage (see Mill emissions).

Fertilisers	*kgCO_2e/tonne*
Ammonium nitrate (AN)	**2,380**
Diammonium phosphate (DAP)	**460**
Ground magnesium limestone (GML)	**547**
Ground rock phosphate (GRP)	**44**
Kieserite (assumed to be the same as MOP)	**200**
Muriate of potash (MOP)	**200**
Sulphate of ammonia (SOA)	**340**
Triple superphosphate (TSP)	**170**
Ammonium Chloride (AC)	**1,040**
Urea	**1,340**

Table 2. Upstream emission factors for the manufacture of fertilisers used in PalmGHG (from Jensson and Kongshaug, 2003 and Ecoinvent, 2010)

Emissions due to field operations

Emissions due to field operations that arise from fossil fuel consumed by machinery used for transport and other field operations, are based on the same emission factor as fertiliser transport from the site of manufacture to the field, i.e. 3.12 kg CO_2e/l diesel (JEC, 2011). Total field fuel used encompasses the fuel used for the transport of workers (when managed by the mill) and materials, including the spreading of fertilisers, the transport of FFB from the growing areas to the mill, and maintenance of field infrastructure. A pragmatic approach has been taken when including all these sources of emissions: given that the plantations do not often record the fuel consumption for specific operations, but only the overall fuel purchased, it was felt more convenient to simply include all the fuel used by the whole plantation over a specific period of time.

Emissions due to peat cultivation

Emissions from peat cultivation include CO_2 emissions due to the oxidation of organic carbon and associated N_2O emissions. Both involve enhanced microbial activity. Research is still ongoing to determine the magnitude of these emissions and how they are affected by and related to factors such as drainage depth, peat subsidence and plantation age. WS2 of the RSPO GHG WG intensively reviewed the impacts of peat cultivation on GHG emissions and identified best management practices for oil palm cultivation on peat soils (RSPO PLWG, 2012). In their findings, the authors put emphasis on the importance of restricting the water table depth to limit CO_2 emissions from peat land.

There is uncertainty due to methodological differences in determining the emission factors for CO_2 emissions due to peat cultivation (Peat CO_2 Emissions) as discussed by the RSPO PLWG (in press, p. 22-23) and Agus et al. (in press). Values based on subsidence measurement range between 54 and 115 t CO_2e/ha/yr for a typical drainage depth of 60 – 85 cm (Page et al., 2011). Values based on flux measurements in Jambi, Riau and Aceh, Indonesia ranged from 18 ± 13 to 66 ± 24 t CO_2e/ha/yr, with the average of about 39 ± 19 t CO_2e/ha/yr (Husnain et al. in press). Similarly, Page et al. (2011) also presented the values ranging from 20 to 57 t CO_2e/ha/yr based on flux measurement, but they argued that these values were too low. In PalmGHG, emissions due to peat cultivation are presently calculated using the following equation based on a review mostly of CO_2 flux measurement (Hooijer et al., 2010):

Peat CO_2 emission (t CO_2/ha/year) = 0.91 x cm drainage depth with 80 cm as the default drainage depth without active water table management or 60 cm if there is an active water table management, i.e. the average water level below the peat surface in the collection drains to be considered as a good management practice (RSPO PLWG 2012).

Hence, peat CO_2 emissions will vary depending on water table management and this is allowed for in the peat emission sheet. The default emissions considered (for 80 cm drainage depth) are thus 72.8 t CO_2/ha/yr (or 54.6 t CO_2/ha/yr for good water table depth management at 60 cm). It needs to be noted, though, that IPCC is currently reviewing the emission factors from tropical peat, so this factor will be updated with the IPCC value once this happens (expected in 2013). Variation due to plantation age (years after planting) is also possible but remains to be quantified. Given the importance of peat emissions in the net GHG balance, guidance will be needed on how drainage depth needs to be checked during the audit process.

For N_2O emissions from peat soils, data relating emissions to drainage depth are presently inadequate and so the IPCC Tier 1 emission factor, i.e. 16 kg N-N_2O/ha/yr (Vol 4 Chap 11 p.11, IPCC, 2006), is used as a default. Further research is needed to define better how agricultural management and in particular water table management, might influence the amount of N_2O emission linked to peat land cultivation. In the meantime users have the option of using actual data measured from the field if these are available.

Mill emissions

At the mill level, two main sources of GHG emissions are considered, fossil fuel consumption and methane (CH_4) production by POME.

The user is required to enter the mill's total diesel consumption of the previous three years, and the average is used. Fuel emissions are calculated using the conversion factor of 3.12 kg CO_2e/l diesel (JRC, 2011).

Methane emissions from POME vary according to the treatment applied. As mentioned above, the amount of POME generated is considered as 0.5 t POME/t FFB (Yacob et al. 2006). The amount of methane produced per unit of untreated POME (where the POME is stored in open ponds) is taken to be 12.36 kg CH_4/t POME (Yacob et al. 2006). However, this amount is reduced if the methane is captured and then either flared and the resultant CO_2 released to the atmosphere as a less potent form of GHG than methane, or used as a fuel to generate electricity. Both the amount of POME and the amount of methane are quite variable depending on the conditions in the mill; the user is encouraged to use more representative values if e.g. volume of POME is measured, and / or values of its organic (COD) load are available.

Calculations of CH_4 production and amounts and losses during digestion, flaring, or electricity production are based on factors from Schmidt (2007) and the Environment Agency (2002). As mentioned above, when CH_4 is emitted, emissions are calculated in CO_2e using a global warming potential of 22.25 kg CO_2e/kg CH_4 instead of 25 kg CO_2e/kg CH_4 (IPCC, 2007b) to allow for reduced emissions of biogenic CO_2 originally fixed by photosynthesis (Wicke et al., 2008; Muñoz et al., 2012). When CH_4 is flared and converted to CO_2 these emissions are not accounted for because of their short-lived biogenic origin. However, provision still needs to be made for a small fraction of methane that escapes conversion. When CH_4 is used to generate electricity then the amount of substituted electricity is calculated based on an energy content of 45.1 MJ/kg CH_4, a Lower Heating Value assumed to be equivalent to that of EU natural gas mix (JRC, 2011). The corresponding emissions avoided by the use of the methane-generated electricity are calculated using the mean of the electricity emission factors for Indonesia and Malaysia (RFA, 2008).

A further credit is given to the user if excess palm kernel shell is sold for use as a substitute for coal in industrial furnaces. If the palm oil mill is isolated from the electricity grid, it may not be possible to sell surplus electricity, and a valid alternative to make the most of the mill by-products is to sell any solid waste to users of solid fuel. Palm kernel shells (PKS) are currently in high demand in Malaysia as they are used to substitute fossil fuels in cement works, plastic and chemical factories, and brick and timber kilns. The price of PKS varies from US$40 - 50 per tonne wet weight ex palm oil mill and has increased in the past years, often exceeding the price of coal. This is shown in Lafarge's 2011 case study of using PKS as an alternative fuel to reduce fossil fuel consumption in two cement plants in Malaysia[6]. The most likely fuel to have been replaced by PKS in those factories is coal[7], and thus the emissions displaced by not burning coal may be considered as a credit for the palm oil system[8]. Assuming a gross energy value of 28.2 MJ/kg for coal and of 20.5 MJ/kg for PKS[9], each tonne of PKS sold by the mill may displace about 726 kg coal in an industrial kiln. The exact amount displaced depends on the quality of coal, and ranges between 600 and 750 kg coal per tonne PKS[10]. The GHG emissions related to the combustion of coal are about 105 g CO_2e/MJ, or ca. 3 kg CO_2e/kg coal. Thus, the approximate emission saving from PKS sold to industrial furnaces used in PalmGHG is -2,203 kg CO_2e/tonne, and ranges from -1,820 to -2,276 kg CO_2e/tonne.

A.3 PalmGHG structure and use

As for RSPO certification, the unit for input data in PalmGHG is the mill and its supply area. Within the supply area of the mill, FFB may be provided by several plantations or estates representing the mill's 'own crop', as well as from out-growers. The latter is a general term and can include supplies from small-holders, external cooperatives, and traders.

The current version of PalmGHG is an Excel spreadsheet with 15 sheets. There is a colour code for data in the sheets which is red for user-defined data, brown for default values, blue for calculated values, and green for linked values. As a default, the yellow-filled input cells contain data for a fictitious mill that should be over-written by the user.

The different sheets of the calculator represent the main components of the final GHG budget. They have been designed in terms of data requirements with inputs being provided by the grower (estate manager) and miller (mill manager). As mentioned, the sheets requiring input data have cells with a yellow fill. Other cells and sheets use these data for further calculations and are protected from inadvertent change to avoid errors.

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[6] http://www.lafarge.com/wps/portal/2_4_4_1-EnDet?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/Lafarge.com/AllCS/Env/NR/CP1610621923/CSEN [consulted on-line 25-Oct-11]

[7] MR Chandran, personal communication by e-mail [13.10.2011]; Mr Pavel Cech, personal communication by e-mail [27.10.2011]

[8] In PalmGHG, the CO_2 fixed in the fruit is not considered as a form of sequestration (RSPO 2011); thus, when such carbon is released back into the atmosphere (e.g. by burning the shells or consuming the oil) this is not considered to be a form of CO_2 emission.

