Life Cycle Assessment of Palm Oil at United Plantions Berhad 2019

Results for 2004 – 2018

Summary report

UNITED PLANTATIONS BERHAD
(Incorporated In Malaysia)
COMPANY NO. 240-A

Preface

This report is carried out by Jannick Schmidt and Michele De Rosa (2.-0 LCA consultants, Denmark) for United Plantations Berhad (Teluk Intan, Malaysia). The study includes data collection and calculation of LCA results for United Plantations Berhad's palm oil production 2004-2018. The study was undertaken during the period January to February 2019.

The current report updates the results of a series of previous studies to also including 2018, and it summarises the main findings of a detailed life cycle assessment report of palm oil production at United Plantations 2004-2018. When citing the report, please use the following reference:

> **Schmidt J and De Rosa M (2019)**, Life cycle assessment of Palm Oil at United Plantations Berhad 2019, Results for 2004-2018. United Plantations Berhad, Teluk Intan, Malaysia.

Jannick Schmidt & Michele De Rosa, Aalborg, Denmark, February 2019

CONTENTS

Executive Summary

Background and objectives

This report presents a summary of a detailed life cycle assessment (LCA) study of palm oil production at United Plantations Berhad (Teluk Intan, Malaysia). LCA is a technique to assess environmental impacts associated with all the life cycle stages of a product or service from 'cradle to grave'. The current study was undertaken during the period January to February 2019 – and it builds on top of four other large studies carried out for United Plantations in 2008, 2011, 2014 and 2017. The study in 2008 was the first LCA of palm oil ever, which was fully compliant with and critical reviewed according to the international standards on LCA: ISO 14040 and 14044.

The environmental impact of palm oil is presented as greenhouse gas (GHG) emissions, i.e. carbon footprint, as well as for a number of other impact categories such as biodiversity, respiratory effects and toxicity. The environmental impacts relate to the life cycle of palm oil from cultivation to the gate of the refinery, including all upstream emissions, e.g. from the production of fertilisers, fuels and machinery. The results are shown per kg of refined palm oil.

Over the last decade, United Plantations Berhad has worked intensively in reducing their environmental impacts. The effect of this work is illustrated by tracking the carbon footprint for the company's production of palm oil from 2004 to 2018.

The primary purpose of the LCA is to document and assess the environmental impacts from the production of palm oil at United Plantations Berhad. Secondly, the purpose is to follow over time the GHG emissions from the production of palm oil at United Plantations Berhad. Thirdly, to compare United Plantation's production of palm oil with average Malaysian/Indonesian palm oil and other major vegetable oils, and fourthly, to analyse improvement options for United Plantation's production of palm oil.

Functional unit

The functional unit is central for an LCA. The functional unit is a quantified performance of the product under study for use as a reference unit, i.e. it is what all the results relate to. The functional unit is defined as 1 kg of neutralized, bleached and deodorized (NBD) vegetable oil for food purposes at refinery gate. The distribution, use and disposal stages are not included.

Data sources and data collection

The oil palm cultivation stage is inventoried for the 12 oil palm plantations owned by United Plantations (nine in Malaysia and three in Indonesia). Similar to this, the palm oil mill stage is inventoried for United Plantations' five palm oil mills (four in Malaysia and one in Indonesia). The refinery state includes an inventory of United Plantations refinery in Malaysia; Unitata. The data for United Plantations' estates, palm oil mills and refinery have been collected on-site in collaboration with the United Plantations Research Department (UPRD). Data for activities outside United Plantations, such as production of fertiliser, fuels and machinery, are obtained from Schmidt (2017) and the ecoinvent database v3 (ecoinvent Centre 2017).

Land use changes and nature conservation

The link between land use (e.g. occupation of 1 hectare during one year) to deforestation and related emissions and biodiversity impacts are included in the study. Since the cultivation of oil palm takes place on already cleared land, it is not associated with any direct land use changes, i.e. land use changes that takes place in the oil palm field – except at replanting which is not associated with impacts because it involves conversion from oil palm to oil palm. However, the use of land for oil palm contributes to the general pressure on land, leading to land use changes somewhere else. This is referred to as indirect land use changes (iLUC). This study covers iLUC by means of a model documented in Schmidt et al. (2015) and Schmidt and Muñoz (2014). This model considers that demand for land leads to two main effects: conversion of land (land use changes) and intensification of land already in use – both effects are associated with GHG emissions.

Besides the iLUC effects described above, the benefits from nature conservation are also included in the study. United Plantations has set-aside large areas as nature conservation in their land bank in Indonesia. The effect of nature conservation is that conversion from forest to oil palm is avoided locally. However, since the decision to conserve land does not reduce the overall demand for land, an equivalent amount of land needs to be taken into production somewhere else, i.e. indirect land use changes are induced. The benefit of nature conservation is the difference between the avoided local impact and the indices indirect impact.

Results: impacts from United Plantations' palm oil production

The results are calculated in three different ways:

1. Results excluding iLUC
2. Results including iLUC
3. Results including iLUC and savings from nature conservation

The most significant impact categories are global warming, respiratory effects, and nature occupation (biodiversity impacts caused by land use changes). All results exclude the stored carbon in the vegetable oil (i.e. CO_2 uptake in the cultivation stage).

The contribution to global warming (not including iLUC) from 1 kg NBD palm oil produced in United Plantations in 2018 is 1.22 kg CO_2-eq. The major part of the contribution originates from the oil palm cultivation stage where the main contributors are field emissions of CO_2 from oxidation of peat soils and N_2O. The major contribution in the oil mill stage is CH_4 from anaerobic digestion of palm oil mill effluents (POME).

When iLUC is included, the total contribution to GHG emissions is 1.55 kg CO_2-eq. per kg NBD palm oil. Hence, iLUC is a significant contributor to GHG emissions.

When also including nature conservation, the impact from the Indonesian production is significantly reduced – the offsets from nature conservation reduces the GHG emissions per kg NBD palm oil from 2.27 to 1.04 CO_2-eq. For United Plantation's entire production, the nature conservation in Indonesia reduces the GHG emissions from 1.55 to 1.18 CO_2-eq. per kg oil.

Results: evolution of GHG emissions over time

The time series for NBD palm oil at United Plantations show reductions from 2004 to 2018 at 46% (without iLUC), 28% (with iLUC) and 54% (with iLUC and nature conservation). Reductions in GHG emissions levels are seen when new technology have been installed replacing older less clean technologies; this mainly relates to the installation of biogas plants, avoiding methane emissions from anaerobic digestion in POME treatment.

Results: palm oil from United Plantations vs. industry averages for other vegetable oils

United Plantations' production of palm oil has been compared with industry averages for four major vegetable oils, namely palm oil (Malaysia/Indonesia), rapeseed oil (Europe), sunflower oil (Ukraine), and peanut oil (India). The comparison showed that palm oil at United Plantations in 2018 performs better than all the other oils for all compared impact categories.

Results: United Plantations' total product portfolio

The GHG emissions associated to United Plantations' total product portfolio, i.e. all the products sold by UP, are 781,000 t CO_2-eq (without iLUC), 965,000 t CO_2-eq (with iLUC), and t CO_2-eq (with iLUC and nature conservation).

1 Introduction

United Plantations is one of the pioneer plantation companies to grow and process oil palm in Malaysia. It has been practicing sustainable agriculture for many years. Currently, it is one of the highest yielding and most efficient producers of palm oil in Malaysia.

This report presents a summary of a detailed life cycle assessment (LCA) study of palm oil production at United Plantations Berhad (Teluk Intan, Malaysia). The current study was undertaken during the period January to February 2019, and it builds on top of four large studies carried out for United Plantations in 2008, 2011, 2014 and 2017. The current study is carried out as a desk study, where the research department at United Plantations have collected the data at the distance. The current update is based on the model developed as part of the larger study in 2017.

Over the last decade, United Plantations Berhad has worked intensively in reducing their environmental impacts. The effect of this work is illustrated by tracking the carbon footprint for the company's production of palm oil each year from 2004 to 2018.

The main focus in the presentation of the results is on greenhouse gas (GHG) emissions, i.e. carbon footprint, but other impacts are also addressed. The environmental impacts relate to the life cycle of palm oil from cultivation to the gate of the refinery including all upstream emissions. The results are shown per kg of refined palm oil. In addition, the results are also shown for the entire product portfolio of United Plantations Berhad in 2018.

1.1 Palm oil production in United Plantations Berhad

United Plantations Berhad has nine estates in Peninsular Malaysia and three estates in Central Kalimantan Indonesia, in total a planted area with oil palm of 43 987 ha. The locations of the estates are illustrated in **Figure 1**. The hectares of each of the 12 estates are summarised in **Table 1.**

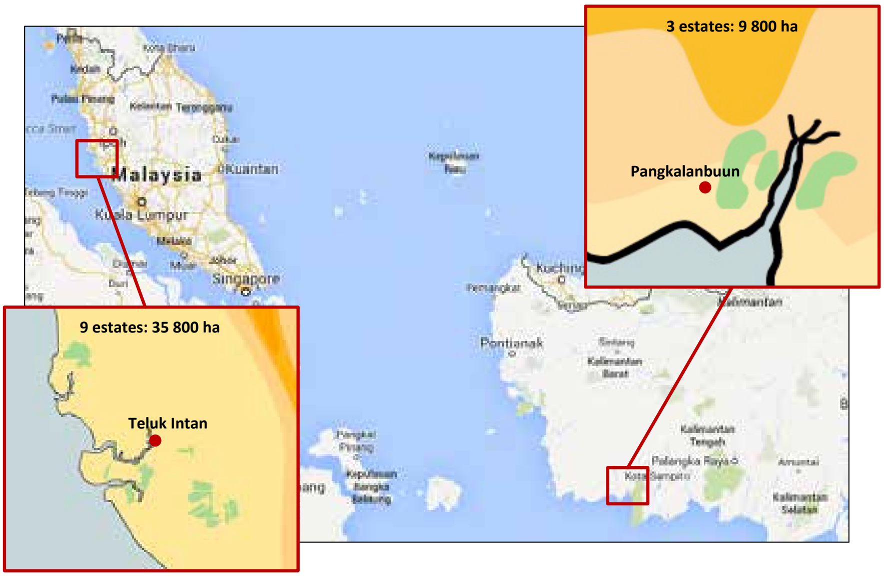

Figure 1: Location of United Plantations Berhad's estates. Map of Malaysia and Indonesia: Google Maps (2014) and detailed maps of United Plantations' estates: United Plantations Berhad (2014a).

