Life Cycle Assessment of Palm Oil at United Plantations Berhad 2024




Results for 2004 – 2023

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

Preface

This report is carried out by 2.-0 LCA consultants 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 2004-2023. The study was undertaken during the period January to March 2024.

The current report updates the results of a series of previous studies, to include also the most recent 2023 results, and it summarises the main findings of a detailed life cycle assessment of palm oil production at United Plantations in the period 2004-2023.

Disclaimer: It should be noted that the GHG emissions per kg palm oil calculated in this study cannot be compared with the results obtained with the GHG accounting tool PalmGHG, due to key methodological differences between the two models. In particular, main differences between the models are: the approach used to deal with land use changes and nature conservation, the modelling of by-products; emission models for nitrogen related field emissions, and peat soil emissions. Moreover, the current study operates without cut-off, i.e. no-inputs to the system are excluded. Further, the currently study includes the GHG emissions relating to the production of pesticides, and results are presented per kg refined palm oil, whereas the PalmGHG does not include emissions related to the production of pesticides, and results are presented per kg crude oil. The GHG emissions calculated in the current LCA study are systematically higher compared to a similar calculation using the PalmGHG.

When citing the report, please use the following reference:

Schmidt J, Serena L, Eliassen J (2024), Life Cycle Assessment of Palm Oil at United Plantations Berhad 2024, Results for 2004-2023. Summary report. United Plantations Berhad, Teluk Intan, Malaysia.

Jannick Schmidt, Lara Serena, Jonas Eliassen, 2.-0 LCA consultants, Denmark, March 2024

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 is a desk-study performed on the distance, carried out January to March 2024, and it builds on top of six other large studies carried out for United Plantations in 2008, 2011, 2014, 2017, 2020, and 2023. The study in 2008 was the first LCA of palm oil ever, which is 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, as well as for United Plantations total product portfolio (corporate GHG footprint).

Over the last decades, 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 2023.

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 quantify the absolute impact of United Plantations' product portfolio, fourthly, to compare United Plantation's production of palm oil with average Malaysian/Indonesian palm oil and other major vegetable oils, and fifthly, 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.

In addition to the functional unit mentioned above, the life cycle results are also shown for United Plantations total product portfolio, i.e. for the sum of all products supplied by United Plantations in 2023.

Data sources and data collection

The oil palm cultivation stage is inventoried for the thirteen oil palm estates owned by United Plantations (ten in Malaysia and three in Indonesia). Similarly, 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 two refineries in Malaysia; Unitata and UniFuji. The data for United Plantations' estates, palm oil mills and refineries have been collected in collaboration with the United Plantations Research Department (UPRD) and Sustainability Department. Data for activities outside United Plantations, such as production of fertiliser, fuels and machinery, are obtained from the EXIOBASE database (hybrid version 3.3.13).

Land use changes and nature conservation

The link between land use (e.g. occupation of 1 hectare during one year) and 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 deforestation activities – 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 its integration in the EXIOBASE database (Schmidt and De Rosa 2018). 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 as well as some smaller areas in Malaysia. 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 induced 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 offsets 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, which is released again in either the use stage or the end-of-life stage, which are not included in the LCA.

The contribution to global warming (not including iLUC) from 1 kg NBD palm oil produced in United Plantations in 2023 is 1.52 kg CO_2-eq. The major part of the impact 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. Previously, one of the main contributions were methane from POME treatment at the oil mills. However, this has been almost eliminated by installation of methane capture facilities at all palm oil mills; the first was installed in 2006, and in 2018 all oil mills had installed biogas capture.

When iLUC is included, the total contribution to GHG emissions is 1.76 kg CO_2-eq. per kg NBD palm oil. Hence, iLUC is a significant contributor to GHG emissions.

When including nature conservation too, the impact from the Indonesian production decreases significantly – the offsets from nature conservation reduces the GHG emissions per kg NBD palm oil of UP's Indonesian production from 2.19 kg CO_2-eq. to 0.21 CO_2-eq. For United Plantations' entire palm oil production, the nature conservation in Indonesia reduces the GHG emissions from 1.76 to 1.36 CO_2-eq. per kg oil.

Results: evolution of GHG emissions over time

The time series for NBD palm oil at United Plantations show a reduction from 2004 to 2023 of 56% (without iLUC), 52% (with iLUC) and 63% 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 and avoiding methane emissions from anaerobic digestion in POME treatment. A large reduction was also obtained with the increased area of nature conservation. Also, the implementation of new technology in refineries and integration of the energy supply between the Jendarata oil mill and Unitata refinery as well as the Optimill and the UniFuji refinery have contributed to optimised utilization of excess energy from the oil mills.

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 three major vegetable oils, namely RSPO certified palm oil and non-certified palm oil (Malaysia/Indonesia), rapeseed oil (Europe), and sunflower oil (Ukraine). The comparison shows that palm oil at United Plantations in 2023 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 807,000 t CO_2-eq (without iLUC), 920,000 t CO_2-eq (with iLUC), and 814,000 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 is a desk-study performed on the distance, carried out January to March 2024, and it builds on top of six other large studies carried out for United Plantations in 2008, 2011, 2014, 2017, 2020, and 2023.

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 2023.

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 2023.

1.1 Palm oil production in United Plantations Berhad

United Plantations Berhad has 10 estates in Peninsular Malaysia and three estates in Central Kalimantan Indonesia, in total a planted area with oil palm of 46,245 ha. The locations of United Plantations' estates, oil mills and refineries are indicated in **Figure 1.1**. The hectares of each of the 13 estates are summarised in **Table 1.**

Figure 1.1: Location of United Plantations Berhad's estates, oil mills, refineries, and other premisses (United Plantations 2023).

Table 1. Overview of United Plantations' oil palm estates in 2023. Planted area includes mature, immature, and replanting area.

Estate	Location	Planted area (ha)
UIE	Malaysia	8,950
Jendarata	Malaysia	5,201
Ladang Ulu Basir	Malaysia	3,737
Charong Estate (Ladang Sungei Erong & Ladang Sungei Chawang)	Malaysia	6,748
Ulu Bernam	Malaysia	3,050
Lima Blas	Malaysia	2,745
Landang Changkat Mentri	Malaysia	2,364
Seri Pelangi	Malaysia	1,329
Tanarata Estate	Malaysia	3,381
PT Surya Sawit Sejati (PT SSS1), Lada estate	Indonesia	4,929
PT Surya Sawit Sejati (PT SSS1), Runtu estate	Indonesia	3,297
PT Surya Seberang Seberang (PT SSS2), Arut and Kumai	Indonesia	514
Total Malaysia	**Malaysia**	**37,504**
Total Indonesia	**Indonesia**	**8,740**
Total all	**Malaysia and Indonesia**	**46,245**

United Plantations has nature conservation reserves in Malaysia and in Indonesia. In 2011, United Plantations 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, 7,900 ha is set-aside as land under permanent conservation. In Malaysia, 389 ha is set-aside as nature conservation reserves.

United Plantations has 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 (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.

Table 2: Overview of United Plantation's palm oil mills and their production in 2023.

Palm oil mill	Location	Biogas capture	Processed FFB, tonne	Produced crude palm oil (CPO)	Produced palm kernels (PK)
UIE	Malaysia	yes	290,613	63,014	12,854
Jendarata	Malaysia	yes	191,281	43,006	8,656
Ulu Basir	Malaysia	yes	83,490	17,894	3,603
Ulu Bernam Optimill	Malaysia	yes	440,302	95,112	19,855
Pt. Surya Sawit Sejati	Indonesia	yes	266,440	58,646	12,817
Total Malaysia	**Malaysia**		**1,005,686**	**219,026**	**44,967**
Total Indonesia	**Indonesia**		**266,440**	**58,646**	**12,817**
Total all	**Malaysia and Indonesia**		**1,272,126**	**277,672**	**57,784**

United Plantations has two palm oil refineries, Unitata and UniFuji, 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 and UniFuji is supplied by the Jendarata mill and Bernam Optimill; partly by exported steam from the palm oil mill boilers and partly by utilisation of the captured biogas from the oil mills' POME treatment. In the refineries, 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 results per kg NBD oil of the current study only includes the refinery processes until NBD oil is produced. However, the results for UP's total product portfolio in section 5.5 includes emissions from all processes for all products sold by UP.