[9] Averages of values provided by MR Chandran, personal communication by e-mail [13.10.2011] and Dr SS Chen, personal communication by e-mail [18.10.2011].

[10] Mr Pavel Cech, personal communication by e-mail [27.10.2011].

For recording extensive data such as those related to plantation history (e.g. Land clearing, Crop sequestration) several rows are provided to allow for diverse supplying areas (e.g. own and out-growers; different numbers of estates), distinguishing between plantations on mineral and peat soils, and differences in types and amounts of fertilisers used. Data for mill outputs, mill operations and emissions, fertilisers and field fuel use, are averaged over three subsequent years in order to smooth out seasonal variability.

The **Instructions** sheet guides the user as follows:

1 Start with the **Mill** sheet, and enter the name of the mill and the year of the GHG evaluation.
2 Go to the **Land clearing** sheet, and start with mineral soils for the mill's own crop. Enter the length of the oil palm cycle. Add additional rows for any extra estates (provision is made by default for four), and update the formulae for totals. Repeat for peat soils (if any) used for the mill's own crop, and then for mineral and peat soils for the out-growers. Now enter the total area of palms planted each year, and the previous land use for each planting year, for the mill's own crop and its out-growers.
3 Go to the **Fertilisers and N_2O** sheet, add additional rows for any extra areas, then enter the transport distances and quantities of fertilisers applied (over the last 3 years), for the mill's own crop and out-growers. Insert additional rows for any fertiliser types not listed.
4 Go to the **Field fuel use** sheet, add additional rows for any extra areas, and enter the total fuel used in the field (over 3 years), for the mill's own crop and out-growers.
5 Go to the **Conservation area sequestration** sheet and enter the area of forest conservation areas, and the amount of carbon that has been sequestered in these areas in the current year.
6 Go back to the **Mill** sheet and enter the FFB throughput and total crop areas (mature and immature) of the mill's own crop and out-growers, and the OER, KER and mill diesel use (over 3 years). Define the type of POME treatment for each of the 3 years. Where appropriate, add data for export of shell for use as a coal substitute; export of electricity from the mill's turbines to housing or to the grid (i.e. outside the palm oil boundary), and data (if any) for the kernel crusher.
7 Go to the **Default data** sheet and check that the data are appropriate for the mill being evaluated. Changes can be made, but must be identified and justified in the [User comments] sheet. (The sheet may need to be un-protected for this operation.)
8 Go to the **Crop sequestration** sheet and check that the data are appropriate for the estate and out-grower areas. The data by default are produced by the OPRODSIM and OPCABSIM models and should be changed if more suitable data from an alternative model or the producers own measurements are available. Any changes must be identified and justified in the **User comments** sheet.
9 Go to the **Synthesis** sheet for the results.

References are listed in the sheet **References and abbreviations**. In the final sheet, **User comments,** users are invited to justify any changes in the default values used, and to comment on the tool, particularly about difficulties encountered.

B. Pilot testing of PalmGHG

B.1 The pilot process

A pilot study of an initial version of PalmGHG was carried out in 2011 with eight mills belonging to six RSPO member or aspiring member companies, to determine its ease of use and suitability as a management tool. The authors are very grateful to the six companies that took part in this process. In June 2011 a preliminary questionnaire was sent to representatives of the pilot companies, which allowed for tailoring the data requirements of the tool to the characteristics of the mills being studied. WS1 members were responsible for guiding company correspondents in using PalmGHG. Mail exchanges, as well as field visits, facilitated the compilation of input data and the calculation of GHG balances.

B.2 Results

The pilot results shown in this report are based on version v.1.8 of PalmGHG, as presented at RT9 in November 2011 (Chase and Bessou, 2011). It should be noted that modifications made since then to the structure and default values in PalmGHG may have resulted in some changes to the outputs as presented here. However, while precise values may differ, the relative contributions of emissions sources and the magnitude of the GHG balances should still be evident, and the hierarchy among systems should not be altered.

Results from eight mills (Table 3) gave an average of 1.03 t CO_2e/t CPO, with a range from -0.07 to +2.46t CO_2e/t CPO. The GHG balances per tonne of CPO are also presented in Figure 4. Note that negative figures (as found in mill A2) mean that the mill is a net GHG sink, i.e. more CO_2 is being fixed through plant growth or avoided emissions from mill energy by-products, than is being emitted. Previous land use and the percentage of the area under peat were the main causes of the variation in GHG balance.

Mills	*Mean tFFB/ha*	*Out-growers included ?*	*Peat soil proportion*	*Previous land use*	*tCO_2e/tCPO*
A1	23	no	0%	shrub	0.05
A2	24	no	0%	shrub	-0.07
B	26	no	0%	cocoa, oil palm	0.79
C1	23	yes	25%	grassland, shrub	0.73
C2	19	yes	80%	grassland, shrub	2.46
F	19	no	0%	logged forest, oil palm	1.85
G	26	yes	0%	wide range from logged forest to arable crops	1.15
H	17	yes	0%	logged forest	1.35

Table 3 : Main characteristics of eight mills and their GHG balances assessed with PalmGHG

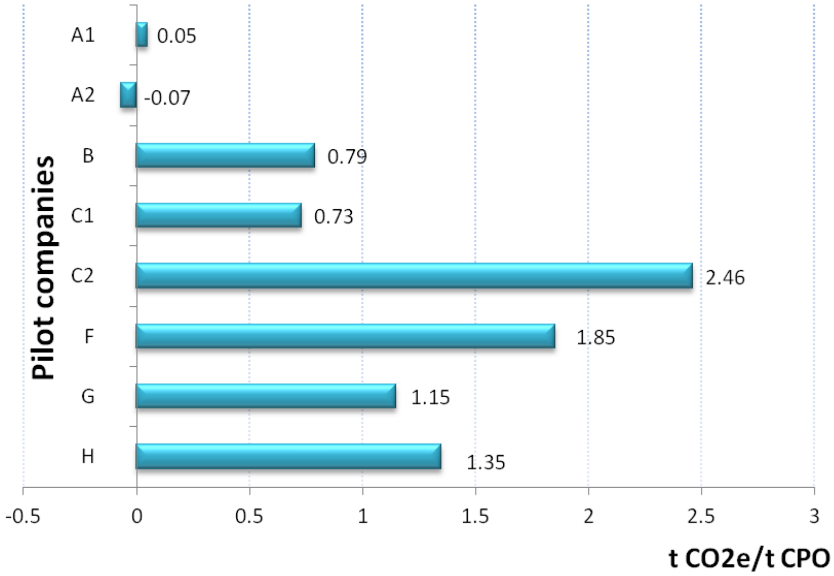

Figure 4: GHG balances of eight pilot mills calculated with PalmGHG

Main emission hot spots are "land clearing", "peat emissions", and "methane emissions from POME". N-fertiliser production and N-related field emissions are also major sources of GHG. Contributions of different sources may vary between estate and out-growers providing FFB to the same mill as shown in Figure 5. Note also that the overall value provided for most of the mills in Table 3 and Figure 4 is a weighted average between estate and out-growers emissions served by a given mill based on their relative production of FFB. Thus it has no direct translation in the net emissions shown in Figure 5. All these results (disaggregated per estate and out-growers, and combined) are shown in the Synthesis tab of PalmGHG (although current versions of PalmGHG do not differentiate estate / out-growers in the mill stage).

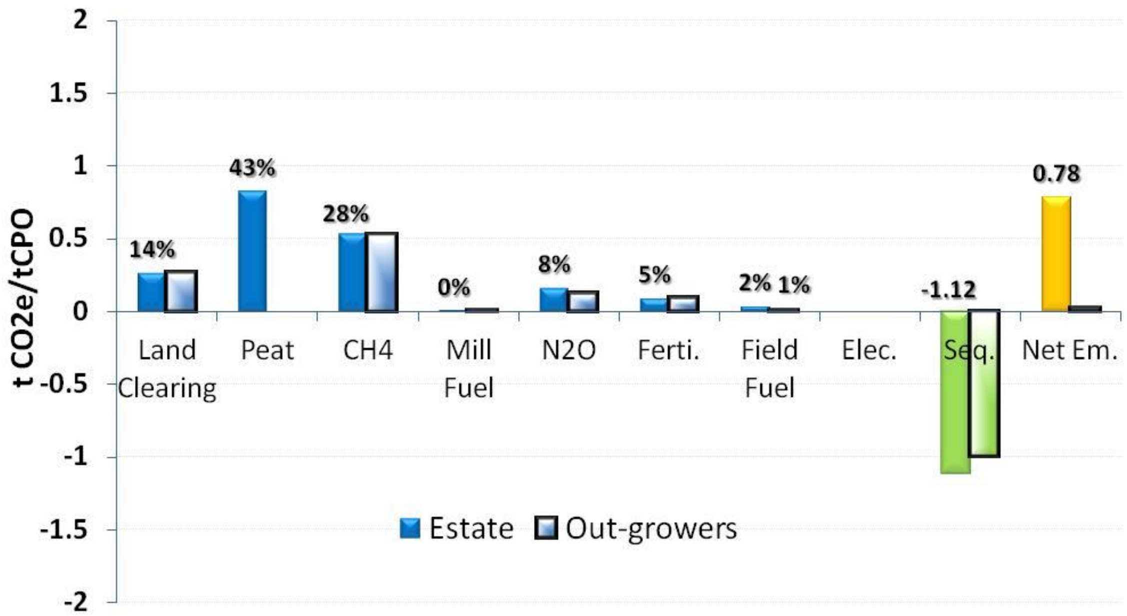

Figure 5: GHG emissions and balances of pilot mill C1 showing the varying contributions of emission sources for estate and out-growers.