Estate	Location	Planted area (ha)
UIE	Malaysia	8,958
Jendarata	Malaysia	5,331
Ladang Ulu Basir	Malaysia	3,737
Ladang Sungei Erong	Malaysia	3,508
Ladang Sungei Chawang	Malaysia	3,240
Ulu Bernam	Malaysia	3,056
Lima Blas	Malaysia	2,745
Landang Changkat Mentri	Malaysia	2,364
Seri Pelangi	Malaysia	1,337
PT Surya Sawit Sejati (PT SSS), Lada estate	Indonesia	4,917
PT Surya Sawit Sejati (PT SSS) , Runtu estate	Indonesia	3,562
PT Surya Sawit Sejati (PT SSS), Arut and Kumai	Indonesia	619
Total Malaysia	**Malaysia**	**34,275**
Total Indonesia	**Indonesia**	**9,099**
Total all	**Malaysia and Indonesia**	**43,374**

Table 1. Overview of United Plantations' oil palm estates in 2018.

United Plantations has nature conservation reserves in Malaysia and in Indonesia. Recently, United Plantations has expanded its operations into Central Kalimantan, Indonesia, where much of the land that has been acquired consists of degraded secondary and logged over forests as well as large tracks of alang-alang grasslands. Of the company's total land bank in Kalimantan, 7,500 ha is set-aside as land under permanent conservation. In Malaysia, 188 ha is set-aside as nature conservation reserves.

United Plantations have four palm oil mills in Peninsular Malaysia and one in Indonesia. **Table 2** provides an overview of the palm oil mills. Since 2013, two mills in Malaysia have been closed, namely the Seri Pelangi mill (May/June 2013) and the Lima Blas mill (August 2015). After the closure of these oil mills, the FFB is transported to the Jendarata and the Ulu Basir mills respectively. The effect of this is that the FFB is transported 38-45 km extra and that it is processed in oil mills with biogas capture. The GHG emissions reductions from biogas capture by far exceed the additional transport. In 2018, the new Optimill with biogas capture replaced the older Ulu Berman oil mill. With this, 100% of United Plantations FFB is processed in oil mills with biogas capture.

Palm oil mill	Location	Biogas capture	Processed FFB, tonne	Produced crude palm oil (CPO)	Produced palm kernels (PK)
UIE	Malaysia	yes	214,754	45,468	8,392
Jendarata	Malaysia	yes	134,079	29,805	7,214
Ulu Basir	Malaysia	yes	124,247	27,064	6,095
Ulu Bernam	Malaysia	yes	312,480	66,342	15,088
Pt. Surya Sawit Sejati	Indonesia	yes	312,632	71,654	12,753
Total Malaysia	**Malaysia**		**785,560**	**168,679**	**36,789**
Total Indonesia	**Indonesia**		**312,632**	**71,654**	**12,753**
Total all	**Malaysia and Indonesia**		**1,098,191**	**240,334**	**49,542**

Table 2: Overview of United Plantation's palm oil mills and their production in 2018.

United Plantations has one palm oil refinery, Unitata, where all crude palm oil produced in United Plantation's Malaysian palm oil mills is refined. A large share of the steam consumption at Unitata is supplied by the Jendarata palm oil mill; partly by exported steam from the palm oil mill boiler and partly by utilisation of the captured biogas from the oil mill's POME treatment. In the Unitata refinery, the crude palm oil undergoes neutralisation, deodorisation and bleaching to produce NBD oil as well as fractioning to produce olein and stearin fractions as well as further refined products such as cocoa butter alternatives, fats for filling, fats for coating, fats for bakery products, vegetable oil for margarine, nutrolein golden palm oil, and salad oils. The current study only includes the refinery processes until NBD oil is produced.

United Plantations produce most of their FFB themselves, but buy some from external growers. The majority of the produced CPO at United Plantations palm oil mills is sold, while some is also provided as feedstock for the Unitata refinery, where it adds up to around half of the feedstock. The other half of the feedstock for the Unitata refinery is CPKO produced externally. The oil mills also sell kernels for further processing in external kernel crusher plants. The Unitata refinery sells refined palm oil and palm kernel oil as well as some palm acid oil (PAO), which mainly contains free fatty acids (FFA).

United Plantations has recently acquired the Unifuji refinery. In 2018, around 15,000 t of the CPO from United Plantations' oil mills was provided as feedstock for the Unifuji refinery. However, this is not shown in Figure 2 because the LCA results from this are not included. This will be added for the LCA update for 2019 to be carried out in 2020.

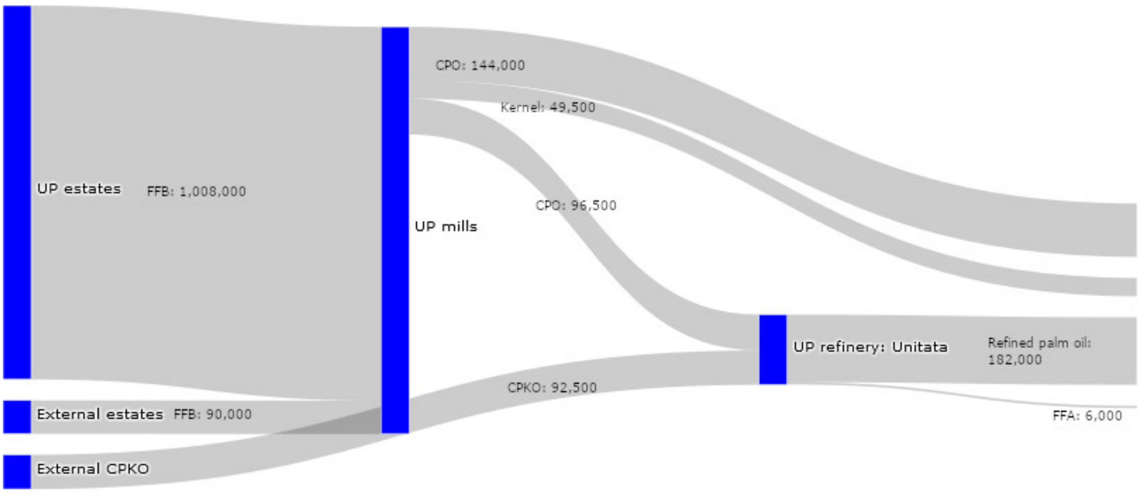

Figure 2: Sankey diagram of the flows of United Plantations, through their estates, oil mills and refinery, Unitata. The product portfolio includes CPO, kernels, refined palm oil and FFA. The FFA (free fatty acid) is also sometimes referred to as palm acid oil (PAO).

1.2 Sustainability in United Plantations Berhad

In keeping with its commitment to the production of sustainable palm oil, the company is interested in documenting its environmental performance and has, accordingly, worked intensively with life cycle assessments of their production since 2008. In order to support future decisions in the company on making the production even more sustainable, the LCA studies also aim to predict the potential environmental benefits of implementing new technologies and practices. Here, the main focus is on the effects of implementing projects like the four CDM projects in its other palm oil mills.

Selected parts of United Plantations' Policies on Carbon Footprint, Pesticides, and Biodiversity & Environment:

Carbon footprint initiatives: "It is the goal of United Plantations to reduce their emissions of GHG by 50% per metric tonnes of NBD Palm Oil by 2018 vis-à-vis the 2004 level." (Bek-Nielsen 2014)

Pesticide use: "In line with RSPO's continuous improvements initiative the Company's Sustainability Committee monitors and reviews the Groups pesticides usage.

Together with several multinational chemical companies, amongst others Bayer, BASF and Syngenta, United Plantations is exploring avenues to reduce overall pesticide usage as well as evaluating alternative safer pesticides and is committed to phasing out those pesticides that fall under the WHO Class 1A and 1B segment when effective and suitable alternatives are available. One example is United Plantations total ban of Paraquat usage. In this context, United Plantations has since February 2008 been working towards minimizing the usage of Paraquat, which has been documented in the annual RSPO Surveillance Audits. In May 2010, the Board based on Management's advice took the decision to voluntarily phase out the usage of Paraquat, a goal which was realized with effect from October 2010 as a combination of less toxic pesticides could be used as alternative substitutes." (United Plantations 2014c)

Biodiversity and Environment Policy:
"We want to ensure that our agricultural operations comply with the following criteria:

- No development on high carbon stock forests (HCS).
- No development on high conservation value forest areas (HCV).
- No development on peat lands.
- Free, prior and informed (FPIC) for indigenous and local communities in all negotiations.
- Compliance with all relevant laws and National Interpretation of RSPO Principles and Criteria."
-

"Environmental commitments in place:

- A zero-burn policy (1989)
- A No primary forest clearing policy (1990)
- A No HCV forest clearing policy (2005)
- A No bio-diesel production/supply policy (2003)
- A No Paraquat use policy (2010)
- A No new planting on peat policy (2010)
- A High Carbon Stock Assessment & Land Use Change Analysis for new plantings (2014) "

(United Plantations Berhad 2014b)

More information is available at: http://www.unitedplantations.com/About/UP_Environment_policy.asp

Box 1: United Plantations' policies on carbon footprint, pesticides, and nature conservation.