United Plantations produces most of their FFB themselves but buys some from external growers. Most of the produced CPO at United Plantations' palm oil mills is processed in UP's refineries Unitata and UniFuji, while a smaller share is sold. Around half of the feedstock for the Unitata refinery is CPKO produced externally. The oil mills sell kernels for further processing in external kernel crusher plants. The final products of the Unitata and UniFuji refineries are various fractions of refined palm oil. A by-product of the refineries is palm acid oil (PAO), which mainly contains free fatty acids (FFA).

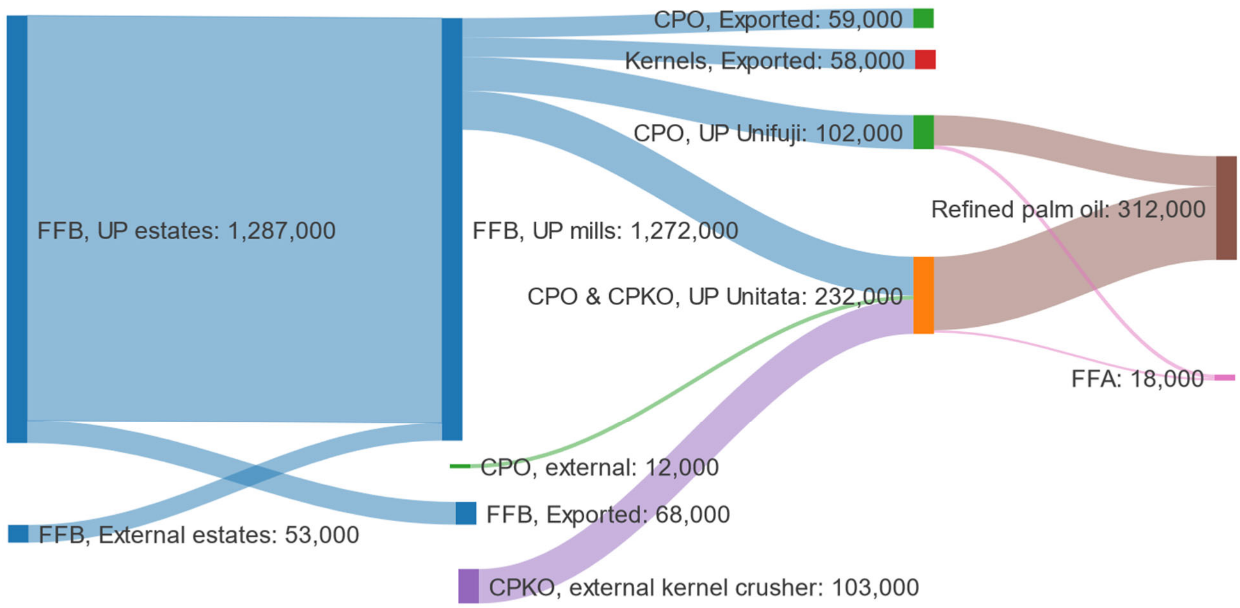

Figure 1.2: Sankey diagram of the flows of United Plantations in 2023, through their estates, oil mills and refineries. The product portfolio includes "CPO exported", "Kernels exported", "Refined palm oil" and "FFA". The FFA (free fatty acid) is also sometimes referred to as palm acid oil (PAO).

1.2 Sustainability in United Plantations Berhad

In line with the Company's commitment towards sustainable palm oil production and its ambitions of decarbonizing its supply chain United Plantations Bhd has chosen to document and voluntarily track its environmental performance. For this reason, it has worked intensively with life cycle assessments of the Company's production since 2008. In order to facilitate a more sustainable production for the Company, the LCA studies also aim to predict the potential environmental benefits of implementing new technologies and practices. Here, the focus is on the effects of implementing projects like the four Clean Development Mechanism (CDM) projects in its palm oil mills.

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

Carbon footprint initiatives: In 2021, we achieved our internal goal of reaching a 60% GHG emissions reduction per MT of refined palm oil produced by 2025 when compared to 2004 levels (with iLUC and nature conservation), four years ahead of time. However, in line with our Group's commitment to environmental leadership, we acknowledge that even more can be done and we therefore set a new target of reaching a 66% reduction by 2030 when compared to 2004 levels (with iLUC and nature conservation). We shall relentlessly pursue to reach this through new initiatives and investments over the next 8 years.

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

In 2020, we successfully phased out Monocrotophos and Metamidophos, which was a key milestone for the UP Group. Concerted efforts to source and evaluate alternatives for the Class 1A insecticides, Monocrotophos and Metamidophos, have been ongoing since 2006 through our collaboration with several multinational chemical companies, amongst others Bayer and BASF (Germany), Syngenta (Switzerland), Cheminova (Denmark), Sumitomo (Japan), Rainbow Agrosciences (China) and UPL (India).

Multiple experimental and existing insecticidal compounds have been evaluated for bagworm control with our partners with no success in matching the efficacy of Monocrotophos and Metamidophos. In recent years our Research Department was able to test new formulations of an existing insecticide that hitherto gave inconsistent bagworm control.

It has now been established that with these new formulations we are able to have a commercially viable and effective alternative to Monocrotophos and Metamidophos albeit obtaining this with a Class II toxicity rating which is a much safer product.

As a result, we have since September 2020 successfully phased out the use of Monocrotophos and Metamidophos for trunk injection control of bagworm. This is a significant achievement as our plantations can now dispense with the use of WHO Class 1A or 1B pesticides for bagworm control and replace this with a safer product.

Environment and Biodiversity Policy:
"Strictly adhere to no deforestation and no new development on peat soils regardless of its depth and fully comply with no new development on High Conservation Value (HCV) area since 2010. We strive to maintain an open and dynamic approach towards continuous improvements in respect of protecting Peat soils, HCV and other fragile areas."

"We want to ensure that our agricultural operations comply with the following NDPE criteria:

- No development on high carbon stock forests (HCS).
- No development on high conservation value forest areas (HCV).
- No new development on peat regardless its depth.
- 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."

Key environmental milestones achieved:

- A zero-burn policy (1989)
- A No primary forest clearing policy (1990)
- No supply policy for the production of first-generation biodiesel (2003)
- Methane capturing facilities introduced (2006) and all mills equipped with methane capturing facilities (2018)
- HCV assessment introduced (2007)
- LCA on palm oil production completed in (2008) with annual updates since then
- No deforestation, no new development on High Conservation Value (HCV) area and no new development on peat soils regardless of its depth (2010)
- Total phase-out of Paraquat (2010)
- HCV combined with HCS assessments and LUCA for new plantings (2014)
- Total phase-out of Class 1A/1B chemicals (Monocrotophos/Methamidophos) (2020)

More information is available at:
https://unitedplantations.com/policies/#Sustainability-Policies

Box 1: United Plantations' policies on carbon footprint, pesticides, and biodiversity & environment.

In 2011, the company expanded its operations into Central Kalimantan, Indonesia, where much of the acquired land consists of degraded secondary and logged over forests as well as large tracks of alang-alang grasslands. The Indonesian oil palm estates cover 8,700 ha. In addition to the land planted with oil palm, 7,900 ha is set-aside as land under permanent conservation.

Carbon Footprint Initiatives and Climate Action

1. **Emissions Reductions & Biogas Plants**
   As a necessary element in our pursuit to combat climate change, significant investments have been made in promoting green energy starting with the Biomass Reciprocating Boiler cum Power Plant and the first Biogas Plants built and commissioned in 2006 as CDM projects (for more information on CDM projects, please refer to No. 4). Today, all of our mills are equipped with Biogas Plants.