B.3 Sensitivity analysis and scenario testing

PalmGHG allows manipulation of input data to test effects of management interventions. Results of scenario testing are given for a set of dummy data for a base case (scenario 1) with the following characteristics: mixed previous land uses, peat area 3%, no POME treatment, OER 20%, estate mean yield 20.2 t FFB/ha, out-growers' mean yield 14.2 t FFB/ha. The scenarios tested are described in the legend of Figure 6, and include variations of scenario 1, considering different previous land uses (scenarios 2 and 3); 100% peat soil (scenario 4); mill technological options (scenario 5); and a mix of options (scenario 6). The results show that high emissions result from clearing logged forest (scenario 2) or peat (scenario 4), and conversely that very low (negative) emissions result from clearing low biomass land such as grassland (scenario 3). Net emissions below 0.5t CO_2e/t CPO can be obtained from a mature industry that is replanting palms on mineral soil, capturing methane, and generating electricity from the biogas (Figure 6, scenario 6). Such results from the pilot and scenario tests provided a firm basis for submitting recommendations to the RSPO EB and for communicating the work of the RSPO GHG WG2 and the use of PalmGHG to a wider audience.

Even though such scenario testing cannot properly be considered as a sensitivity analysis, it certainly provides good insights into the sensitivity of the results to specific parameters. As commented above, one of the most critical parameters is the presence and extent of peat, as well as the emission factor considered for peat oxidation; the latter is particularly variable, and thus special attention should be paid to any modification introduced by the user. The results are also highly sensitive to the plantation history, i.e. the types of previous land uses replaced by oil palm plantations. In this case, evidence of land clearing history such as aerial photographs may be used to support the results. Finally, changes in POME treatment considerations have a significant effect on results; such considerations include the POME and COD generation factors; CH_4 emission factors from the POME (as well as e.g. losses of CH4 from collection / combustion systems); and treatment technologies for POME (anaerobic digestion in lagoons; flaring; combustion for electricity generation).

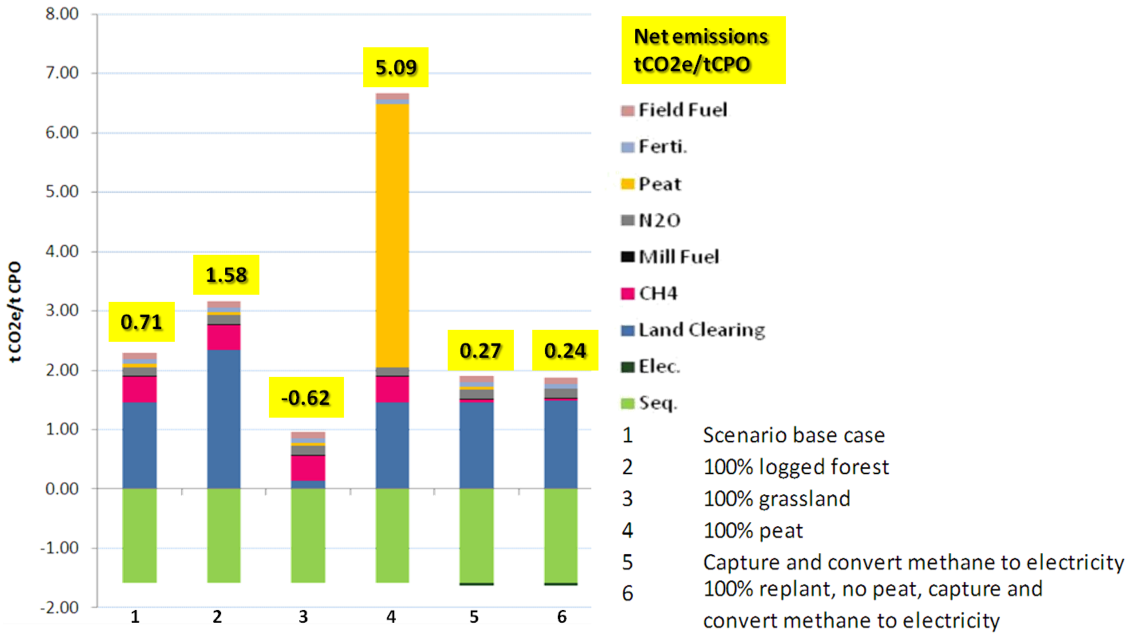

Figure 6: Results of scenario tests involving previous land use, soil type and POME treatment (Chase and Bessou 2011). As noted above, these results were calculated with a previous version of PalmGHG, and the absolute values would differ with the parameters described in this report.

B.4 Feedback on content and use of PalmGHG

Companies taking part in the pilot tests provided significant feedback leading to further improvement of the tool. Further comments on the usability of PalmGHG were made by the peer review panel. The main proposals, some of which have since been accounted for in the current *Beta* version 1.0 of PalmGHG were as follows:

- There was a need for documentation to accompany the model to give a better and clearer explanation of its use and structure. (The present report is an outcome of this request and further publications will follow).
- Graphs should be presented on each worksheet to show directly the effects of adjusting key variables (Not yet implemented).
- Each worksheet should include a brief explanation to explain its contents and purpose. (Done)
- A diagram showing the main components (estate, out-growers, mill, kernel plant) and the model boundary should be included in the Introduction. (A diagram on the model boundary has been added in the Introduction sheet and further diagrams are planned).
- Production data for the estate and the out-growers need to be more clearly distinguished especially those for FFB supply and PO/PK production by the mill. Perhaps out-grower data should be shown on separate sheets?
- The method of changing the crop life span is presently not explicit and is presumably a manual process. It needs specifying, and perhaps linked to cells in Land Clearing sheet (Not implemented yet).
- The tool will benefit from the incorporation of further routines and data produced by WS2 and WS3, as soon as these become available (in progress).
- The tool will benefit from additional technology options and uses of co-products: new mill technologies avoiding POME generation; alternative uses of EFB. (This has not been implemented yet, and there remains a need for continuous improvement of the tool as new technologies become available and their GHG effects are understood).
- Addition of N2O production from palm necromass (not implemented yet).
- Consideration of key performance index (KPI) for efficiency (e.g. fertiliser use per tonne of CPO; diesel use per tonne CPO; tonnes CPO per ha; etc.) in the synthesis tab in order to facilitate management (not implemented yet).
- Addition of a user defined option for methane production (where measurements of POME production and COD removal are available) (not implemented yet).
- Software development options should be incorporated by a programmer once PalmGHG is peer-reviewed. (To be done by the end of 2012). These include:

  i) Selection of CPO or biodiesel option at the start of each PalmGHG run, to simplify the operation of PalmGHG for those not concerned with biofuel production (once biodiesel calculations are integrated in PalmGHG).

  ii) Allowing the user to enter a range of values for key variables within sensible pre-defined limits set for each cell with the default values indicated.

  iii) Integrate alternative models for crop sequestration such as the one developed by ICRAF.

  iv) Protection of cells where appropriate to prevent loss of defaults.

v) Provision for production of a time-stamped labelled list of all variables/options that have been selected to produce the balance for each run of the model.

vi) Provision of references for all default values used and linkage of this information to the source of the data.

vii) Provision of guidance for the user to assess the quality of input data.

The main difficulties encountered by the pilot companies were related to data collection. As already mentioned, some difficulties may be eased as the recording process becomes routine. However, collecting data from out-growers is likely to continue be a problem unless they are assisted or guided in this and in the use of PalmGHG.

In future developments of PalmGHG, further options may be implemented to (i) link more parameters with their references (already partly implemented), (ii) to facilitate changes in default parameters and values when available, and (iii) to make pop-up comments appear with suitable instructions. The PalmGHG software should also come with a simplified instruction manual.

At the company level, it might be worthwhile connecting PalmGHG to the field and mill data base where collected data are stored. File format and guidelines for export from this data base into PalmGHG should be defined and provided by the programmer charged with developing the PalmGHG software.