More recently, the company has also expanded its operations into Central Kalimantan, Indonesia, where much of the land that has been acquired consists of degraded secondary and logged over forests as well as large tracks of alang-alang grasslands. The Indonesian oil palm estates cover 9,179 ha. In addition to the land planted with oil palm, 7,500 ha is set-aside as land under permanent conservation.

CDM projects in United Plantations Berhad

United Plantations is currently hosting four CDM projects commissioned by the Royal Danish Ministry of Foreign Affairs. The four CDM projects are briefly described below:

3 methane recovery and utilisation projects at: Jendarata palm oil mill, Ulu Basir palm oil mill and UIE palm oil mill: A significant contribution to global warming from palm oil production is the emissions of methane from the anaerobic ponds which are used for palm oil mill effluent (POME) treatment. In order to reduce GHG emissions, the anaerobic ponds in the three palm oil mills have been replaced by digester tanks where the generated methane-containing biogas is captured. In the Jendarata palm oil mill, the biogas produced is sent to the nearby palm oil refinery Unitata where it substitutes fuel oil used for steam generation. In the Ulu Basir and UIE palm oil mills, the captured biogas is partly flared and utilised as fuel substitute in the oil mill boilers.

The annual reductions of GHG emissions of the three biogas CDM projects are.

- Jendarata palm oil mill: 20,271 tonne CO_2-eq.
- Ulu Basir palm oil mill: 23,973 tonne CO_2-eq.
- UIE palm oil mill: 14,848 tonne CO_2-eq.

Jendarata steam and power plant: Usually palm oil mills are self-sufficient of steam and power supply. This energy is produced by burning the biomass produced (fibre and shell) from the processed fresh fruit bunches (FFB). The empty fruit bunches (EFB) are usually applied in the plantation as mulch. GHG emissions can be reduced if the energy production in the palm oil mill is increased and the excess energy (steam and power) is exported substituting energy produced by burning fossil fuels. As part of the CDM project, the old low efficiency boilers in Jendarata palm oil mill have been replaced by a new high efficiency boiler in 2006. This was followed by another even more efficient biomass boiler that was commissioned in late 2017 boosting efficiencies further. The new biomass reciprocating boilers have a higher capacity and steam pipes from the palm oil mill to Unitata have been established. In addition to the fibre and shell, the new power plant allows for the burning of the EFB, and the excess steam is exported to Unitata where it displaces fossil fuel used for steam generation.

The annual reduction of GHG emissions of the biomass CDM project is
- Jendarata steam and power plant: 8,851 t CO_2-eq.

Box 2: CDM projects in United Plantations Berhad. The GHG-emission reductions are obtained from (UN CDM project no. project 0558 2006; UN CDM project no. project 1153 2007 ; UN CDM project no. 5150 2011 ; UN CDM project no. 3622 2011).

2 Methodology

2.1 What is a life cycle assessment?

Life cycle assessment (LCA) is a technique to assess environmental impacts associated with all the stages of a product or service from 'cradle to grave', that is, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. Not all LCAs include the use and end-of-life stages of a products life cycle. These LCAs are called cradle-to-gate studies. The general procedures, requirements and terminology of LCA are defined in the international standards on LCA ISO 14040 and 14044, which the current study follows.

The functional unit is central for al LCA. The functional unit is a quantified performance of a product system (see **Figure 3**) for use as a reference unit, i.e. the functional unit is what all the results relate to.

Product stages and foreground/background systems: The main stages of palm oil production are illustrated in **Figure 3**: cultivation, palm oil mill and refinery stages. The boxes in the figure are called activities, and the arrows represent flows. Often the activities in a life cycle system are grouped in a foreground system and a background system. The foreground system includes the LCA activities for which data are collected and modelled in the study, while the background system includes the activities for which generic and existing data are used, i.e. often from LCA databases.

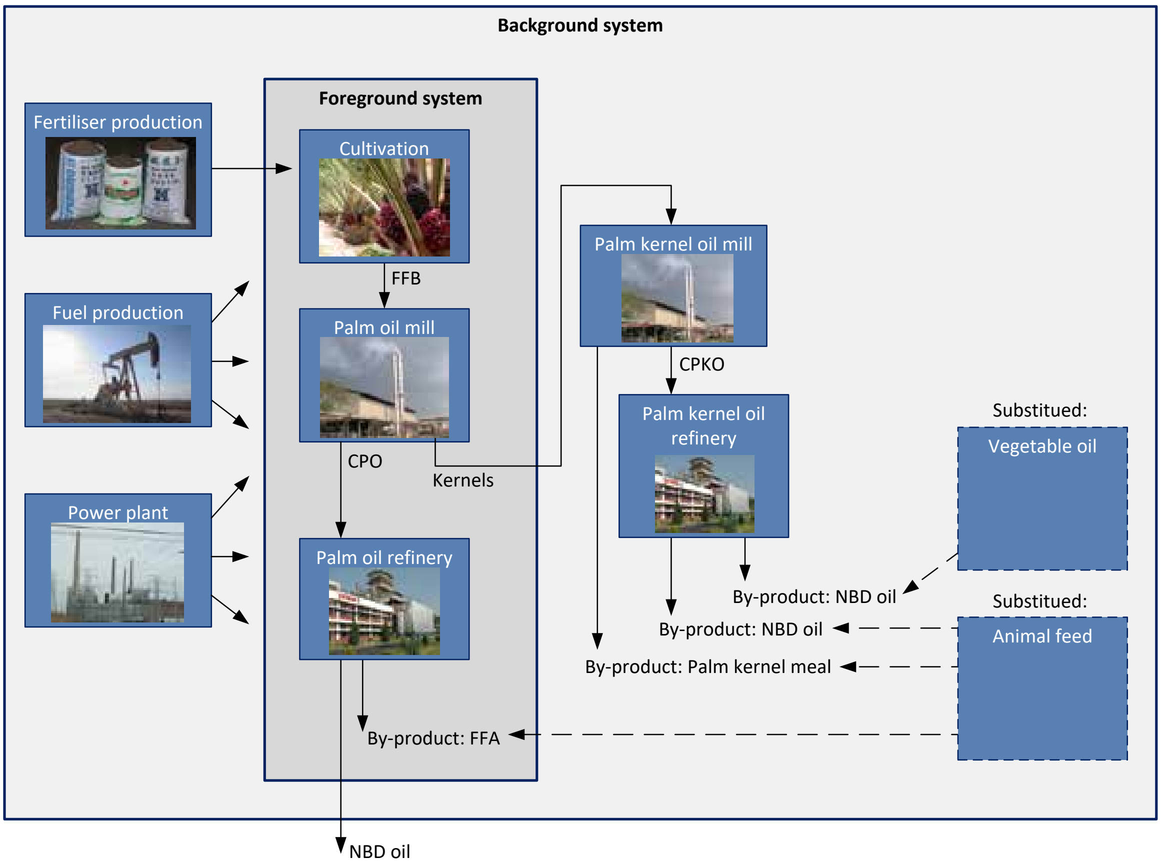

Figure 3: The main stages of the product system for palm oil production. Dotted lines and boxes represent negative flows and substituted activities respectively. The FFA (free fatty acid) is also sometimes referred to as palm acid oil (PAO). Pictures: UP picture library and Wikipedia.

System boundary and life cycle emissions: The outer boundary of **Figure 3** represents the system boundary, which is the boundary between the technosphere (where the activities are) and the environment. The net output of the system is the product under study, here refined oil (neutralised, bleached and deodorised, NBD). Each activity in the system is associated with emissions. Emissions are flows from the technosphere to the environment, i.e. flows that cross the system boundary. The sum of all emissions that cross the system boundary constitutes the life cycle emissions related to the product under study.

Common GHG emissions from palm oil production are:

- nitrous oxide (N_2O) from fertiliser production and crop cultivation where the fertiliser is applied,
- carbon dioxide (CO_2) from combustion of fossil fuels and peat decay during crop cultivation (if it involves organic soils), and
- methane (CH_4) from anaerobic digestion of palm oil mill effluent (POME) in ponds in the palm oil mill.

By-products: Some of the activities in **Figure 3** supply by-products, e.g. the palm kernel oil mill supplies palm kernel meal (PKM) and the refineries supply palm acid oil (PAO)[1] free fatty acids (FFA). Both PKM and PAO are used as animal feed. Assuming that a change in demand for refined palm oil does not affect the output of animal products, then a change in the supply of PKM and PAO will substitute alternative production of animal feed.

Life cycle impact assessment: Most often, an LCA software is used for calculating the life cycle emissions. The current study used SimaPro 8. The number of different calculated emissions is often very high – especially when collecting detailed data and when linking to large databases to represent the background system. It is not unusual that 500-1000 different emissions are included in the results of life cycle emissions. Presenting and interpreting so many emissions individually is not meaningful. Therefore, a so-called life cycle impact assessment (LCIA) is carried out. This involves that the emissions are 'characterised', which means that each of the different emissions is multiplied with 'characterisation factors' that represent the emissions' relative contribution to a number of impact categories. For each impact category included, an aggregated result is produced, in a given unit of measure. For example, Global Warming Potential is calculated in kg CO_2-eq. from the contribution of CO_2, CH_4, and N_2O emissions, among others. The principle of characterisation is illustrated in **Figure 4**.