   These projects combined have since helped to significantly reduce our emissions of CO2 by 70% and CH4 by 80% at the respective operating units thereby paving the way for additional green investments.

2. **Biogas to Grid Project**
   The UIE biogas plant began operations in 2010 where biogas generated from the palm oil mill effluent is exported as electricity to Unitata refinery. In 2023 a total of 7,585,092 kWh of electricity was generated from the biogas plant which is similar to the quantum supplied in the previous year. In 2023, the Jendarata biogas plant also started to export electricity from the biogas electrification plant to Unitata refinery which in return reduces the purchases of coal generated electricity from Tenaga Nasional Berhad (TNB). Throughout the year, it generated a total of 6,645,860 kWh of electricity.

3. **Biomass Reciprocating Boiler**
   The first Biomass Reciprocating Boiler (BRB1) was successfully commissioned in 2006 and supplied green steam to Jendarata Palm Oil Mill as well as the Unitata Refinery, thus playing a crucial role in reducing the fossil fuel consumption at the refinery. Since then the Company has built and commissioned another 7 biomass reciprocating boilers with the latest unit at UIE (M) installed in 2019.

4. **Former CDM projects in United Plantations Berhad**
   United Plantations built and commissioned its first of four CDM projects in 2006. This was done in close cooperation with the Royal Danish Ministry of Foreign Affairs. CDM projects are a classic example of carbon footprint initiatives which turn voluntary commitments of the Company into reality.

   The 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.

   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.

Box 2: Carbon footprint initiatives and climate action at United Plantations Berhad.

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 2.1**) 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 2.1**: cultivation, palm oil mill and refinery stages. The boxes in the figure are called activities, and the arrows represent flows between the activities. 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 primary 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.

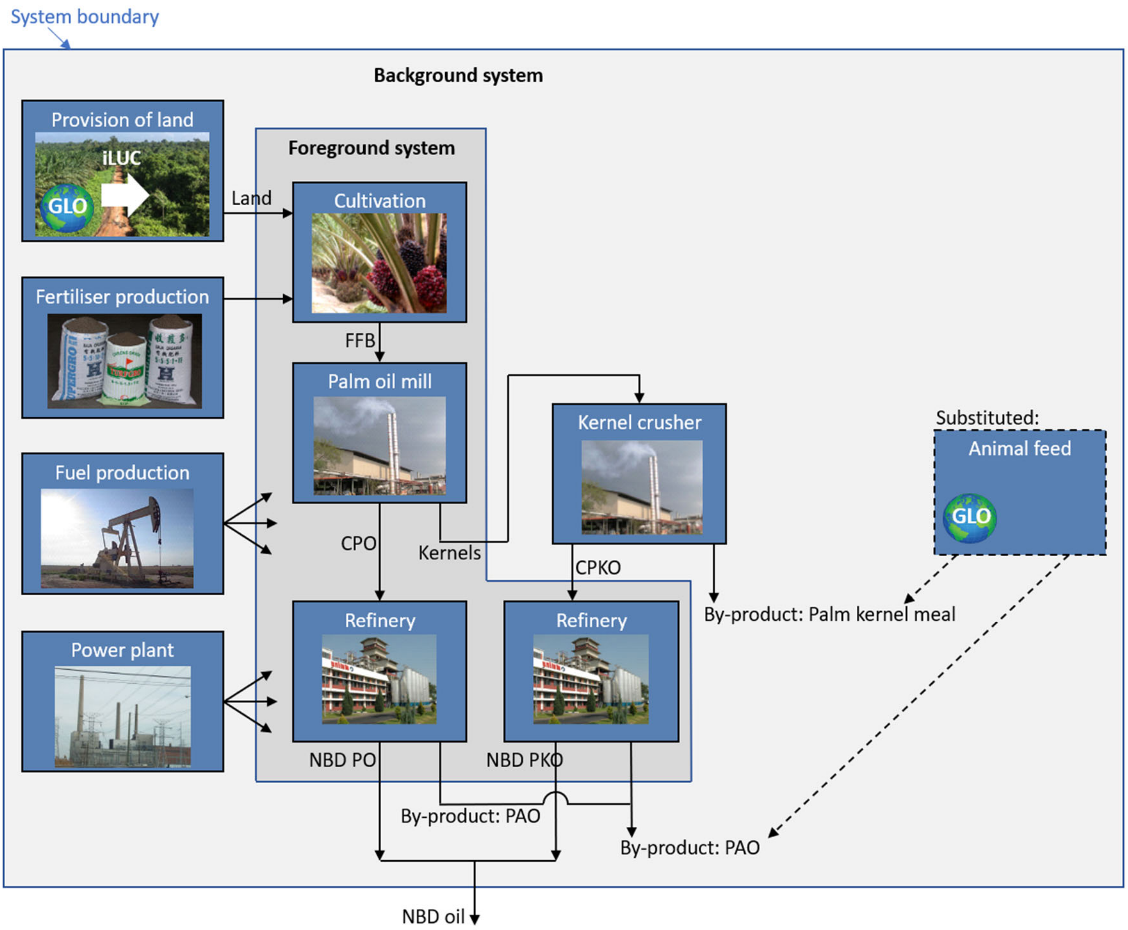

Figure 2.1: The main stages of the product system for palm oil production. Dotted lines and boxes represent negative flows and substituted activities respectively. The PAO (palm acid oil) is also sometimes referred to as free fatty acids (FFA). Pictures: UP picture library and Wikipedia.

System boundary and life cycle emissions: The outer boundary of **Figure 2.1** 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 2.1** supply by-products, e.g. the palm kernel crusher supplies palm kernel meal (PKM) and the refineries supply palm acid oil (PAO)[1]. Both PKM and PAO are used as animal feed. Since a change in demand for refined palm oil does not affect the output of animals and thereby the need for animal feed, 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 uses SimaPro 9. 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 such a high number of 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 several impact categories. For each impact category, 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 2.2**.

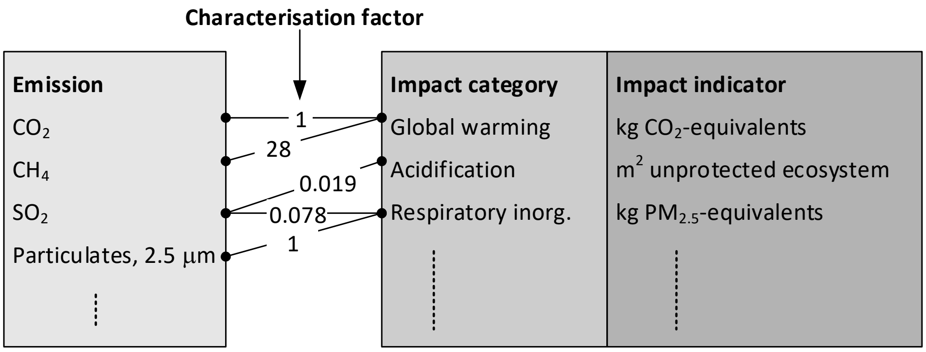

Figure 2.2: The principle of characterisation.

[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 GHG emissions

2.2 Indirect land use changes (iLUC)

Land use changes account for around 11% of global GHG emissions (IPCC 2020). 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 model applied in this study is described in Schmidt et al. (2015) and it is integrated in the background LCA database EXIOBASE. This is described in Schmidt and De Rosa (2018).

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, e.g. 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 location where the land use change occurs, 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 2.3**. The activities within the grey box in the figure (the activities that represent iLUC) are described in the following.