C. Conclusion and next steps

WS1 members together with colleagues from the other workstreams of RSPO GHG WG2 have contributed to provide new information, a new tool, and recommendations to the RSPO EB concerning the monitoring of GHG emissions. PalmGHG is a comprehensive GHG calculator representative of the state of the art in terms of data use and output that conforms to international methodologies for GHG accounting. It uses information directly relevant to palm oil production that should either be easily available at the mill level or which can be substituted with default data. During pilot testing it was shown that PalmGHG, by identifying GHG emission 'hot spots', can help to define GHG reduction strategies.

Feedback from the companies involved in the pilot indicated that there were problems in collecting data, especially when data were needed for three subsequent years. It should however be noted that difficulties related to data recording should progressively diminish once the monitoring of GHG emissions becomes routine. On the other hand, difficulties encountered with collecting data from out-growers are not so easily resolved and indicate a need for a specific strategy to help out-growers record and collect data on a routine basis.

In the next update, a function that allows users to estimate the net GHG emission savings of palm biodiesel in accordance with the methodology laid down in the EU RED will be included.

Finally, PalmGHG needs reprogramming to make it more user-friendly. The current spreadsheet is rather complex and not easy to follow and not all the sheets and data used for the background calculations are of interest to all users. A more user-friendly software would allow users to generate results quickly, but at the same time provide a means to change default parameters when necessary and undertake tests of alternative scenarios.

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Appendix. Critical Review of PalmGHG Tool

Critical Review Statement

The PalmGHG has been reviewed following the provisions in ISO 14044. The development of the PalmGHG tool is seen as a major step forward in enabling and encouraging the palm oil industry in their work on GHG emission mitigation. The reviewers found the study interesting and are looking forward to follow the future use of the tool.

"The critical review process shall ensure that:

1. the methods used to carry out the LCA are consistent with the international standard;
2. the methods used to carry out the LCA are scientifically and technically valid;
3. the data used are appropriate and reasonable in relation to the goal of the study;
4. the interpretations reflect the limitations identified and the goal of the study;
5. the study report is transparent and consistent"

1) Since this is a GHG tool the LCA is not consistent with the ISO standards which advises other environmental impact categories. However, this is explicitly outlined and justified in the report. The report includes the four components "Goal and scope definition", "Inventory analysis", "Impact assessment/results" and "Interpretation/sensitivity analysis" of LCA. Not only the structure, but also the content follows closely and in sufficient detail the standards. The requirement by ISO 14044 stating that the critical review panel shall consist of at least three experts was accomplished. We can therefore state that the methods used are consistent with the international standard.
2) Significant changes to the report and the model were made based on the initial critical review. As with any agriculture or food LCA there are several ways of defining the system boundaries, sequestration models, data collection etc. While the method used to carry out the LCA are scientifically and technically valid there are still a few major deviations from the requirements in ISO 14044 that users should be aware of:
   a. <u>Allocation</u>: The PalmGHG tool uses allocation and does not consider substitution. Hence, the ISO-hierarchy on allocation is not followed.
   b. <u>Data quality</u>: According to ISO14044, a data quality assessment shall be included in the study. This is missing in the PalmGHG tool and report.
   c. <u>Sensitivity analysis</u>: According to ISO14044, important choices on data, system boundaries, allocation and LCIA are to be assessed in sensitivity analyses. The sensitivity analyses in the LCA report do not reflect the required comprehensiveness of sensitivity analyses. Of special importance are uncertainties in data related to POME methane, peat CO_2/N_2O, field emissions of N_2O, and land clearing.

- The data used for the LCA and tool are well documented although a traditional data quality assessment table as described in the ISO standards would be a useful addition to the report. The report includes a calculation example and an interpretation of the results. The interpretation phase of the study does not include an evaluation which, according to ISO14044, shall include consistency check, completeness check and sensitivity check. The goals of the GHG tool are consistent with the results. It is challenging to include limitations of results for a tool since this is the responsibility of the user.

3) The report is well written, illustrated with diagrams and the length seems to be appropriate. Readability seems to be the main goal (certainly a good one), but also the structure is now clear and suggests to the trained reader that the international standards were used.

The GHG tool has been developed using the guidelines and framework for LCA as described in ISO 14040/44. The report is detailed, transparent and the results reflect the goals of the study. However, the intended audience is palm oil producers with limited LCA background so it is essential that the tool is user friendly. The current version focuses more on getting the science right but the user friendly interface is still being developed. Several of the authors' responses refer to future developments. It is crucial for the success and strength of this tool that the future developments result in a more user friendly version.

Monica Skeldon (coordinator of peer review panel), Deloitte

Jannick H Schmidt, 2.-0 LCA consultants

Jacob Madsen, Deloitte

Thomas Fairhurst, Tropical Crop Consultants Ltd.

26th October 2012

Itemised comments from peer review

These are provided in the following pages.

Date: 8/27/2012	Jannick H Schmidt, **2.-0 LCA** consultants; Jacob Madsen, Deloitte; Thomas Fairhurst, Tropical Crop Consultants Ltd.

(1)	(2)	(3)	(4)	(5)	(6)
Com. #	**Page No.**	**Para/ Worksheet/ Table/Note** (e.g. Table 1)	**Comment (justification for change)**	**Proposed change**	**Decisions** on each comment submitted
			Are the methods used in the tool consistent with the ISO14040/14044 standards and / or other standards for GHG accounting such as PAS 2050 or WRI's GHG protocol? Does the method specify the following elements, which are common in LCA studies?		
			General Aspects - *LCA Commissioner, practitioner of LCA (internal or external)* No issues		
#1	p 10, 23		**General Aspects** - *date of the report* **Versions:** The text refers to two different dates of the tool; page 10 refers to a version of April 2012 and page 23 refers to a version of May 2012.	Check and correct version date.	Now all referring to the latest edited version of September 2012
#2			**General Aspects** - *Statement that the report has been conducted according to accepted carbon accounting guidelines* **Reference to standard:** The report only refers to RED – but not all results are calculated according to this directive. Reference to ISO14044 (or any standard) is missing in the report.	Ensure that reference is made to the relevant standards/accounting principles.	The tool has NOT been constructed as 100% compliant with any standard, even though it generally follows ISO 14044. This has now been clarified in the text.
			Goal of the study – *reasons for developing the tool* The goals of the tool are stated clearly in the report		
			Goal of the study – *its intended applications* Its applications and purposes are stated clearly in the report		
			Scope of the study – *function, including performance characteristics and any*		

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Com. #	**Page No.**	**Para/ Worksheet/ Table/Note** (e.g. Table 1)	**Comment (justification for change)**	**Proposed change**	**Decisions** on each comment submitted
			omission of additional functions in comparisons. Clear		
#3	p 10		**Scope of the study** – *functional unit explained* **Functional unit:** The tool operates with three different functional units; 1) CO2-emissions per hectare, per tonne CPO, and per tonne CPKO. The rationale behind the different functional units and guidance on which ones to use are missing. This is highly problematic, since many mitigation actions would fall out differently depending on a functional unit based on per t palm oil or per ha plantation is used. Especially, the functional unit on a hectare basis may produce misleading results because the crop yield and OER% have no effect on the results. Example; if a plantation stops using fertiliser, the GHG emissions per hectare will be reduced, but the emissions per tonne palm product will increase. One hectare is not a function – it can rather be used as a data collection unit in the plantation stage.	Delete the functional unit based on per ha.	The Synthesis sheet has been redesigned, by itemising each source of emissions or sequestration or CO2e credit as t CO2e, separately for the field (split into Own Crop and Outgrowers), Mill and Kernel crusher (where the split between own crop and outgrowers has been removed). The t CO2e has been allocated at each stage to area, t FFB or t crop product, as appropriate. The reference to impacts per ha has been kept because it is a useful unit for management at the plantation level, although we agree this is not a functional unit.
#4	p 10		Four different purposes of the tool are mentioned; 1) Identification of hotspots in the life cycle of palm oil products, with the aim of guiding GHG reduction opportunities, 2) Internal monitoring of GHG emissions, 3) Reporting to RSPO of progress, 4) Reporting to RED for biodiesel certification. To meet the three first purposes of the tool, there is no need for solving the allocation problem between the co-products CPO and PK. Here the functional unit could be t CPO+PK.	Consider to use default functional unit = 1 t CPO+PK at gate of palm oil mill. When the purpose is to produce results which are compliant with the RED, then use functional unit = one MJ palm oil biodiesel	We agree that there is no need for allocation in order to meet the three first purposes; however, given that the allocation is done by mass the results would be exactly the same if expressed per tonne CPO; per tonne PK; or per tonne of CPO+PK. In addition, no producer sells CPO and PK as a combined product, and

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Com. #	**Page No.**	**Para/ Worksheet/ Table/Note** (e.g. Table 1)	**Comment (justification for change)**	**Proposed change**	**Decisions** on each comment submitted
					thus we have not changed the units. The results are already expressed also per MJ palm biodiesel. The synthesis page has been updated, though (see #3)
#5	p 10		**Scope of the study** – *System boundary including omissions (emissions?) of life cycle stages, processes or data needs, quantification of energy and material inputs and outputs, assumptions about electricity production* **Modelling approach:** It is stated that the study follows an attributional LCA approach. However, it is not explained what this actually means? Further, it is stated that "the impacts are those linked to the production unit without considering market equilibrium with other production sectors or any feedback mechanisms." It is not clear what is meant with this? If 'market equilibrium' refers to the standard assumption of full elasticity between supply and demand in LCA, the same assumption is used in consequential modelling. Also, if 'feedback mechanisms' refer to the exclusion of rebound-effects, the same exclusion is often used in consequential modelling.	Make clear what is meant – or just delete this paragraph. ISO 14044 does not operate with the term "attributional".	The term attributional has been deleted, and the explanation of the link to standards has been improved.
#6	p 10		**iLUC:** According to the Peters et al. (2012)[11], around 9% of global carbon emissions in 2010 originated from deforestation. Hence, the exclusion of iLUC in an LCA of agricultural products is highly problematic.	Preferably iLUC should be included. If not, the exclusion of iLUC should be clearly indicated with the results output of the tool, so that users of the tool do not oversee this lack of a major GHG contribution.	The reviewer raises an important point with iLUC. However, we think including iLUC is beyond the scope of the tool, as it makes sense when assessing policies to expand production/ shifts between commodities. Here we want to assess the hotspots of a specific plantation, once the decision to devote such land to palm oil has already been made.