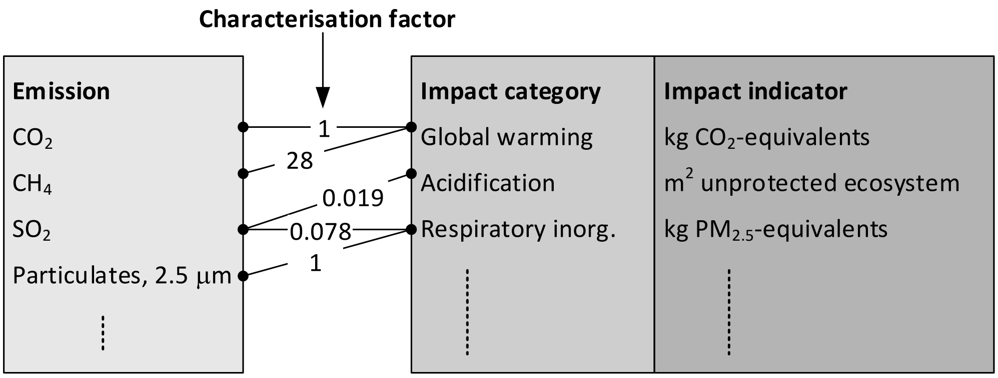

Figure 4: The principle of characterisation.

[1] Palm acid oil (PAO) is very similar to palm fatty acid distillate (PFAD) but has a lower free fatty acid (FFA) content.

LCA can be used by decision makers to fulfill several objectives:

- To provide a picture as complete as possible of the interactions of an activity with the environment.
- To identify major environmental impacts and the life-cycle stages or "hot-spots" contributing to these impacts.
- To compare environmental impacts of alternative ways to produce the same product.
- To identify improvement options.

Further, LCA has many application areas, such as (ISO 14040):

- Environmental performance evaluations
- Environmental labels and declarations
- Environmental communication
- quantification, monitoring and reporting of entity and project emissions and removals and validation, verification and certification of greenhouse gas emissions

2.2 Indirect land use changes (iLUC)

Land use changes account for around 11% of global GHG emissions (IPCC 2014b). Most often emissions from land use changes are not included in LCA. This is regarded as a major lack of completeness since land use changes, such as deforestation, constitute a major contributor to global GHG-emissions. But what is indirect land use changes? The applied method in this study is described in Schmidt et al. (2015) and Schmidt and Muñoz (2014).

What is indirect land use changes (iLUC)? The term '*land use change*' refers to the fact that crop cultivation is associated with land use changes which involve that land cover types with a high carbon stock (forests) are converted into land cover types with a lower carbon stock (oil palm plantation and other cropland). Such changes in carbon stocks are related to CO_2 emissions. The term '*indirect*' refers to the place of the land use change, which is somewhere else than where the crop is grown. When modelling the effect on land use changes from crop cultivation, such as oil palm, the challenge is to identify the additional land use changes relating to a change in the cultivation of a given area during a given period. All cultivated crops are grown on already cleared land – obviously, this land can be more or less recently cleared. However, the choice to cultivate a piece of already cleared land cannot lead to the clearing of this particular plot of land (because it is already cleared). Therefore, when land is cultivated it is not associated with any direct land use changes (clearing of the land) on the same plot of land as is being cultivated – instead it contributes to the general demand for arable land, and consequently land use changes somewhere else.

Land is regarded as an asset input to crop cultivation – in line with other assets, such as tractors. Indirect land use changes are then the upstream effect of this input of land – analogically, the upstream life cycle emissions related to the manufacture of the tractor could be called 'indirect tractor effects'. This is depicted in **Figure 5**. The activities within the grey box in the figure (the activities that represent iLUC) are described in the following.

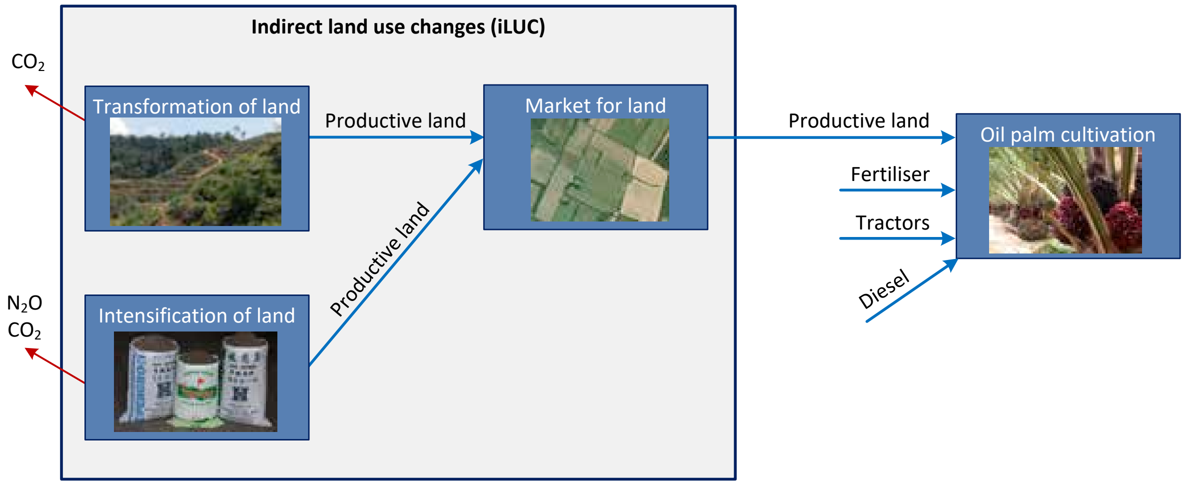

Figure 5: Conceptual representation of the iLUC model used in the study. (Pictures: UP picture library, Jannick Schmidt, Google Maps)

2.3 Nature conservation

The effect of nature conservation can briefly be described as redirecting where and how new land is brought into productive purposes. When conserving a specific plot of land, local specific eco-systems and carbon stocks are conserved, but the global overall demand for land can be assumed not to be affected. Hence, an equivalent amount of the function of the conserved land will be brought into production somewhere else. This is illustrated in **Figure 6**, where the direct effect refers to the on-site local effects and the indirect effects refer to the equivalent amount of land that will be brought into production somewhere else.

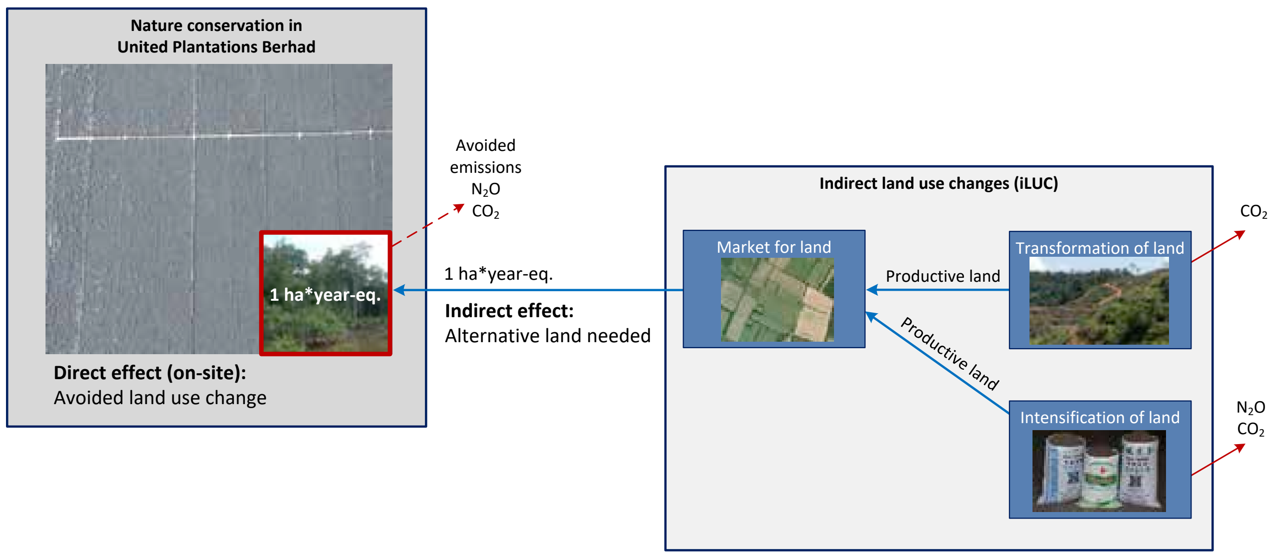

Figure 6: Direct and indirect effect of nature conservation. Here illustrated as nature conservation in oil palm cultivation. Pictures: Oil palm field (Google Maps 2014) and nature (Nature conservation reserve in United Plantations Berhad Indonesia, picture taken by Jannick Schmidt).

The concept as lined out above means that the nature conservation is a good idea as long as the conserved land hosts a higher value, i.e. biodiversity and carbon stock, than the alternative land to be brought into production. It should be noted that the land equivalent to be brought into production (to compensate for the conserved land) does not necessarily need to be the same area as the conserved land nor it needs to be land at all. This is because productive land can also be created by changing in the productivity (yield) of land, which is already productive, i.e. without changing the area of the productive land.

The effect of nature conservation is quantified per year. Then, this effect is attributed to the palm oil production this year. The following three elements are included in the quantification of the effect of nature conservation:

- Direct (on-site) effects from avoided transformation of land: One-year delay of the effects from transformation from non-productive land (i.e. the conserved land) to productive land (i.e. the land use cover that is avoided by the conservation).
- Direct (on-site) effects from occupation of land: Direct emissions from occupation during one year (e.g. avoided CO_2 and N_2O emissions from drained peat land if the conserved land is wetland).
- Indirect (remote) effects induced by avoiding transforming the conserved land into productive land. This is modelled via the iLUC model, see **section 2.2**.