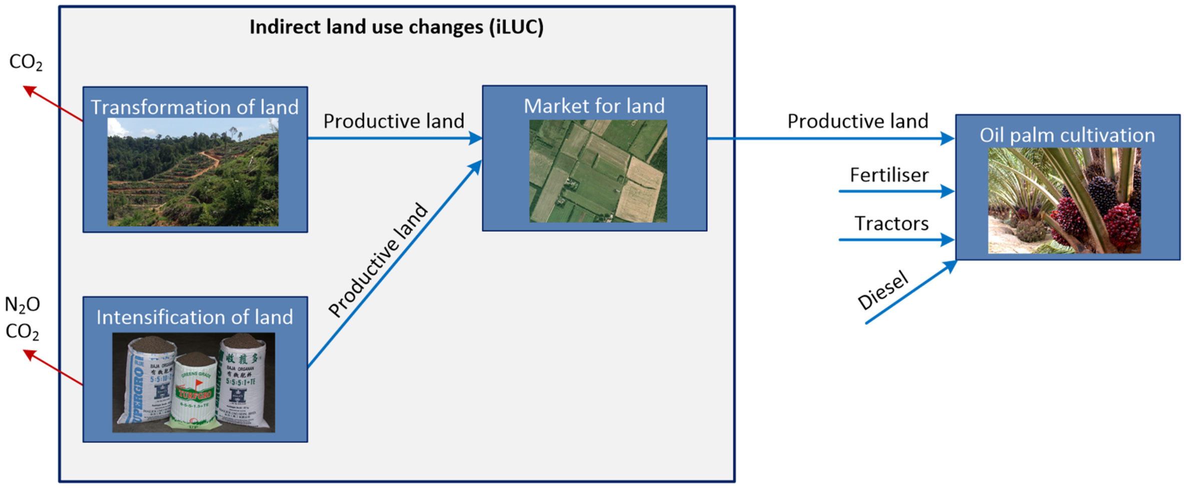

Figure 2.3: Conceptual representation of the iLUC model used in the study. (Pictures: UP picture library, Jannick Schmidt, Google Maps)

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 2.4**, 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.

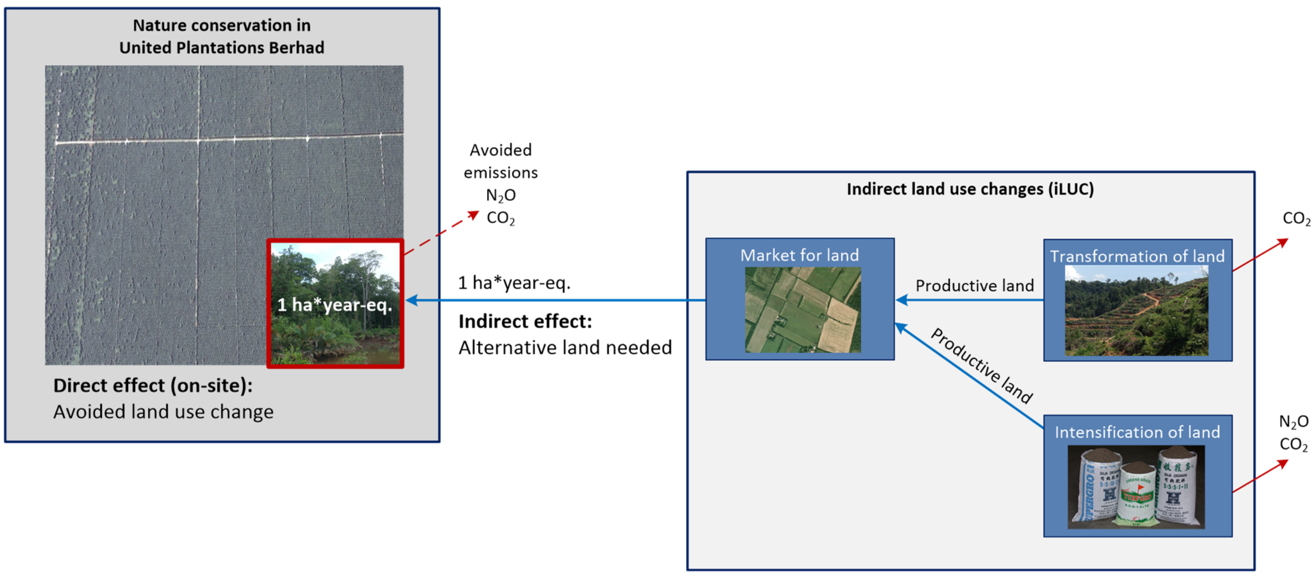

Figure 2.4: Direct and indirect effect of nature conservation. Here illustrated as nature conservation in oil palm cultivation. Pictures: Oil palm field (Google Maps 2014) and nature (Nature conservation reserve in United Plantations Berhad Indonesia, picture taken by Jannick Schmidt).

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, i.e. the sum of all products sold by United Plantations (see **Figure 1.2**):

- 68,000 t fresh fruit bunches (FFB)
- 59,000 t crude palm oil (CPO)
- 58,000 t kernels
- 312,000 t refined palm oil
- 18,000 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 3.1** and **Figure 3.2**. 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 kernel crushers, and when the Indonesian palm oil mill sells crude palm oil for refining.

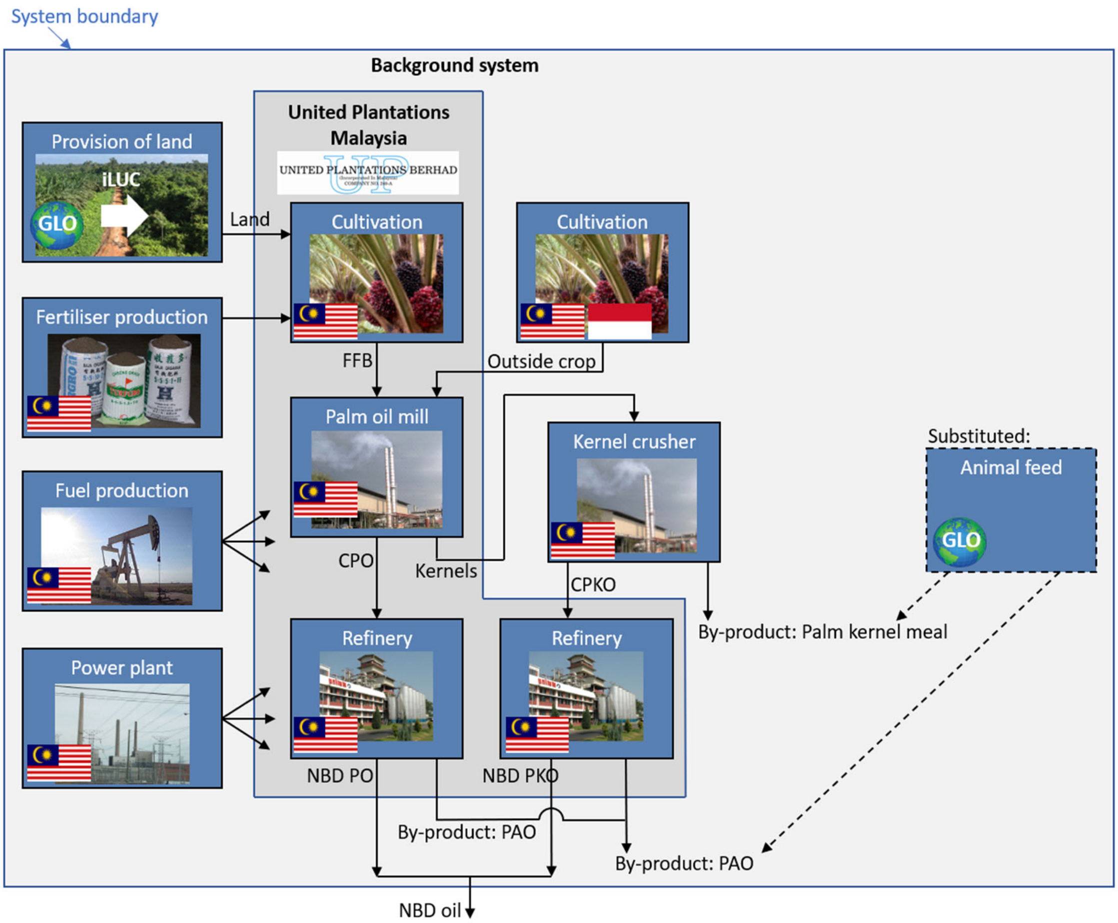

Figure 3.1: System boundaries for UP's palm oil production in Malaysia. Pictures: UP picture library and Wikipedia.