[11] Peters G. P., Marland G., Le Quéré C., Boden T., Canadell J. G., Raupach M. R. (2011). Rapid growth in CO_2 emissions after the 2008-2009 global financial crisis. Nature Climate Change 2, 2–4

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					The study cited by the reviewer does not refer to iLUC specifically, but LUC: we agree it is paramount to include LUC, but only dLUC is relevant for the purposes of PalmGHG.
#7	p 13-14		**Emissions from land clearing:** Emissions from direct land use changes (dLUC) are included, e.g. transformation from rubber to oil palm. It makes no sense to include dLUC when iLUC is excluded. This leads to highly misleading results; e.g. if oil palm is established on a previous rice field, this will show carbon removals due to a higher carbon stock in oil palm than rice. In this calculation the following is ignored/excluded: Obviously, the establishment of an oil palm plantation on a previous rice field does not lead to a net reduction in global production and consumption of rice (or other food). Instead, the establishment of oil palm plantations on lands which are already in use will just re-locate the ongoing clearing of land for agriculture. Hence, the net land use effect of establishing an oil palm plantation on a previous rice field may be similar as if the plantation was established in logged forest or other land use types which are likely to be transformed into agricultural land.	For the results based on RED, iLUC should be excluded in order to be in compliance with the RED. If iLUC is not included, then dLUC should also be excluded. If this is not implemented, the results should be clearly marked, so that the user is aware that the results deviate from actual cause-effect relationships and that the results are potentially misleading. For the results based on RED, dLUC should be kept as they are in order to be in compliance with the RED.	Again, the type of land shifts alluded to here are very relevant and need to be included in land use policy assessments; however, such displacement effects are beyond the control of individual growers. If at some point RED or other regulations request for inclusion of iLUC and provide guidance on how to do it, this may be included in PalmGHG for biodiesel.
#8	p 14-16	'Crop sequestration' & 'Land clearing'	**Carbon balance and Crop sequestration:** The tool includes annual crop sequestration. When an oil palm plantation is established by clearing old oil palm stands, the tool ensures that the emitted CO2 from clearing is equal to the crop sequestration during the whole crop cycle. Hence, when establishing an oil palm plantation in a previous oil palm plantation the net CO2 from clearing and crop sequestration is zero. Hence, the inventory of CO2 from clearing of oil palm and crop sequestration makes no difference for the results. Thus, a major simplification of the tool and carbon balance accounting can be made by operating with zero CO2 emissions from clearing when transforming oil palm to oil palm and by excluding crop sequestration – without affecting the results.	It is proposed to exclude CO2 emissions from land clearing when transforming from oil palm to oil palm, and to exclude CO2 removal from crop sequestration. Three relative complex pages of text in the report can be skipped (p 14-16), and some 'hard-to-follow' operations in the excel file can be skipped in the sheets 'Land clearing' and 'Crop sequestration'. This has no effects on the calculated results.	This is potentially a useful shortcut; however, it is only true if there are no differences in growth between successive oil palm crops that might occur for example due to use of different planting materials, different palm ages at clearing or different growth conditions during the crop life. In addition, this would only simplify the calculations

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					for operations that involve 100% replanting (with same planting material). It is indeed a good comment to take into account for potential future developments, but no changes have been implemented in the current version.
#9	p 13-16		**Documentation of carbon balance:** The report does not document that the carbon balance in the full crop cycle is maintained (when considering land clearing of oil palm for the establishment of a new oil palm plantation).	If the proposed change above is not implemented, the report should carefully justify that the carbon balance of the full crop cycle is maintained.	Some further explanations have been provided under Figure 3 in the report, although this may not always be the case as explained in #8.
#10	p 13		**Amortization of dLUC emissions:** CO2 from land clearing is divided by the number of years in the crop cycle. When considering transformation of oil palm to oil palm this ensures carbon balance (not necessarily – see comments above.) – but as mentioned above this transformation (and crop sequestration) can be excluded. The amortization period of one crop rotation is arbitrary and it is not related to any kind of cause-effect relationships; why should the emissions from the transformation of a logged forest to oil palm be divided by 25 years? If the logged forest was transformed to a rice field with two harvests per year – should the emissions from the transformation then be divided by 0.5? (No!).	Amortisation of emissions from land transformation should be avoided because this is arbitrary – and thereby arbitrary LCA results are produced. It is proposed to exclude dLUC and include iLUC instead – for iLUC amortisation can be avoided by operating with time dependant CO2 emissions based on the Bern Cycle (IPCC 2007, p 211-213). For the results based on RED, amortisation should be kept in order to be in compliance with the RED.	The justification of using a different amortisation period to the 20 years suggested e.g. in PAS 2050 and RED is now clarified in the text; this allows consistent consideration of emissions and sequestration, without biasing the results in favour of younger or more mature plantations. 20 years are used for the biograce (RED) tab
#11	p 16		**Conservation area sequestration:** It seems strange that sequestration in conservation areas is included. This issue is related to the problem of including dLUC and excluding iLUC, see comment #7. If a palm oil company decides to set aside some land for conservation, the actual effect will be that the agricultural production somewhere else will increase. If one palm oil producer starts to produce less palm oil, the global consumption and production will not decrease; the 'missing' production capacity will just be established somewhere else.	Exclude conservation area sequestration.	The point raised by the reviewer is an important one to be considered when assessing national land use policies, but such indirect effects cannot be attributed to individual producers: if one builds a house, we do not assess the iLUC of not

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					growing palm oil. It is true though that the treatment of conservation areas needs further guidance; this is currently being discussed in RSPO and with other roundtables, so the section is left as a placeholder in the calculator. Specific guidance will be provided to auditors to check the input data used in this section.
#12			**Electricity assumptions**: Not clear how the user partitions electricity used for own operations and electricity sold into the grid. If the user enters 50% sold to the grid does that mean the balance is used in 'own operations'?	Include further explanation	Further explanation has been provided in the tool (cells A37, A61)
#13			**Scope of the study** – *Cut off criteria for initial inclusion of inputs and outputs, including description of cut-off criteria and assumptions, effect of selection on tool outputs, inclusion of mass, energy and environmental cut-off criteria* Concern over how Conservation Block seq can be verified. Does it provide a loop hole for growers to 'adjust' their CO2 emissions?	Include description for how this verification can occur or acknowledge this as a weakness.	As suggested in #11, special attention will be given to the conservation block sequestration in the audit process where input data to PalmGHG are checked.
#14			**Life Cycle Inventory Analysis** – *data collection procedures* **Inconsistency in background data:** Default results and results calculated according to the RED are based on different default/standard values, e.g. kg CO2e for AN fertilizer (and several others).	Input parameters/standard values should be the same for default results and for RED results – except in cases where the RED specifies that something specific shall be used.	The tool is designed so as to use only one set of default values: the RED ones or the ones provided by RSPO, which come from a larger review. This means that the tool may generate two different results depending on the defaults selected, but this is not inconsistent: any two LCA studies will usually

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					provide different results even if the same primary data are used. The key thing is that different defaults are not used for the same concept (e.g. different emission factors for diesel) in the same study (e.g. GHG per MJ biodiesel for RED; or GHG per tonne CPO according to RSPO)
#15			Data entry can be difficult and susceptible to errors.	A form should be provided with the model so that the user can assemble all the data on paper, cross check, and then perform data entry.	This is a very valid point, taken forward as recommendation for the further software development, which will focus on the user friendliness
#16			**Life Cycle Inventory Analysis** – *qualitative and quantitative description of unit processes* **Description of unit processes:** The unit processes are generally not described. According to ISO 14044 section 5.2 this shall be included in the LCA report.	It is proposed to include flow charts and/or tables for each unit process (or life cycle stage) that defines and describes the inputs and outputs: - Oil palm plantation stage - Palm oil mill stage - Palm kernel oil mill stage - Biodiesel production stage	Again, this is a useful point but it has not been included in detail for the time being. A generic description of what is in and out of scope is given in each section, and detailed flow charts may be incorporated in the next software development in order to help data entry and transparency.
#17	p 10		**Life Cycle Inventory Analysis** – *sources of published literature* *i. Values used for carbon stocks, vegetation sequestration numbers, and anaerobic digestion are pulled from the best sources* **Carbon stock, coconut:** In table 1, the carbon stock for coconut seems to be too	Correct value and use correct citation.	The reference has been checked. Draft Commission Decision of (31 December 2009) on guidelines for the calculation