3 Goal and scope of the study

3.1 Purpose and functional unit

This LCA study has four goals:

- The primary purpose of the LCA is to document and assess the potential environmental impacts from the production of palm oil at UP.
- Secondly, to follow over time the GHG-emissions from the production of palm oil at UP, in order to identify trends.
- Thirdly, to compare UP's production of palm oil with average Malaysian/Indonesian palm oil as well as industry averages of rapeseed oil, sunflower oil and peanut oil.
- Finally, the purpose is also to analyse improvement options for UP production of palm oil.

The functional unit is defined as one kilogram (kg) of edible fats and oils as defined in CODEX STAN 19-1981 (2013). For the included oils, the reference flow is one kg refined (Neutralised, Bleached and Deodorised; NBD) vegetable oil at refinery gate. Most oils are traded as bulk oils in trucks or ships; thus, no packaging is needed for delivery of the product of interest.

In addition to the functional unit mentioned above, the life cycle results are also shown for United Plantations product portfolio of (see **Figure 2**):

- 144,000 t crude palm oil (CPO)
- 49,500 t kernels
- 182,000 t refined palm oil
- 6,000 t palm acid oil (PAO)

3.2 System boundaries

Results are presented for United Plantation's production in Malaysia and Indonesia separately and as a whole. The system boundaries are presented in **Figure 7** and **Figure 8**. For the Malaysian production, all the three life cycle stages: cultivation, oil mill and refinery are managed by United Plantation, while the Indonesian production only involves the cultivation and the oil mill stages. United Plantations interacts with the Malaysian/Indonesian palm oil industry when United Plantations' oil mills receive outside crops, when kernels are sent to processing in palm kernel oil mills, and when the Indonesian palm oil mill sells crude palm oil for refining.

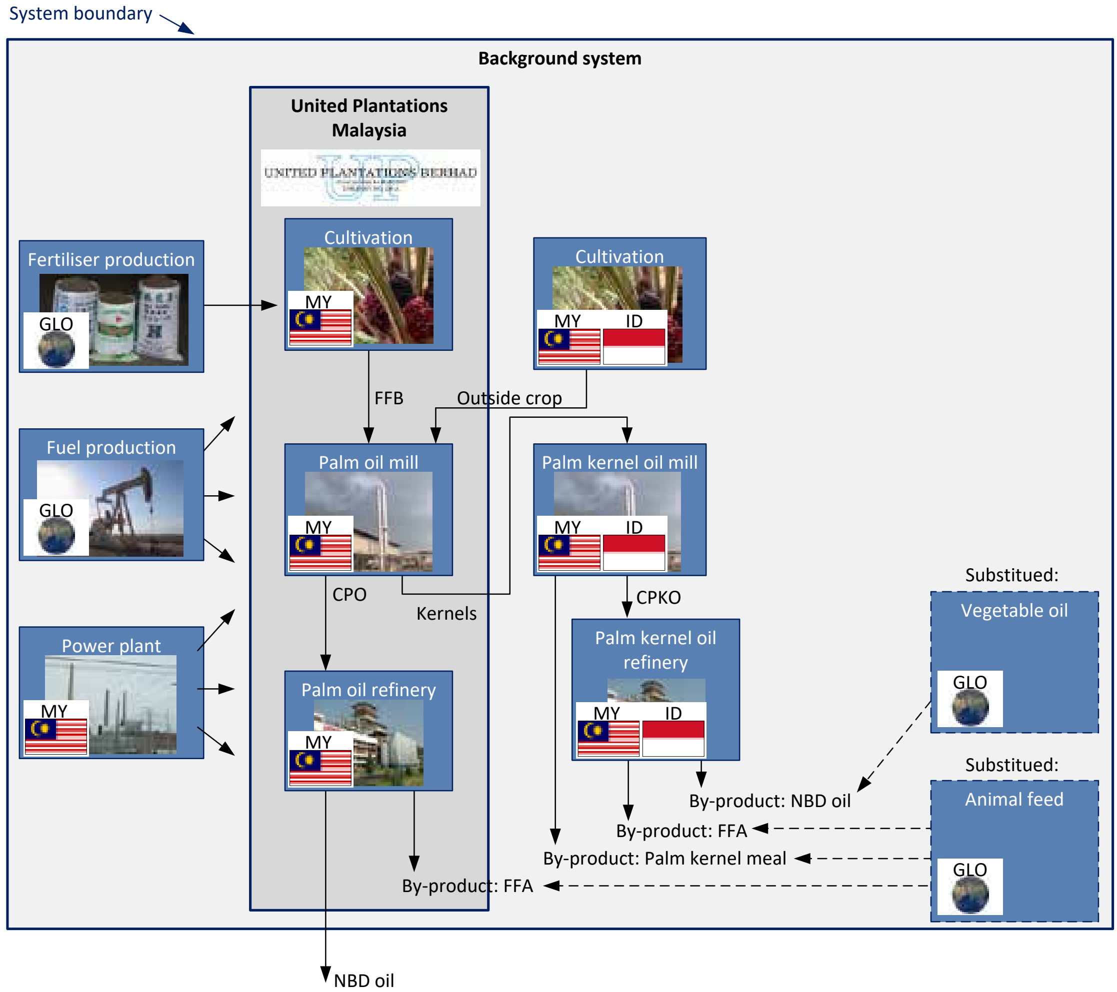

Figure 7: System boundaries for UP's palm oil production in Malaysia. Pictures: UP picture library, Google Earth 2014 and Wikipedia.

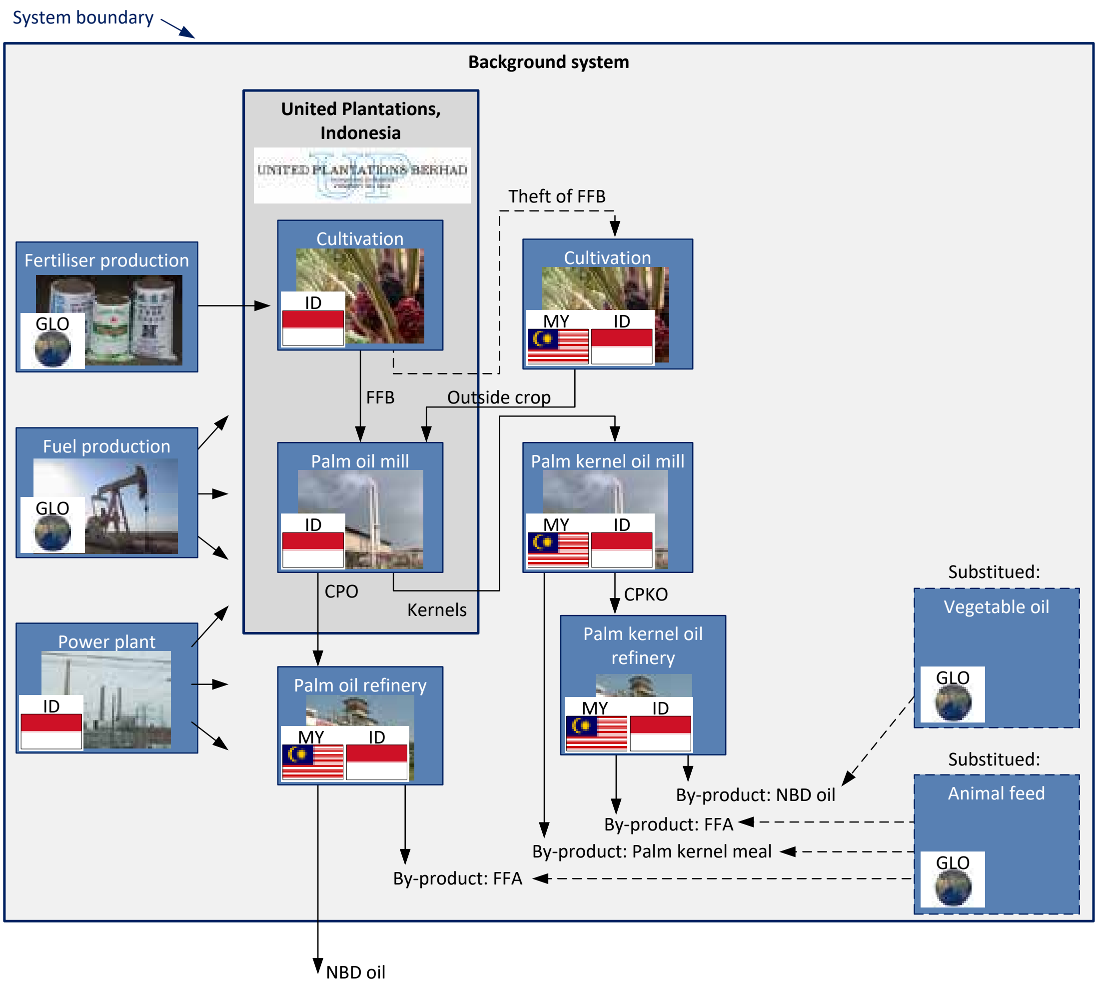

Figure 8: System boundaries for UP's palm oil production in Indonesia. Pictures: UP picture library, Google Earth 2014 and Wikipedia.

3.3 Data collection and calculations

Detailed data collection for United Plantations Berhad has been carried out for each year from 2004 to 2018. The data have been collected as part of four major LCA projects for United Plantations in 2008, 2011, 2014 and 2017. Each of the projects have involved several weeks of onsite data collection in collaboration with United Plantations Research Department (UPRD) including interviews with estate, oil mill and refinery managers. The data collection of the current study for United Plantations production in 2017 is carried out by UPRD and the data have been provided at the distance.