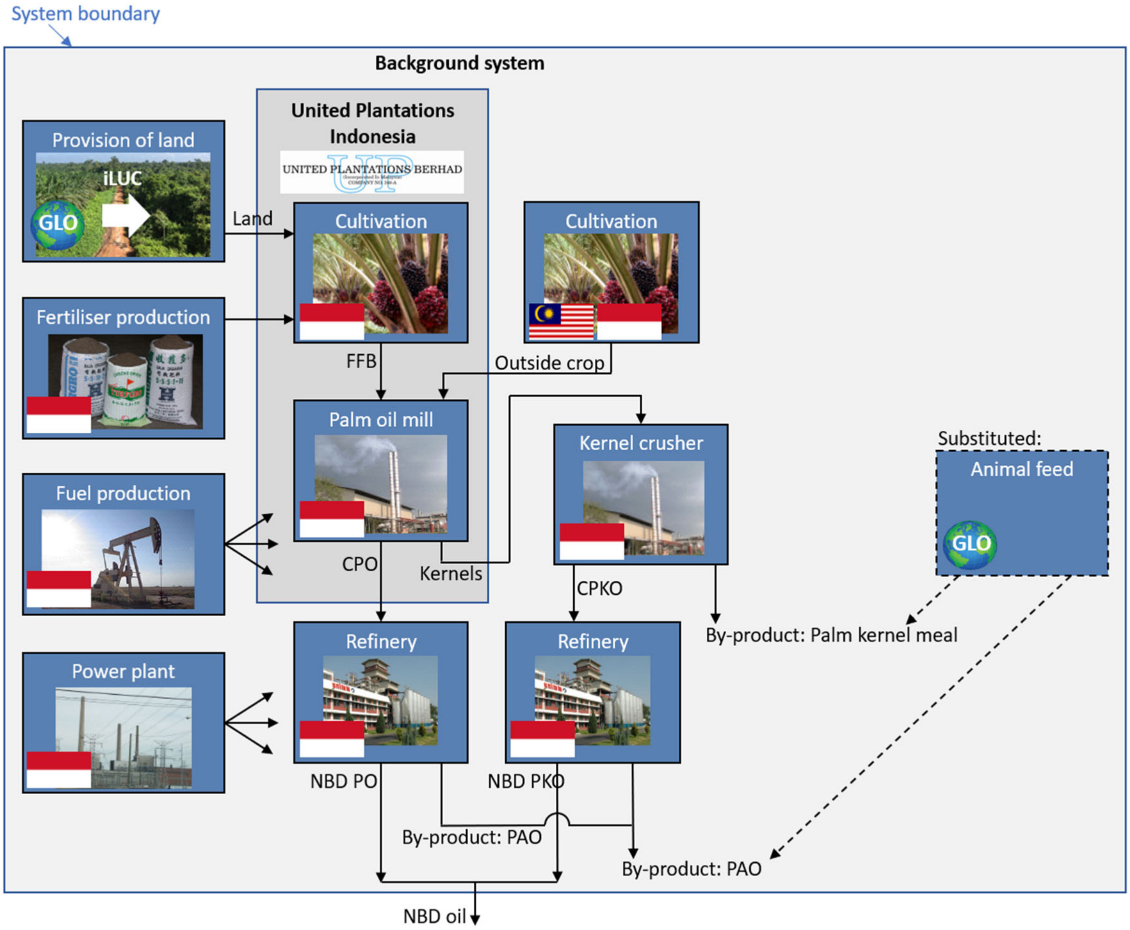

Figure 3.2: System boundaries for UP's palm oil production in Indonesia. Pictures: UP picture library and Wikipedia.

3.3 Included environmental impacts

A broad range of environmental indicators are considered in the LCA of palm oil at United Plantations Berhad:

- Global warming
- Biodiversity
- Respiratory effects
- Toxicity (to humans and ecosystems)
- Eutrophication
- Acidification
- Photochemical ozone formation (smog)
- Mineral and non-renewable energy resources depletion

The method used for life cycle impact assessment (LCIA) in this LCA of palm oil at United Plantations is the Stepwise 2006 method, version 1.7[2]. The method is described and documented in Annex II in Weidema et al. (2008) and in Weidema (2009). The environmental impact categories in the Stepwise method are described in **Appendix 2: Explanation of units in the Stepwise LCIA method**. Below, **Table 3** presents the characterisation factors for some important emissions to four of the impact categories.

Table 3: Characterisation factors: selected emission's/exchange's contribution to the included impact categories in the Stepwise v1.7 method.

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			
Accelerated land transformation from forest to arable		1		
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

Global warming: Special attention is given to the impact category global warming. There are several reasons for this:

- 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

In Stepwise 2006 v1.7, 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).

[2] A CSV file with the Stepwise v1.5 for SimaPro 9 is available here: http://lca-net.com/services-and-solutions/impact-assessment-option-full-monetarisation/

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. Thus, it can be argued that the climate 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 emitted is 0.00772 kg CO_2-eq.

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 accelerating 1 ha transformation of forest to arable land by 1 year. The nature occupation impact is caused via the indirect land use change model. This is described in detail in section 3.4.2 and appendix 2 here: Schmidt and de Saxcé (2016).

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), and 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 lifetime intake of a pollutant (cases/kg intake). The impact is included as the sum of human toxicity carcinogenic and non-carcinogenic in Stepwise v1.7 (Weidema et al. 2008, annex II; Weidema 2009).

4 Life cycle inventory

The life cycle inventory includes data collection and modelling of the product system. This is described in this section.

4.1 Data collection

Detailed data collection for United Plantations Berhad has been carried out for each year from 2004 to 2023. The data have been collected as part of six major LCA projects for United Plantations 2008, 2011, 2014, 2017, 2020, and 2023. 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 2023 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 kernel crusher), 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.

4.2 Modelling of emissions

The LCA includes the modelling of several important emissions.

Field emissions: Field emissions include emissions related to the application of fertilisers as well as to decay of crop residues. Nitrous oxide (N_2O) are calculated using the tier 2 approach in IPCC (2019). To be able to use the most accurate input data for the IPCC model, detailed nitrogen balances have been established for all estates for 2004-2023. In addition to N_2O, the N-balances also include ammonia (NH_3), nitrogen oxides (NO_x), and nitrate (NO_3^-). The latter three emissions lead to indirect N_2O emissions. These are calculated based on IPCC (2019).

CO_2 and N_2O emissions from managed peat soils are calculated based on IPCC (2014). 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 (2014) 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 around 60 cm.

Detailed pesticide usage figures from United Plantations are used to account for emissions to soil of the active ingredients.

Palm oil mill boiler emissions: Detailed energy balances are established for each palm oil mill. Combined with measured emissions of particulates and NO_x from United Plantations, the fuel inputs are used to model stack emissions.

4.3 Modelling of by-products:

The palm oil mills, palm kernel crushers, and refineries produce by-products. Below, it is described how by-products are modelled.

By-products from palm oil mills

- **Excess shell:** sold as a biofuel, which replaces coal in e.g. the cement industry.
- **Biogas:** some is exported to the Unitata and UniFuji refineries, where it reduces the need for fuel oil, some biogas is utilized in biogas engines to produce electricity, which substitutes grid electricity in Malaysia, and some biogas is burned in the oil mill boilers, where it reduces the need for burning shell. The additional shells are sold as biofuel (see 'excess shell above).
- **Exported steam:** the steam is used in the Unitata and UniFuji refineries, where it reduces the need for fuel oil.
- **Kernels:** Sent to external processing in kernel crushers.