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			high – I would estimate it to be lower than oil palm and rubber. The cited reference (European Commission 2009) does not contain data on carbon stocks!		of land carbon stocks for the purpose of Annex V of Directive 2009/28/EC. European Commission, Brussels. 26 p. Note that the C stock of crops such as coconut, oil palm and rubber will depend on age. At its maximum economic lifetime coconut is probably similar to rubber. Six independent sources give values for mature rubber of from 62 to 116 tC/ha, with a mean of 90.2 tC/ha. Three sources for coconut range from 75 to 98 t.
#18	p 17		**POME:** The amount of POME per tonne FBB is assumed to be 0.5 tonne based on Yacob et al. (2006). Compared with other sources, this seems to be in the lower end, e.g. Ma et al. (2007)[12] specify 675 kg POME per tonne FFB. Further, the amount of POME is affected if the oil mill has a decanter and EFB press.	The applied value should be further justified and maybe adjusted. Further, the amount of POME could be made variable with respect to different technologies (decanter and EFB press).	This is an important area for further development; actual values for POME generation, and perhaps CH4 generation based on COD content, could be used instead of the value suggested by default. The user can already replace the defaults used in the tool with proper justification, and future updates of the tool will consider the possibility of more sophisticated approaches to CH4 estimation.

[12] Ma A N, Choo Y M, Toh T S and Chua N S (2007), Renewable energy from palm oil industry. Not published. Updated version of chapter 17 in: Singh G, L K Huan, Leng T and D L Kow (1999), Oil Palm and the Environment – A Malaysian Perspective. Malaysian Oil Palm Growers Council, Kuala Lumpur

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#19	p 17	Fertiliser and N2O	**Fertiliser, unit:** It is not specified whether the unit is kg nutrient (N/P2O5/K2O) or kg total fertiliser (from the calculations in the tool it can be seen that the unit is kg total fertiliser).	Specify that the unit is kg total fertiliser.	This has been clarified in the tool
#20	p 17	Default data	**N% in POME:** The N% (=0.045%) in POME seems to be too low. According to Singh et al (1999, p 186)[13], the N content in POME is 39.2 kg N/kg dry POME. Applying a moisture content at 93% (Ma et al., 2007)[14], the N% can be determined as 0.27%.	Check and possible correct N% in POME.	The average value of 39.2 in this article refers to digested POME *solids*, which is not relevant as we are considering POME *liquid (*after digestion); values in raw POME (before digestion) also tend to be higher but land application of raw POME is illegal in at least Malaysia and Indonesia. The preceding article by Lim et al in the same book shows that the N content of POME varies with the treatment system adopted. The value of 0.045% is that given by Gurmit (1995) (The Planter, 71, 361-386) for the supernatant of the ponding system which is generally the most common POME treatment employed. Values could well vary in individual cases and with different types of POME treatment: a note has been added to the report on the

[13] Singh G, D L Kow, K H Lee, K C Lim and S G Loong (1999), Empty Fruit Bunches as Mulch. In: Singh G, L K Huan, Leng T and D L Kow (1999), Oil Palm and the Environment – A Malaysian Perspective. Malaysian Oil Palm Growers Council, Kuala Lumpur

[14] Ma A N, Choo Y M, Toh T S and Chua N S (2007), Renewable energy from palm oil industry. Not published. Updated version of chapter 17 in: Singh G, L K Huan, Leng T and D L Kow (1999), Oil Palm and the Environment – A Malaysian Perspective. Malaysian Oil Palm Growers Council, Kuala Lumpur . This is the same as reference [2].

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					uncertainty in this parameter, and the user is encouraged to use own values if measures are available.
#21	p 17	Fertiliser and N2O	**N-balance and N2O from crop residues:** The N2O emissions related to the inputs of N in POME and EFB are included. But the inputs of N from the decomposition of pruned fronds, spent male flowers, cover crop and biomass from replanting are not included. This is inconsistent, and it leads to an underestimation of N2O emissions. There are no valid arguments to distinguish between POME/EFB and pruned fronds/ spent male flowers/biomass from replanting/cover crop – and to exclude some of these N inputs	It is proposed to establish an N balance for the crop cycle in order to document and ensure that all flows of N are addressed. As a minimum it should be ensured that all inputs of N sources are included in the calculation of N2O.	For the time being, N in other crop residues that had not yet been considered have now been included in the N2O calculations. The possibility of a full N balance will be studied in the future.
#22	p 18		**CH4 from POME:** Data are directly applied as kg CH4 per t POME, and POME quantity is directly applied as t POME per t FFB. This approach oversees that the quantity of POME varies depending on technology (see comment #18) and that CH4 per t POME depends on digestion (CODin versus CODout).	It is proposed to further parameterise CH4 to reflect dependencies on underlying conditions (decanter, EFB press, CODin, CODout) Check that the quantity of POME is correct/not underestimated, see comment #18.	As #18
#23	p 19		**CH4 when digestion is applied:** The report is not transparent. Parameters and calculations are only present in the excel tool – not the report.	Document parameters and calculations for digestion of POME.	This was explicit in other parts of the report, and it has now been clarified.
#24	p 19		**Utilisation of captured biogas:** The only considered utilisation of captured biogas is generation of electricity. To my knowledge, a widely used practise is to use the biogas as fuel substitute in the palm oil mill boiler which leads to more excess shells for export.	Consider if the applied utilisation of biogas in the tool is appropriate – possible include more options.	Kernel shell exports are already included (see p. 20): if they increase thanks to biogas fed into boilers then this will be captured.
#25		Mill	**Methane assumptions:** Three distinct methane assumptions are available (D, E and F). It is not possible to combine the assumptions, e.g. if an oil mill installs a digestion plant in the middle of a year, or if the fate of the captured methane is partly flaring and partly utilisation. Both of the mentioned examples are more normal than the applied distinct three options.	Enable the user to enter percentages of POME being treated conventionally, digestion with electricity generation and digestion with flaring.	Good point; the user now has the option to enter the different % each treatment represents.
#26	p 21		**Inputs for biodiesel production:** Reference is made to the Biograce project. However, this project contains several reports and excel tools. The reference is not clear	Make the reference to Biograce clearer; reference to specific report/file.	Agreed; more / clearer references are now provided

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#27	p 21		**Uncertainties in Biograce:** It is stated that Biograce is associated with uncertainties, e.g. peat soil emissions. However, it does not seem like these emissions in PalmGHG are adopted from Biograce? Then text in the report is not relevant for the PalmGHG tool.	Check and possible exclude comment on uncertainties on peat soil emissions in Biograce.	Done
#28		Mill	**Life Cycle Inventory Analysis** – *Are calculation procedures for relating data to unit process and functional unit adequate?* **Mill divided into own crop and outgrower:** It seems awkward that the mill calculations are divided into own crop and outgrower. This is an unnecessary complication of the mill calculations, which makes it difficult to follow the calculations. There is only one mill and it operates in the same way regardless if the FFB comes from own plantation or outgrowers – the subdivision is only relevant for the production of FFB.	Do not divide the mill into own crop and outgrower.	Done. See #3 above
#29		Synthesis	**Results are generally calculated per ha:** It seems inappropriate that all results are calculated per ha. It does not make sense to present oil mill results on a hectare basis – here more relevant reference flows are t FFB or t CPO. The use of this inappropriate reference unit is probably also the reason why the results per t CPO and per t PK are not calculated correct (highly underestimated because of error in allocation, see comment #32).	Do not present results on a hectare basis. Instead, it is proposed to present results per t CPO which is the actual functional unit of the study.	See #3 above
#30			**Life Cycle Inventory Analysis** – *validation of data including data quality assessment and treatment of missing data.* The final model should have validation checks built in so that when the user enters values outside the model returns warnings.	Include validation checks for users and requires users to declare sources of data entered	Some checks are already included in the tool, but we agree these could be extended. However, significant consultation would be needed for this e.g. to decide the most important checks ones, and relevant ranges of data; this is thus left for future development of the tool.