Detailed data have been collected for:

- Product flows: FFB yields, crude palm oil and kernel production, and production of refined palm oil.
- Material use: Fossil fuels, fertilisers, pesticides, and other chemicals.
- Energy: Detailed energy balances for oil mill boilers including exported steam for external utilisation.
- By-products: Benefits from the utilisation of kernels (in palm kernel oil mill), biogas from palm oil mill effluent treatment, residues from FFB,
- Specific laboratory tests and measurements, e.g. moisture and nitrogen content of different parts of the oil palm, and data on palm oil mill effluent (quantities and COD).
- Inventory of the use of capital goods: Material use for buildings, machinery, vehicles etc.

The LCA includes the modelling of a number of important emissions: Field emissions of nitrous oxide (N_2O) are calculated using the tier 1 approach in IPCC (2006). To be able to use the most accurate input data for the IPCC model, detailed nitrogen balances have been established for all estates for 2004-2018. CO_2 emissions from managed peat soils are calculated based on IPCC (2014a). These data are adjusted to reflect water management assuming there is a linear relationship between CO_2 emissions and drainage depth. The emission figures from IPCC (2014a) are assumed to represent an average drainage depth at 75 cm. Because of good water management, United Plantations ensure that the average drainage depth is kept at 60 cm.

3.4 Included environmental impacts

The following environmental impacts are included in the life cycle assessment of palm oil at United Plantations Berhad:

- Global warming
- Biodiversity
- Respiratory effects
- Toxicity (to humans)

The method used for LCIA in this LCA of palm oil at United Plantations is the Stepwise 2006 method, version 1.5[2]. The method is described and documented in Annex II in Weidema et al. (2008) and in Weidema (2009).

Global warming: Special attention is given to the impact category of global warming. There are several reasons for giving special attention to GHG emissions:

- It is a major environmental issue on the global agenda;
- Food (and biofuel) production causes a major contribution of the total global GHG emissions
- It is a high priority issue for United Plantations; and

In Stepwise 2006 v1.6, global warming is calculated using the IPCC's global warming potential (GWP) for a time horizon at 100 years. The indicator for GWP_{100} is kg CO_2-eq. The characterisation factors are based on IPCC's fifth assessment report (IPCC 2013). For methane, the characterisation factors are changed according to Muñoz and Schmidt (2016). For palm oil LCAs, the difference between characterisation factors for GWP_{100} from IPCC (2007) to IPCC (2013) are mainly relevant for methane and nitrous oxide, where the characterisation factors have changed from 25 and 298, to 28 and 265 kg CO_2-eq/kg respectively.

It is common to exclude CO_2 emissions of biogenic origin in LCA. One example is that plant uptake of CO_2 from the atmosphere goes into the palm oil as carbon; when the palm oil is used (digested), the carbon content is converted to CO_2 which is emitted to air. In this case, the uptake and emission are equal and they appear with a relative short time interval. Then it can be argued that the climatic effect is very small. This is the reason why such uptake and emissions are typically excluded from LCA. However, there are other situations where biogenic CO_2 becomes important, i.e. for land use changes from land cover types with a high carbon stock (forests) are converted into land cover types with a lower carbon stock (oil palm plantation and other cropland). These emissions are included. However, since the effect on deforestation from land use only includes the timing of deforestation (see **section 2.2** on indirect land use changes), the characterisation factor is a special time dependant GWP-factor. The GWP_{100} effect of emitting 1 kg CO_2 1 year earlier than it would have been is 0.00772 kg CO_2-eq.

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[2] A CSV file with the Stepwise v1.5 for SimaPro 8 is available here: http://lca-net.com/services-and-solutions/impact-assessment-option-full-monetarisation/

Table 3: Characterisation factors: selected emission's/exchange's contribution to the included impact categories in the Stepwise v1.6 method (the time dependent GWP is not part of Stepwise).

Emissions/exchanges	Global warming kg CO_2-eq./kg	Nature occupation ha*year agr/ha*year	Respiratory effects kg PM2.5-eq./kg	Toxicity (to humans)
CO_2, fossil	1			
CO_2, biogenic, at time zero	0			
CO_2, biogenic, accelerated 1 yr	0.00772			
CH_4, biogenic	27.75			
N_2O	265			
Land occupation, annual crops		1		
Land occupation, oil palm		0.87		
Particles <2.5 um			1	
Particles <10 um			0.536	
NH_3			0.121	
NO_x			0.127	
SO_2			0.078	
Toxic substances				Not listed: thousands

Nature occupation (biodiversity): Nature occupation refers to impacts on biodiversity caused by occupation of land. The impact is measured using the unit ha*year equivalents arable land, which represents the impact from the occupation of one ha of arable land during one year. The impact is assessed on the basis of the duration of area occupied (ha*years) multiplied with a severity score, representing the potentially disappeared fraction (PDF) of species on that area during the specified time.

Respiratory effects: The impact on human health related to respiratory effects (from emissions of inorganic substances) is expressed as equivalents of particles ($PM_{2.5}$). Typically, the major contributing emissions to this impact category are particles ($PM_{2.5}$ and PM_{10}), ammonia (NH_3), sulphur dioxide (SO_2), nitrogen oxides (NO_x).

Toxicity (to humans): The impact on human health related to emissions of toxic substances is expressed in comparative toxic units (chloroethene, C_2H_3Cl) per kg emission. The model considers fate, exposure and effects. Exposure includes inhalation and ingestion of drinking water, leaf crops, including fruit and cereals, root crops, meat, dairy products and fish. The effect factor reflects the change in lifetime disease probability due to change in life time intake of a pollutant (cases/kg intake). The impact is included as the sum of human toxicity carcinogenic and non-carcinogenic in Stepwise v1.5 (Weidema et al. 2008, annex II; Weidema 2009).

3.5 Key input data for the LCA

The table below summarizes key data for the environmental performance of palm oil production at United Plantations Berhad in Malaysia and Indonesia, respectively. This is compared with the industry average for Malaysia and Indonesia; data based on (Schmidt 2015).

Table 4: Key input data for the LCA of palm oil production at United Plantations Berhad for 2018, compared with baseline data for the industry.

Key data	Unit	United Plantations 2018		Industry average 2011
		Malaysia	Indonesia	Malaysia & Indonesia
Cultivation stage				
FFB yield (mature)	t/ha	26.67	24.69	18.9
Fertiliser input	kg N/ha	137	214	162
Fossil fuel	MJ/t FFB	131	161	99
Peat soil	%	9.2%	9.6%	18%
Nature conservation	ha	188	7,500	~0%
Oil mill stage				
FFB from third parties	%	0%	29%	n.a.
Oil extraction rate (OER)	%	21.5%	22.9%	20.30%
Kernel extraction rate (KER)	%	4.68%	4.08%	5.20%
Share of POME treated with biogas capture	%	100%	100%	5%
Refinery stage				
Refined oil yield relative to CPO input	%	94%	n.a.	95%
Palm acid oil (PAO) relative to CPO input	%	6.3%	n.a.	4.60%

4 Results

4.1 Potential impacts from UP's palm oil production

The contribution to global warming (not including iLUC) from 1 kg NBD palm oil produced in UP in 2018 is 1.22 kg CO_2-eq. The major part of the contribution originates from the oil palm plantation stage where the main contributors are field emissions of CO_2 from oxidation of peat soils and N_2O. The overall contribution from the oil mill stage is negative. This is because the substitutions caused by the kernels (kernel oil substitutes the marginal source of oil on the market and the kernel meal substitutes the marginal source of animal feed) exceeds the other contributions from fuels etc. The major contribution in the oil mill stage is CH_4 from POME treatment – though this is small because all POME is treated with biogas capture. As for the oil mill stage, the overall contribution from the refinery stage is also negative. This is because the substitutions caused by the free fatty acids (which substitute animal feed) exceed the other contributions from fuels, chemicals etc.

If iLUC is included, the total contribution to GHG emissions increase from 1.22 to 1.55 kg CO_2-eq. per kg NBD palm oil. Hence, iLUC is a significant contributor to GHG emissions.

4.2 Nature conservation

Recently, United Plantations has expanded its operations into Central Kalimantan, Indonesia, where much of the land acquired consists of degraded secondary and logged over forests as well as large tracks of alang-alang grasslands. Of the company's total land bank in Kalimantan at least 7,500 ha is land under set-aside for permanent conservation. Of the 7,500 ha 31% is on peat swamps. Furthermore, United Plantations has 188 ha nature conservation reserves in Malaysia. This study quantifies and includes in the account the GHG emission savings from nature conservation. The applied methodology is novel and compatible with the applied method for the modelling of iLUC.

When including nature conservation, the impact from the Indonesian production is significantly reduced; the GHG emissions are reduced from 2.27 kg CO_2-eq. to 1.04 kg CO_2-eq. per kg NBD oil. It should be noted that both the area of and the carbon stocks in the reserves have been estimated using a conservative approach. The nature conservation reserves in Malaysia are too small to significantly reducing the results for the Malaysian production. For United Plantation's entire production, the nature conservation reserves reduce the GHG emissions from 1.55 to 1.18 CO_2-eq. per kg oil. For nature conservation, the reduction is mainly associated to the conservation of peat soils, but also the conserved above ground carbon contributes.

4.3 Time series of GHG emissions from palm oil at United Plantations Berhad

Below, time series of GHG emissions from palm oil at UP are presented. **Figure 9** shows results without iLUC, **Figure 10** shows results with iLUC, and **Figure 11** shows the results including nature conservation.