By-products from kernel crushers

- The outputs of kernel crushers are crude palm kernel oil (CPKO) and kernel meal (PKM). The CPKO is processed in the Unitata and UniFuji refineries, where the output is NBD PKO, which is regarded as part of the functional unit. The PKM is sold as animal feed. Since feed and PKM is traded on the global market, global marginal feed is substituted: this is a combination of soybean meal (marginal protein feed) and wheat and maize (marginal energy feed). The substituted protein and energy feed is balanced so that the amounts of proteins and energy in the feed matches the substituted feed.

By-products from refineries

- **Palm acid oil (PAO):** This is sold for various purposes. It is assumed that the marginal use of PAO is animal feed. The substitution hereof is described above under 'By-products from kernel crushers'.

4.4 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 in 2016 (Schmidt and De Rosa 2020).

Table 4: Key input data for the LCA of palm oil production at United Plantations Berhad in 2023, compared with baseline data for the palm oil industry for Indonesia and Malaysia. The industry averages are obtained from Schmidt and De Rosa (2020).

Key data	Unit	United Plantations 2023			Industry average 2016	
		Malaysia	Indonesia	Total	RSPO cert.	Non-cert.
Cultivation stage						
FFB yield (mature)	t/ha	29.0	24.5	28.1	21.1	18.5
Fertiliser input	kg N/ha	148	182	155	170	64
Fossil fuel	MJ/ha	3,373	3,927	3,231	2,940	2,940
Peat soil	%	11.0%	3.2%	9.5%	11.0%	19.0%
Peat drainage depth	cm	60.1	60.0	60.1	57	75
Nature conservation per oil palm planted area	ha/ha	1%	90%	18%	3%	0%
Oil mill stage						
FFB from third parties	%	0%	20%	4%	-	-
Oil extraction rate (OER)	%	21.8%	22.0%	21.8%	21.9%	19.8%
Kernel extraction rate (KER)	%	4.5%	4.8%	4.5%	5.6%	5.4%
Share of POME treated with biogas capture	%	100%	100%	100%	16%	2.4%
Refinery stage						
Refined oil yield relative to CPO input	%	92.4%	n.a.	92.4%	95.3%	95.3%
Palm acid oil (PAO) relative to CPO input	%	7.49%	n.a.	7.49%	4.60%	4.60%

Table 5 presents United Plantations data on conservation area, in Malaysia and Indonesia, from 2004 to 2023.

Table 5: United Plantations conservation area, for Indonesia and Malaysia from 2004 to 2023, measured in hectares.

		Conservation area	
Year	Unit	Indonesia	Malaysia
2004	ha	0	331
2005	ha	0	331
2006	ha	0	331
2007	ha	0	331
2008	ha	0	331
2009	ha	0	331
2010	ha	0	331
2011	ha	8229	331
2012	ha	8229	331
2013	ha	8229	331
2014	ha	8229	331
2015	ha	8229	331
2016	ha	8229	331
2017	ha	8229	331
2018	ha	8229	331
2019	ha	8229	331
2020	ha	8229	356
2021	ha	8120	356
2022	ha	8314	356
2023	ha	7901	389

5 Results

5.1 Impacts from UP's palm oil production

The contribution to global warming from 1 kg NBD palm oil produced by UP in 2023 is 1.36 kg CO_2-eq. This result includes the impact from indirect land use changes (iLUC) as well as the GHG emissions offset from nature conservation. **Table 6** shows a detailed contribution analysis, disaggregating the GHG emissions of 1.36 kg CO_2-eq. per kg refined oil.

It should be noted that the GHG emissions per kg palm oil calculated in this study cannot be compared with the results obtained with the GHG accounting tool PalmGHG, due to key methodological differences between the two models. In particular, main differences between the models are: the approach used to deal with land use changes and nature conservation, the modelling of by-products; emission models for nitrogen related field emissions, and peat soil emissions. Moreover, the current study operates without cut-off, i.e. no-inputs to the system is excluded. Further, the currently study includes the GHG emissions relating to the production of pesticides, and results are presented per kg refined palm oil, whereas the PalmGHG does not include emissions for the production of pesticides, and results are presented per kg crude oil. The GHG emissions calculated in the current LCA study are systematically higher compared to a similar calculation using the PalmGHG.

Results for all other impact categories are presented in Appendix 1: Characterized results for all impact categories. An explanation of the impact categories can be found in Appendix 2: Explanation of units in the Stepwise LCIA method.

Cultivation stage

The major part of the contribution originates from the oil palm cultivation stage where the four main contributors are 1) field emissions of CO_2 from oxidation of peat soils, 2) N_2O from nutrient cycle, 3) indirect land use changes caused by land occupation, and 4) offsets from nature conservation.

Oil mill stage

The overall contribution from the oil mill stage is negligible. This is because the substitutions caused by the kernels (kernel oil substitutes the marginal source of vegetable oil on the market and the kernel meal substitutes the marginal source of animal feed) counteracts the other contributions from POME emissions, fossil energy, transport etc. The major contributions in the oil mill stage is CH_4 from POME treatment (though this is small because all POME is treated with biogas capture), crops sourced from outside United Plantations, and other (transport, assets etc.).

Refinery stage

The refinery stage is dominated by the purchase of outside CPO, energy use, material use, and a negative impact related to the by-product of palm acid oil (which substitutes animal feed). It should be noted that the energy use is modelled as inputs of fossil fuels, while, in reality, this is largely sourced from biogas, steam and electricity from the oil mills. The credits for the utilisation of the energy by-products from the oil mill are included under the oil mill as substituted production of fossil energy.

Nature conservation

If nature conservation is excluded, the results change to 1.76 kg CO_2-eq. per kg NBD palm oil, while if both nature conservation and iLUC are excluded, the result is 1.52 kg CO_2-eq. per kg NBD palm oil. Hence, United Plantations more than offset their contribution to iLUC by setting aside 0.18 ha nature conservation per hectare of oil palm planted area.

Table 6: GHG emissions results for UP's palm oil production in 2023 (kg CO_2-eq per kg of NBD palm oil) with iLUC and nature conservation.

Life Cycle Stage	Contribution (kg CO_2-eq/kg NDB oil)	2023
UP oil crop cultivation		
	Field emissions (related to nutrient cycle)	0.35
	Field emissions (related to peat drainage)	0.51
	Materials: Fertilisers, chemicals, and packaging	0.17
	Energy	0.05
	Other (transport, waste treatment, assets, and services)	0.13
	Indirect Land Use Changes (iLUC)	0.28
	HCV nature conservation	-0.43
	Total crop cultivation stage	**1.05**
Palm oil mill		
	POME treatment, incl flared biogas	0.12
	Outside crops	0.11
	Energy: diesel, petrol, lubricants[3]	0.01
	Other (transport, waste treatment, assets, and services)	0.13
	By-product: Utilisation of biogas for steam generation in refineries	<0.00
	By-product: Utilisation of biogas for power generation	-0.08
	By-product: Utilisation of exported steam as fuel substitute in refineries	-0.08
	By-product: Exported electricity from oil mill turbine	<0.01
	By-product: kernel	-0.17
	By-product: exported shells used as coal substitute	-0.02
	By-product: EFB to field application	<0.01
	Total palm oil mill stage	**0.0026**
Refinery		
	Outside CPO, RSPO certified	0.12
	Materials: chemicals and water	0.06
	Energy	0.24
	By-products: PFAD/PKFAD	-0.11
	Total refinery stage	**0.31**
All stages		
	Total	**1.36**

Table 7 shows the same detailed contribution analysis, when disaggregating the GHG emissions of 1.36 kg CO_2-eq. per kg refined oil, broken down into scope 1, 2 and 3, so it is possible to see how much each scope contributes to the total result.

Scope 1 refers to direct emissions from owned or controlled sources. Scope 2 represents the indirect emissions from the generation of purchased electricity, steam, heating & cooling. Scope 3 measures the indirect emissions (not included under Scope 2) that occur in the life cycle of the product, including both upstream and downstream activities.