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#31			**Life Cycle Inventory Analysis** – *tool has the ability to perform a sensitivity analysis* **Sensitivity analysis:** Generally, the report contains no sensitivity analysis, qualitative assessment of sensitivity or comparison of applied data with data from other data sources. According to ISO 14044 section 5.2 such considerations shall be included. However, the tool does allow for the user to assess sensitivities. The user can investigate, for example, the impact of fertilizer use choices (urea versus other choices), POME management (CH4 capture and flaring or cogeneration) and previous land use (effect of standing biomass at planting) on emissions	As a minimum such analysis/assessments should be presented for the most critical assumptions and data: - CH4 emissions from POME treatment (and underlying parameters) - N2O field emissions (and underlying parameters) - Peat CO2 and N2O emissions (and underlying parameters) - dLUC and iLUC	We agree that a thorough sensitivity analysis will be important. However, the scenario testing provided so far, which has now been further clarified and commented, is enough for the purposes of illustrating the key tool sensitivities.
#32	p 11, 19	Synthesis	**Life Cycle Inventory Analysis** – *allocation principles and procedures, including documentation and justification of allocation procedures and uniform application of allocation procedures* **MAJOR ERROR:** In the sheet 'Synthesis' the result per t CPO and per t PK (cell P10:Q11) are not calculated correctly. The formulas contain a term where the allocation factor is multiplied. By doing so, the already mass-allocated results are multiplied with the allocation factor again. This underestimates the results for CPO by around 20% and for PK by around 80%.	**MAJOR ISSUE:** Correct error	Thanks for pointing out this error; it has now been corrected.
#33	p 11		**Allocation and consistency:** Mass allocation is used (default) between CPO and PK and between CPKO and PKE. In cases where biomass based energy is exported, the allocation problem is solved by substitution. Hence, different allocation principles are applied to different co-products of the palm oil mill – this is not consistent. According to ISO 14044, section 4.3.4.2, allocation procedures shall be uniformly applied.	Ensure that allocation procedures are consistent.	Allocation is clearly an area where we have not tried to follow strictly the recommendations in ISO. In any case, ISO recommends to apply allocation uniformly to similar inputs and outputs; we have treated the main products (CPO; CPKO) uniformly (using mass

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					allocation) and energy by-products (such as electricity and PKS sold as coal substitute) also uniformly but with a different approach (system expansion). This is justified because the purpose of the tool requires it to provide results for the two main products and thus system expansion is not appropriate to CPO and CPKO, but required to "exclude" other by-products from the results.
#34	p 11		**Allocation and ISO 14044:** The applied allocation method is not in accordance with ISO 14044; according to ISO 14044, section 4.3.4.2, allocation shall/should be avoided whenever possible.	Avoid allocation by using substitution. Data and methods are available in: - Schmidt J H (2007), Life assessment of rapeseed oil and palm oil. Ph.D. thesis, Part 3: Life cycle inventory of rapeseed oil and palm oil. Department of Development and Planning, Aalborg University, Aalborg. http://vbn.aau.dk/fbspretrieve/10388016/inventory_report - Schmidt J and Weidema B P (2008), Shift in the Marginal Supply of Vegetable Oil. International Journal of Life Cycle Assessment, 13 LCA (3) 235-239 <DOI: 10.1065/lca2007.07.351>	See #33
#35	p 11		**Justification of allocation method:** The applied allocation methods are not justified.	Provide appropriate justification.	See #33; further justification is provided in the text (section A1)
#36	p 11		**Missing co-products:** The following co-products are not considered: - Plantation stage: pruned fronds (mulch and nutrients), chopped stands after re-planting (mulch and nutrients) - Palm oil mill stage: boiler ash (road material)	Address the missing co-products.	This is a fair point, which has only been partially taken into account: the C in fronds and stands is included; the nutrients returned are

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					somehow considered with the reduced input of fertilizers (if we considered the avoided burdens we'd double-count). We have not identified boiler ash as an important co-product, as it does not displace major impacts. As mentioned in the introduction, PalmGHG focuses on those sources and sinks of GHG emissions that make a material difference in the net balance.
#37	p 10		**Global Warming Impact Assessment** - *the most appropriate GWP impact assessment methodology used* **Biogenic CO2:** The IPCC (2007) GWP100 method is used. Special characterisation factor is determined for biogenic CH4. A description of characterisation factors for CO2 (biogenic versus fossil) is missing.	Describe characterization factors for biogenic and fossil CO2.	Biogenic CO2 is considered neutral and only direct emissions are considered; thus a CF of 22.25 for bio-methane is used. This is now further explained in the text, and further description is provided in references.
#38	p 13-16, 19		**Biogenic CO2 and consistency:** Biogenic CO2 is not dealt with consistently. Emissions from land clearing and removals from crop sequestration are included – but emissions from biogas flaring and biomass combustion are excluded. It is not clear how or if this affects the results (under or overestimation – or in balance)?	Check for consistency of how biogenic CO2 is dealt with. Describe in report, and justify that results are not over- or underestimated due to double counting or due to missing emissions.	As #37 C fixation in the FFB is NOT included; this is the C that makes it into the POME, and thus it is justified to apply a differentiated factor to the biogenic methane and to exclude the CO2 from burning such methane. On the other hand, uptake into the trunk is considered, and thus emissions need to be accounted for land clearing.

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			Global Warming Impact Assessment - *limitations of the GWP results explained*		
#39			**Other impact categories and limitations:** Limitations of GWP are not explained. Other relevant impact categories are biodiversity, landscape, respiratory effects caused by particulate and NH3 emissions.	Include short description of limitations of GWP results.	This is further explained in section A1.
#40			**Efficiency**: The tool doesn't explore the relationship between yield and emissions. Is there a positive correlation between high yield and low emissions when all other parameters are held constant? In other words with efficient management (leading to high yield) emissions are lower per kg CPO produced?	Include a short description explaining this limitation of the model or adjust the model accordingly.	Exploration of such relationships is a potential output of the tool, not an integral component of it; a comment suggesting this application has been added in the introduction (A1)
#41			**Efficiency**: Fertilizer use efficiency is an important and underused measurement in oil palm (Cassman et al., 1998; Dobermann, 2007; Dobermann and Cassman, 1997; Fairhurst, 1999). Increasing nutrient use efficiency reduces the emissions related to fertilizer use per kg fertilizer applied. In other crops (e.g., rice, maize) nutrient use efficiency is used widely. Measurements can be carried out in oil palm and are used extensively at Bah Lias in their fertilizer trials.	Would be useful to explore the relationship between resource use (e.g., fertilizer) efficiency and carbon emissions. Do more efficiently management plantations achieve lower emission rates per kg CPO produced?	See #40 above
			Results Summary and Presentation – *Is the summary of the results (in the excel file) easy to interpret and clear to the user*		See #3 above
#42		Synthesis	**Results per hectare:** The results are presented as GHG emissions per hectare which is not an appropriate functional unit, see comments #4, #5 and #29.	Present result break-down per t CPO instead of per ha.	
#43		Synthesis	**Result categories – sequestration and emissions:**The presentation of results is divided into sequestration and emissions. Several of the items under sequestration should not be categorized as sequestration; methane and mill electricity credit and PK credits are just avoided inputs related to the applied allocation approach (substitution). This has nothing to do with sequestration.	Remove methane and mill electricity credit and PK credits from the heading 'sequestration' and include it as negative contributions under the heading 'emissions'.	See #3 above
			Results Summary and Presentation – *Assumptions and limitations associated with the interpretations of results, both methodology and data related presented clearly*		These are certainly important points; in terms of completeness, the

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#44			*and thoroughly* **Evaluation:** According to ISO 14044, section 4.5.3 an evaluation of completeness, sensitivity and consistency shall be included in the study. This is missing in the PalmGHG tool and report.	Include evaluation of completeness, sensitivity and consistency in the LCA report.	introduction now further specifies that the bulk of GHG emissions from palm oil (as identified in many sources) are captured in PalmGHG. Specific analyses of sensitivity may only be performed in specific applications, and guidance is provided for the user.
#45			**Results Summary and Presentation** – *data quality assessment* **Data quality assessment:** According to ISO 14044, section 5.2, a data quality assessment shall be included in the study. This is missing in the PalmGHG tool and report.	Include data quality assessment in the LCA report.	The tool is to be used with actual data, which would ensure representativeness etc. The defaults provided in the tool are good today, but their quality (e.g. technological, temporal and geographical representation) will depend on each application. The reviewer makes a good point, which is to be considered in a next version, and guidance given to the user so they can assess the quality of each parameter for their specific application.
#46			Each parameter and the respective units used for measurement should be presented in separate columns to avoid any confusion.	Change presentation of parameter and units	This is an important specification to improve the usability of the tool, which will be implemented in its future upgrade.
			Results Summary and Presentation – *full transparency in terms of value-choices, rationales and expert judgments* The tool and the report provides a complete and transparent product where all		

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			results can be traced to the individual data entry, assumptions and estimates		
			Are the methods used to carry out the study scientifically and technically valid? Specifically with regards to: i. Accounting of carbon stocks in the plantation and land clearing sections ii. Accounting for emissions from POME at the mill iii. Accounting for field emissions		
#47			i. Need some form of verification for the Conservation Block seq. sheet. How to prevent submission of incorrect and/or exaggerated data; maps or satellite imagery are probably the only clear way to validate claims for Conservation blocks, such data should also be audited by a qualified third party. Additional comments are included in previous comments	The plan should be to incorporate in the RSPO auditing process	As #11
			Are the data and data sources used appropriate and reasonable in relation of the goal of the tool?		
			Yes		
			Is the tool transparent and consistent?		
#48			Need to make sure the user is informed of the units for each cell that must be completed. In the final model the user should be able to go through a stepwise process to fill in the required data. Additional comments included in previous sections.	Show teach parameter and its units in separate columns. Hide data that is not relevant to the data entry process.	As #46
			General Comments		