The time series for NBD palm oil at UP show reductions at 46% (without iLUC) and 40% (with iLUC) from 2004 to 2018. When including nature conservation, the reduction is 54%.

Declines in the GHG emissions levels typically occurs when installing a new technology replacing less clean technologies. At six points in time, new cleaner technologies have been installed; namely biogas plants and biofuel boiler, see **Figure 9** and **Figure 10**. This is either by installing a biogas or biomass plant or by closing down old mills and then treating the FFB in mills with cleaner technologies. Significant reductions in GHG emissions can be observed following the installation of each biogas capture facility. Further, the Seri Pelangi and Lima Blas oil mills closed in 2013 and 2015 respectively. After that, the FFB have been processed in oil mills with biogas capture. A reduction can be observed in the figures for 2010-2011 (where biogas capture was installed in UIE and Ulu Basir) and 2012-2013 (where biogas capture was installed in PT Surya Seberang Seberang), but not for 2006-2007. This is due to the lower yields recorded in all the years when the new technologies were installed; after 2006, 2010 and 2012. For the two last installations, the benefits of the cleaner technologies have exceeded the increasing GHG emissions due to lower yields. This is not the case for the first one in 2006.

Despite yields mainly decreased from 2008 to 2016, the installation of new technologies has kept the GHG emissions more or less constant – there has even been a decreasing trend. The introduction of the new estates in Indonesia from 2011 has not significantly affected the overall impact on GHG emissions – a highly efficient palm oil mill with biogas capture from POME contributes to lower emissions, while the yields draw in the opposite direction. From 2011-2015, the yields in Indonesia have been significantly lower than in Malaysia; mainly because the palms are young and have not reached yet the average yield for oil palms throughout their life cycle. In 2011, the yields in UP's Indonesian estates were 36% lower than in Malaysia. This gap has steadily been smaller from 2011 to 2018, where it was 11%. In 2016, a higher oil extraction rate in the Indonesian oil mill gave, for the first time, higher crude oil yields per hectare than the Malaysian estates. The reduction from 2017 to 2018 is due to the replacement of the old Ulu Bernam mill with the new Optimill with biogas capture. Further, high yields in 2018 also contributes to the reduction in GHG emissions.

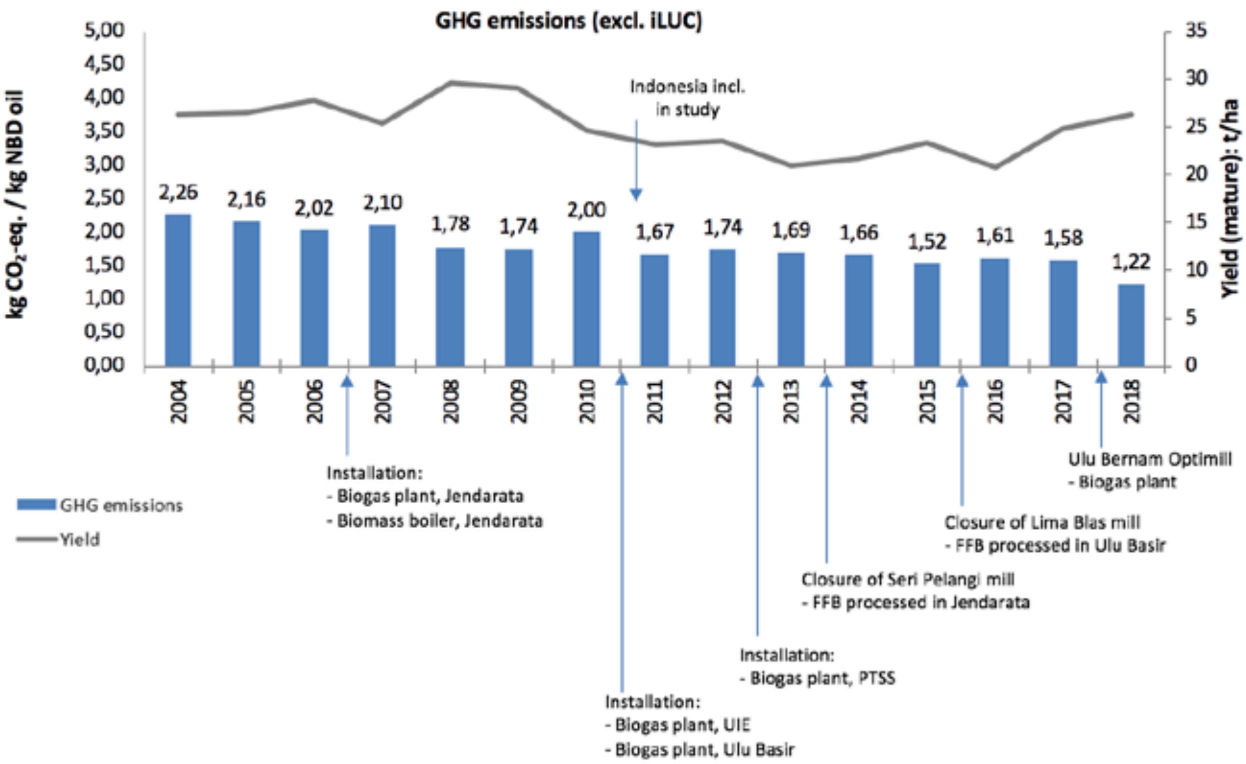

Figure 9: Time-series for NBD palm oil at United Plantations Berhad (without iLUC) for year 2004-2018.

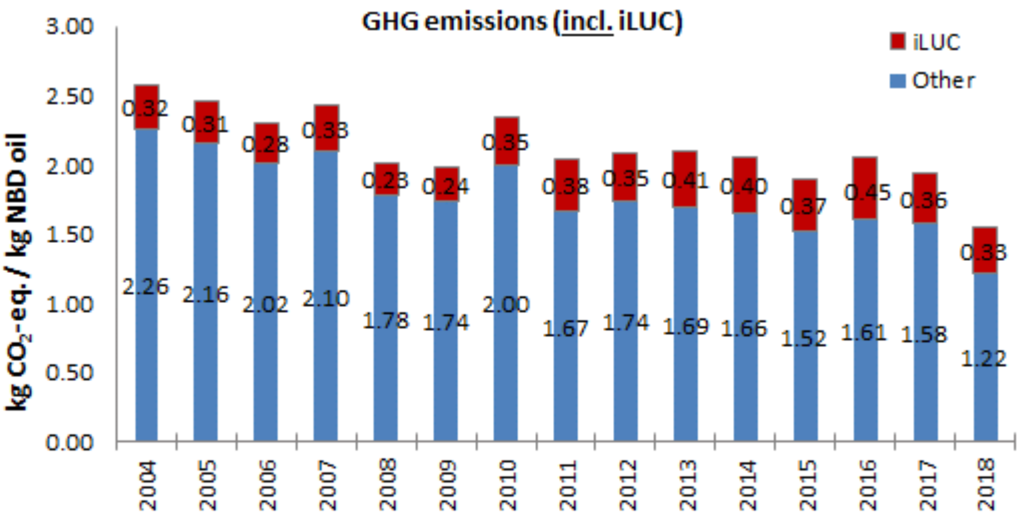

Figure 10: Time-series for NBD palm oil at United Plantations Berhad (with iLUC) for year 2004-2018.

Figure 10 shows that the contribution from iLUC has reached a maximum in 2016 due to the extremely low yields obtained in that year, because iLUC is directly proportional to the land use and inversely proportional to the yields. Similarly, in 2008 the yields were the highest recorded at United Plantation Berhad and the iLUC contribution was the lowest observed until now.

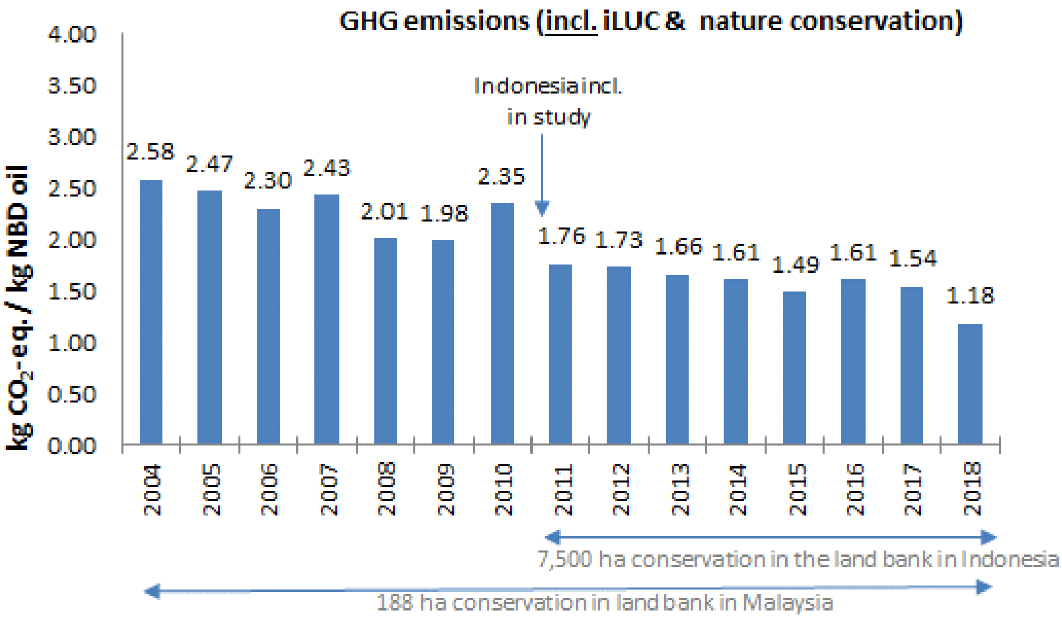

Figure 11: Time-series for NBD palm oil at United Plantations Berhad (with iLUC and nature conservation) for year 2004-2018.