[3] The substituted energy related GHG emissions from by-products in the oil mill have changed in the 2024 model compared to the 2022 model because data exported steam from Jendarata oil mill to Unitata refinery are based on reported numbers by Unitata in the 2024 model, while in the 2022 model it was based on theoretical figures from a calculated energy balance for Jendarata.

Table 7: GHG emissions results for UP's palm oil production in 2023 – broken down into scope 1, 2, and 3 (kg CO2-eq per kg of NBD palm oil). Results include iLUC and nature conservation.

Life Cycle Stage	Contribution (kg CO_2-eq/kg NDB oil)	Scope 1	Scope 2	Scope 3	Total 2023
UP oil crop cultivation					
	Field emissions (related to nutrient cycle)	0.35			0.35
	Field emissions (related to peat drainage)	0.51			0.51
	Materials: Fertilisers, chemicals, and packaging			0.17	0.17
	Energy: diesel, petrol, lubricants	0.04		0.01	0.05
	Other (transport, waste treatment, assets, and services)			0.13	0.13
	Indirect Land Use Changes (iLUC)			0.28	0.28
	HCV nature conservation	-0.43			-0.43
	Total crop cultivation stage	**0.47**	**0.00**	**0.58**	**1.05**
Palm oil mill					
	POME treatment, incl flared biogas	0.12			0.12
	Outside crops			0.11	0.11
	Energy: diesel, petrol, lubricants	0.01		1.32E-03	0.01
	Other (transport, waste treatment, assets, and services)			0.13	0.13
	By-product: Utilisation of biogas for steam generation in refineries			<0.01	<0.01
	By-product: Utilisation of biogas for power generation			-0.08	-0.08
	By-product: Utilisation of exported steam as fuel substitute in refineries			-0.08	-0.08
	By-product: Exported electricity from oil mill turbine		<0.01		<0.01
	By-product: kernel			-0.17	-0.17
	By-product: exported shells used as coal substitute			-0.02	-0.02
	By-product: EFB to field application	0.01		-0.01	<0.01
	Total palm oil mill stage	**0.14**	**0.00**	**-0.13**	**0.0026**
Refinery					
	Outside CPO, RSPO certified			0.12	0.12
	Materials: chemicals and water			0.06	0.06
	Energy	0.13	0.08	0.03	0.24
	By-products: PFAD/PKFAD			-0.11	-0.11
	Total refinery stage	**0.13**	**0.08**	**0.10**	**0.31**
All stages					
	Total	**0.75**	**0.07**	**0.54**	**1.36**

The total impact per kg NBD palm oil is divided on scope 1, 2 and 3 as 0.75 kg CO_2-eq., 0.07 kg CO_2-eq., and 0.54 kg CO_2-eq. respectively. Scope 1 is mainly caused by emissions in the cultivation stage, scope 2 is dominated by energy inputs in the refinery stage, and scope 3 is mainly caused by iLUC, fertiliser, and other inputs in the cultivation stage, and outside crop and other inputs in the oil mill stage, and outside crop and chemicals in the refinery stage.

5.2 Nature conservation

In 2011, 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 7,900 ha is land under set-aside for permanent conservation. Of the 7,900 ha 33% is on peat swamps. Furthermore, United Plantations has 389 ha nature conservation reserves in Malaysia. Of this, 24% is on peat swamps. 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 reduces from 2.19 kg CO_2-eq. to 0.21 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 reduce the results for the Malaysian production. For United Plantation's entire production, the nature conservation reserves reduce the GHG emissions from 1.76 to 1.36 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. The contribution analysis for the results including iLUC and nature conservation is shown in **Table 6**.

The contribution from nature conservation accounts for the indirect effect of nature conservation, i.e. that nature conservation in one place will increase the demand for land somewhere else. In other words, the only credit to UP's nature conservation accounted in the results is the higher carbon stock in the nature conservation compared to land that is currently being converted to arable land around the world (Schmidt 2016). The high GHG emission saving from nature conservation is due to the fact that a significant share of UP's nature conservation in Central Kalimantan is on waterlogged peatland. If this peat was drained and converted to arable land, it would cause significant GHG emissions. Hence, UP is actively preventing peat for being converted to oil palm.

5.3 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 5.1** shows results without iLUC, **Figure 5.2** shows results with iLUC, and **Figure 5.3** shows the results including nature conservation.

The time series for NBD palm oil at UP show a reduction of 56% without iLUC, 52% with iLUC and 63% with iLUC and nature conservation from 2004 to 2023.

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, biofuel boiler and the UniFuji refinery, see **Figure 5.1** and **Figure 5.2**. This is either by installing a biogas or biomass plant, by closing down old mills and then treating the FFB in mills with cleaner technologies, or by implementing the new efficient refinery UniFuji, which enables for a much better utilisation of energy by-products from the Optimill. 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.

Reductions can be observed in the results for:

- 2006-2007, where biogas capture and biomass plant were installed in Jendarata
- 2010-2011, where biogas capture was installed in UIE and Ulu Basir
- 2011, where the Indonesian estates were operating and included in the study
- 2012-2013, where biogas capture was installed in PT Surya Seberang Seberang
- 2017-2018, where the Bernam Optimill with biogas plant was installed
- 2018-2019, where the UniFuji refinery was installed

Despite yields mainly decreased from 2008 to 2016, the installation of new technologies has kept the GHG emissions at decreasing trend. The introduction of the new estates in Indonesia from 2011 has significantly reduced the overall impact on GHG emissions due to a highly efficient palm oil mill with biogas capture from POME contributing to lower emissions and a large area dedicated to nature conservation largely on peat soil.

From 2011-2015, the yields in Indonesia have been significantly lower than in Malaysia; mainly because the palms are young and had 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 2016, where it was 5%, though the last couple of years, the gap has been 13-14%. 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 in results 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. In 2019, the GHG emissions further decreased compared to 2018. This is mainly due to a more efficient use of palm oil mill energy by-products from the Optimill in the new UniFuji refinery.