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#49			The model rightly omits soil organic carbon as a possible source of sequestration because of the difficulty of making proper measurements (in particular there is great spatial variation in soil organic carbon under mature palms because of the impact of discrete crop residue application). Soil organic carbon measurements must be corrected for changes in bulk density, that occur over time. However, some research should be carried out to develop a method to measure changes in soil carbon stocks under oil palm, where both spatial variability and changes in soil bulk density are taken into account. Wageningen University has much experience in this area (Prof Ken Giller, ken.giller@gmail.com). The new model provides the means to measure carbon sequestration in forest reserves within a concession but there must be carefully written regulations on how such carbon sequestration is measured based on satellite imagery and other mapping tools.	Recommend conducting research to develop a method to measure changes in soil carbon stocks under oil palm, where both spatial variability and changes in soil bulk density are taken into account.	We agree this is a key area for further research, and it will be passed on to RSPO or other funding bodies.
#50			**Underestimation of results:** Several assumptions and errors which all tends to lead to underestimation of the results have been identified: - Comment #7 and #8: iLUC is excluded and dLUC is included. This leads to significant underestimation of GHG-emissions for plantations which are established on land with lower carbon stock or which are kept as oil palm in several crop cycles. - Comment #18 and #22: Applied figures on POME quantity seem low. This leads to possible underestimation of CH4 - Comment #21: N inputs are missing leading to underestimation of field emissions of N2O - Comment #32: Error in allocation which leads to underestimation of GHG emissions per t CPO at around 20%	The recommended changes are specified under the respective comments.	Please see replies to each specific comment
#51			**Reporting:** ISO 14044, section 5.2 provides some useful headings with which the LCA report can be structured. In the report many important items and assumptions are hidden in the text. This makes it unnecessary time consuming to find what one is looking for. E.g. the functional unit is found in the text in a three pages chapter on goal and scope without any sub-headings.	Include more sub-headings in the report, e.g. to make it easier to identify the functional unit, assumptions, cut-off criteria, allocation principles, LCIA method etc. Rename the heading 'Scientific background' to 'Life cycle inventory'.	Agreed; the report now follows the sections suggested in ISO and by the reviewer, and some of the contents have been further specified or moved.

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			Some issues are described on different pages, under strange sub-headings, and some issues are missing: - Allocation: p 11, 12, 19 (substitution), and 21 - cut-off criteria: exclusion of iLUC on p 10 and other exclusions on p 12 - LCIA method: p 10, and emission factor for CH_4 on p 19 under the sub-heading 'Mill'. Further, the heading 'Scientific background' contains descriptions which are usually placed under a heading called 'Life cycle inventory'.		
#52			**Open the excel file:** When the excel file is opened, a message is popping up, that the workbook contains links to other data sources.	This should be avoided.	This bug has now been addressed
#53	p 22		**Guidelines:** Under bullet 3 and 4, it is stated that the user can add rows for extra areas in the PalmGHG excel tool. Firstly, rows do not represent areas? Secondly, it is not specified exactly where to add extra rows? Thirdly, if extra rows are inserted, I'm not sure that the entered values in these rows will be included in the calculations?	Make guideline clearer.	Done. The tool now offers cells to provide input of up to four estates and outgrower areas each
#55			**Data integrity**: Although Excel makes it easy to use and understand it also opens up for substantial risks. The developers have locked cells but these are not difficult to bypass for an experienced excel user. The risk associated with excel tools is that everyone can make changes and it is impossible to track who made the changes and what was changed.	Recommend eventually transitioning tool to a platform that enables tracking of changes by users or provides more protection of underlying data.	Thanks. This is indeed the plan by RSPO: once the scientific aspects of the tool have been agreed, a more user-friendly version will be developed, addressing aspects such as data integrity, etc.
#56			**Data entry**: In the final model the user should be led through a process to enter raw data only and then the results should be presented. This would make data entry more convenient and reduce the likelihood of errors. Error checking mechanisms should be built into the model (e.g., cross check that the land area balances with the sum of the different land use types used). In the final model the user should be able to store different runs so that it is possible to investigate options for lowering emissions (fertilizer use, POME	Recommend making the data entry process more automated by including prompts.	As #55

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			management, etc).		
#57			**Upfront calculations:** Instructions should be supplied on how to calculate data before data entry. Examples include extraction rates, shell transport by road and seas (from where to where?).	Include additional instructions in excel file on how to calculate metrics that require additional calculations prior to entry into spreadsheet.	As #55
#58			**Definition**: How is export of mill electricity measured? From the meters on the steam turbines?	Include additional clarification	Export of surplus electricity from conversion of methane has been clarified.
#59			**Calculation clarity**: How to calculate % of mill electricity exported?	Include additional clarity	As #58
#60			**Clarification**: Kernel crushing plants may also use electricity from the mill, in addition to diesel fuel.	Provide an option for additional fuel sources to be reported	If electricity from the mill is used in the crusher this would then appear as lower diesel consumption (and probably less electricity being exported to the grid)
#61			**Definition**: Assume biomass is always dry matter? Definition needed.	Include additional clarification	Correct – biomass = dry weight. Strictly it refers to living tissue but for convenience the term can also cover material undergoing decomposition such as frond piles (which, strictly should be considered to be necro-mass).
#62			**Definition**: Need to define the different previous land use types. For example, what is 'logged forest'? Could be forest that has been logged thirty years ago.	Definitions needed	The text has been expanded lightly to clarify that these definitions are not strict; especially the termed 'logged' which can cover a variety of situations.
#63			**Definition**: Define source of fertilizer. Is it place of manufacture (e.g., N fertilizer) or mining (e.g., potash)?	Provide more clarity around fertilizer origins	It can refer to either source; this is now clarified in the tool
#64			**Fertilizer sources**: No provision for Ammonium chloride N fertilizer (used in PNG, for example).	Add additional fertilizer source	Ammonium chloride has now been added as an alterative fertiliser

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#65			**Clarity**: It is unclear how the model accommodates users that use EFB as fuel for electricity generation and export.	Provide additional clarity	This has not been observed in many mills, but is certainly something to be considered in further evolution of the tool once this practice becomes more mainstream. At the moment if this is practised it will appear in the results as increased electricity sold to the grid, and thus a larger credit for the mill.
#66			**Results Presentation**: The model could provide the user with very useful efficiency ratios such as kg oil/kg fertilizer nutrient, kg oil/kg diesel used.	Recommend including additional efficiency metrics on the 'Synthesis' tab	Similar to #40.
#67			A method should be provided for users that want to enter their own data on crop sequestration. Values will certainly vary considerably across the oil palm belt.	Include additional method for user determined sequestration.	We agree such guidance is useful, although it was beyond the scope of this group to provide a method to estimate crop sequestration. We would recommend that the producer carries out some basic on-site growth measurements of fronds and trunk for palms of different ages following the methods described by Corley et al (1971) and Corley and Tinker (2003, p 93.) Planting density and total frond number also need to be recorded. Note that these data require to be analysed further before being used to generate sequestration values. The report has now been expanded to consider these alternative sources of crop

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					sequestration data.
#68			**Biomass calculations:** Consider calculating the biomass production based either on: • yield or production using harvest index to calculate back to total biomass production using a constant value; or • on a simple measurement of vegetative growth like petiole cross section and frond production rate that is correlated with total biomass production. This could then eliminate the need to work up complex models to estimate the amount of biomass produced.	Revise how biomass production is calculated.	As #67
#69			**Nutrient recovery**: They have measured fertilizer nutrient recovery (% of nutrients applied that are recovered in the palm biomass) in field experiments(Prabowo *et al.*, 2004; Prabowo and Foster, 2006; Prabowo *et al.*, 2002).	Recommend reviewing this literature to verify the assumptions made in the model. In general, recovery efficiency is a better assessment of N losses because recovery by the palms is measured and what is not recovered is assumed lost unless soil analysis data shows that nutrients not taken up have accumulated in the soil. For example, in the model, it is assumed that 55% of N is lost so recovery efficiency is only 45%. Is this correct?	Thanks for suggesting these references; this is again an area where many different values could be used as default, but in any case the user may chose a different one if there is evidence that the new value will be more adequate (e.g. by suggesting such references. We assume that 30% (not 55%) is lost (IPCC default)
#70			**Peat emissions**: The method for peat assumes that all peat is the same. In reality peat varies greatly between sites with topogenous (small in-valley peat areas) peats behaving very differently from ombrogenous (peat dome) peats. Therefore, water level management may not be a sufficiently robust all inclusive parameter to assess emissions.	Third party measurements may be required to verify claims on water management in peat are correct.	This is certainly an area for further research, and one of the hotspots where further guidance will be provided for checks during the audit process

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