4.4 Comparison of palm oil from UP with industry averages of other vegetable oils

UP's production of palm oil has been compared with industry averages for four other vegetable oils; namely palm oil (Malaysia/Indonesia), rapeseed oil (Europe), sunflower oil (Ukraine), and peanut oil (India). The industry averages are obtained from Schmidt (2015). **Figure 12** shows results excluding iLUC, and **Figure 13** shows results including iLUC and both iLUC and nature conservation. **Figure 13** shows separately the effect of nature conservation – see bars 'UP ex nature' and UP incl nature'. The data used for the industry averages do not include emissions of pesticides and heavy metal contaminants in fertilisers. Therefore, the contributions to toxicity are not included in the comparison.

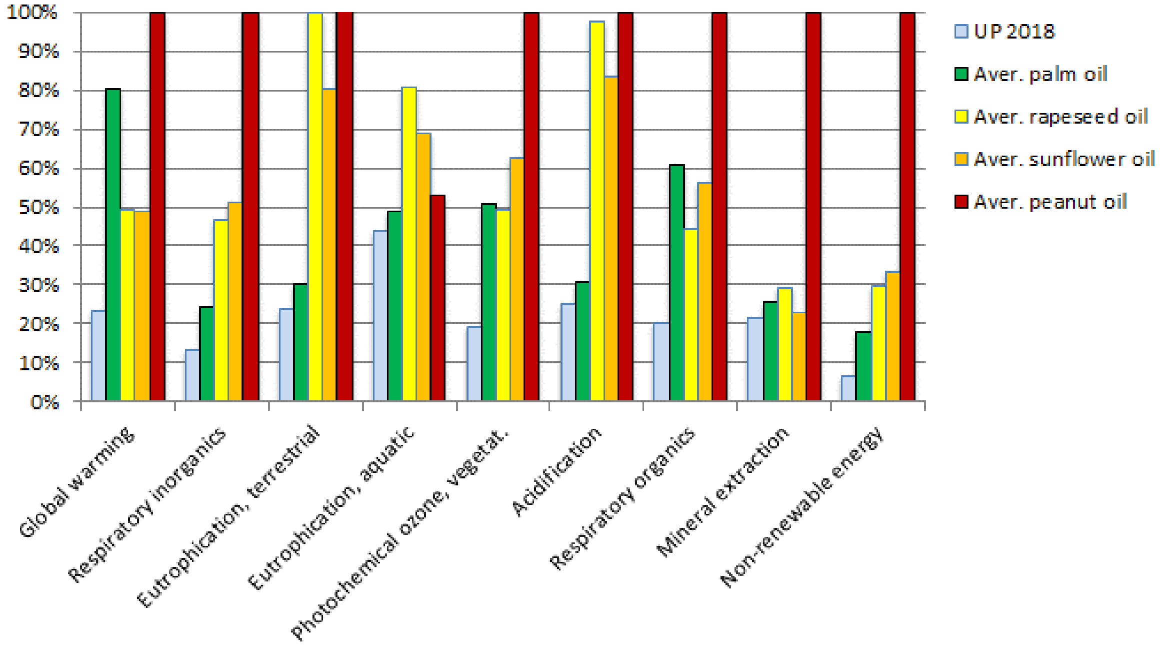

Figure 12: Comparison of LCIA results **(excluding iLUC)** for 1 kg NBD palm oil at United Plantations Berhad in 2018 with industry averages for 2011 for palm oil (Malaysia and Indonesia), rapeseed oil (Europe), sunflower oil (Ukraine) and peanut oil (India).

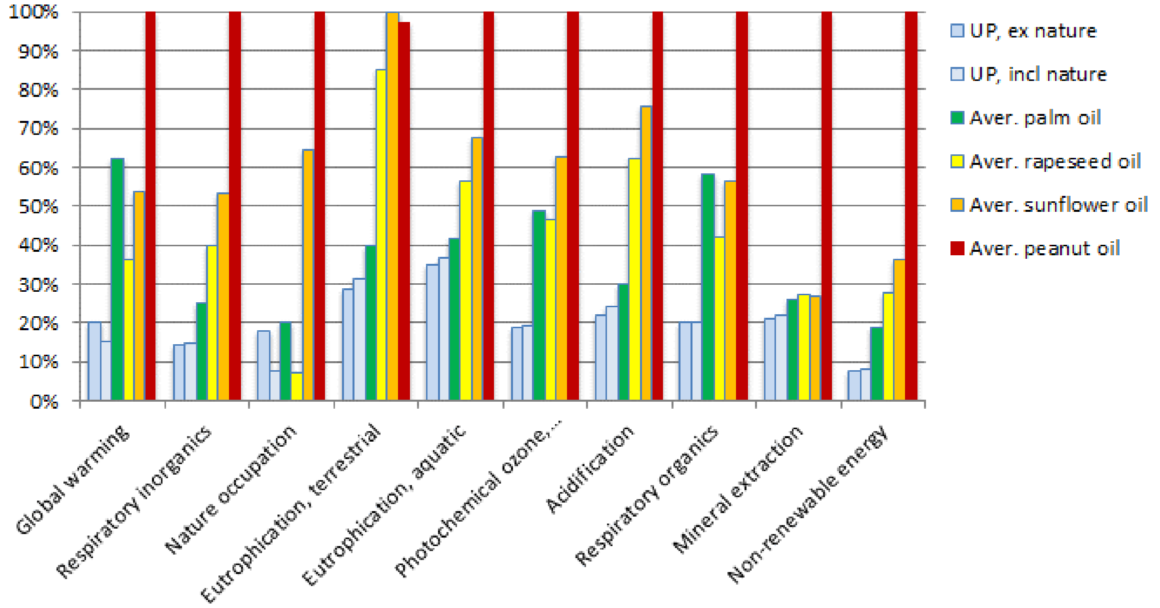

Figure 13: Comparison of LCIA results **(including only iLUC and both iLUC and nature conservation)** for 1 kg NBD palm oil at United Plantations Berhad in 2018 with industry averages for 2011 for palm oil (Malaysia and Indonesia), rapeseed oil (Europe), sunflower oil (Ukraine) and peanut oil (India).

It appears from the comparative results that palm oil at UP performs better than all the other oils for all impact categories, except for ‘nature occupation’ when comparing with the industry average for rapeseed oil. The low nature occupation impact for rapeseed oil is related to the rapeseed oil mill by-product, rapeseed meal, which causes substitution of soybean cultivation, which is in turn associated with relatively low yields and hence high land use.

4.5 Results for UP's total product portfolio in 2018

Table 5 shows the results for the entire 2018 product portfolio of United Plantations in terms of GHG emissions (1000 t CO_2-eq.), divided by the three main production stages: cultivation; oil mills and UP's refinery, Unitata. The results for the cultivation stage are further divided in contributions from oil palm cultivation at United Plantations' estates and external estates. Similarly, the results for the oil mill stage are shown separately for United Plantations' mills and for the external production of CPKO.

The table shows the results with iLUC and nature conservation, with iLUC only and without iLUC and nature conservation. Nature conservation reduces the global warming impact of the total UP's product portfolio by 8%.

Table 5: GHG emissions results for UP's total product portfolio in 2018 (1000 t CO_2-eq).

GHG emissions	Excluding iLUC	With iLUC, without nat. cons.	With iLUC and nat. cons.
Cultivation stage (UP estates)	302	415	340
Cultivation stage (external estates)	61	75	75
Oil mill stage	6	6	6
Oil mill stage (external production of CPKO)	366	422	422
Refinery (Unitata)	46	46	46
UP Total	**781**	**965**	**889**

5 Highlights

GHG emissions 2018: The GHG emissions per kg NBD palm oil from palm oil production at United Plantations Berhad in 2018 are calculated as:

- Result without iLUC and nature conservation: 1.22 kg CO_2-eq.
- Result with iLUC and without nature conservation: 1.55 kg CO_2-eq.
- Result with iLUC and nature conservation: 1.18 kg CO_2-eq.

Reductions in GHG emissions 2004-2018: United Plantations Berhad, via their efforts towards a more sustainable production, have achieved remarkable reductions in the GHG emissions per kg NBD oil:

- Reduction 2004-2018 without iLUC and nature conservation: 46%
- Reduction 2004-2018 with iLUC and without nature conservation: 40%
- Reduction 2004-2018 with iLUC and nature conservation*: 54%

**The extent of nature conservation within United Plantations' land bank in 2004 and 2018 was 188 ha and 7,500 respectively.*

Comparison of United Plantations palm oil production with average palm oil and other oils: The GHG emissions from United Plantations' production have been compared with average Malaysian/Indonesian palm oil production, European rapeseed oil, Ukrainian sunflower oil, and Indian peanut oil.

Without iLUC and nature conservation

- **Palm oil, United Plantations (=index100) 100**
- Palm oil, MY&ID average 343
- Rapeseed oil, European average 212
- Sunflower oil, Ukrainian average 208
- Peanut oil, Indian average 428

With iLUC and without nature conservation

- **Palm oil, United Plantations (=index100) 100**
- Palm oil, MY&ID average 306
- Rapeseed oil, European average 179
- Sunflower oil, Ukrainian average 264
- Peanut oil, Indian average 493

With iLUC and nature conservation

- **Palm oil, United Plantations (=index100) 100**
- Palm oil, MY&ID average 403
- Rapeseed oil, European average 236
- Sunflower oil, Ukrainian average 348
- Peanut oil, Indian average 649

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