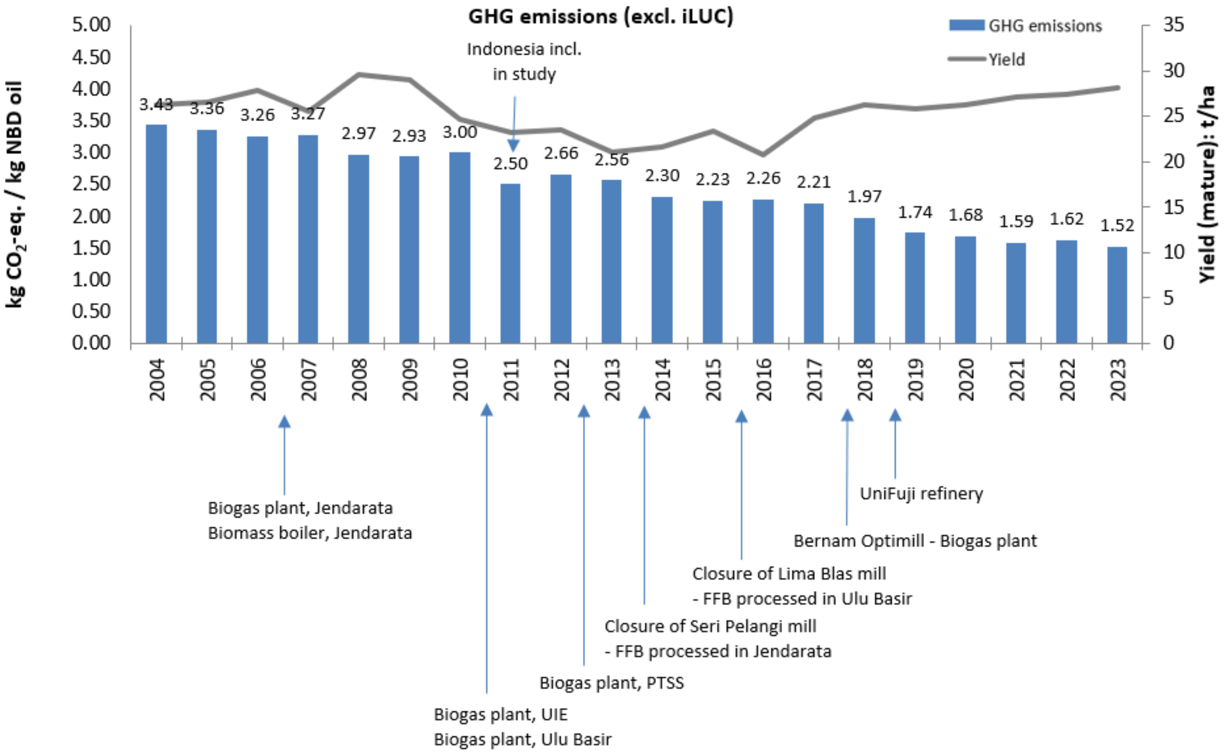

Figure 5.1: Time-series for NBD palm oil at United Plantations Berhad 2004-2023. Results exclude contributions from iLUC and off-setting from nature conservation.

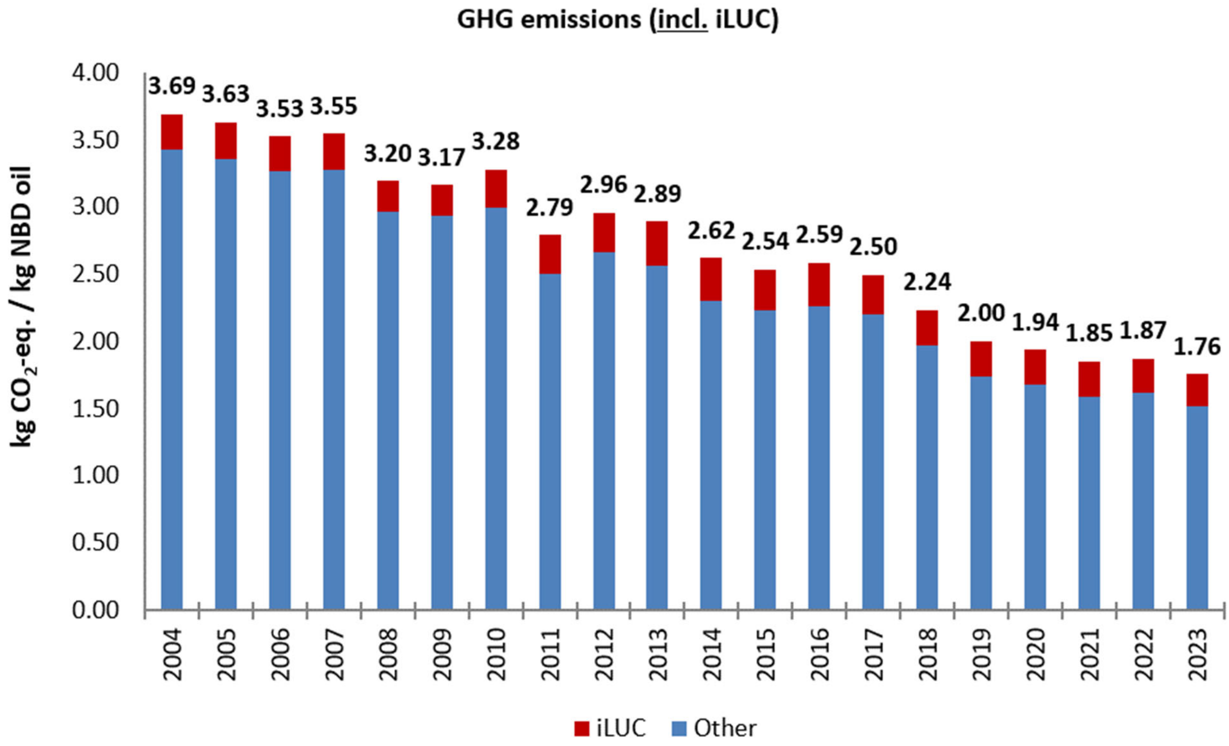

Figure 5.2: Time-series for NBD palm oil at United Plantations Berhad 2004-2023. Results include contributions from iLUC. Off-setting from nature conservation is not included here.

Figure 5.2 shows that the contribution from iLUC (red part of bars in figure) 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.

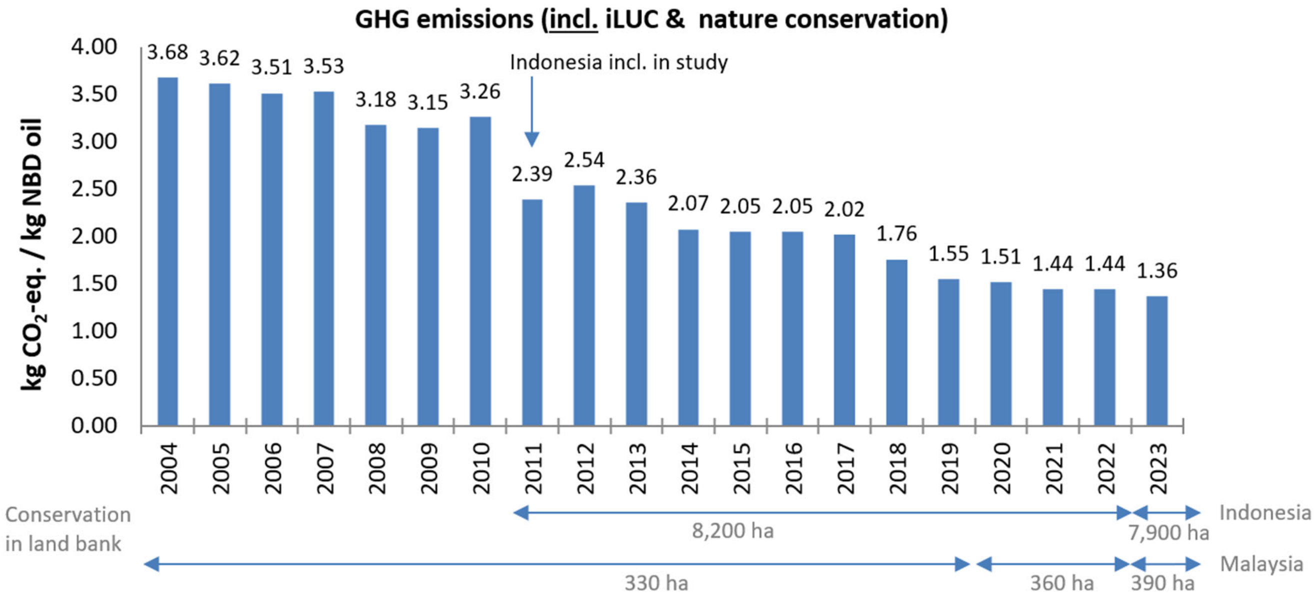

Figure 5.3: Time-series for NBD palm oil at United Plantations Berhad 2004-2023. Results include contributions from iLUC and off-setting from nature conservation. The indicated nature conservation areas are rounded figures. The actual areas are indicated in **Table 5**.

Table 8 shows the same results for the latest three years as in **Figure 5.3**, here broken down into scope 1, 2, and 3.

Table 8: Time-series for NBD palm oil at United Plantations Berhad 2020-2023, broken down into scope 1 (direct emissions), scope 2 (purchased electricity), and scope 3 (the rest). Results include contributions from iLUC and off-setting from nature conservation.

GHG emissions (kg CO_2-eq/kg NDB oil)	2020	2021	2022	2023
Scope 1	0.77	0.73	0.78	0.75
Scope 2	0.08	0.09	0.07	0.07
Scope 3	0.66	0.63	0.59	0.54
Total	**1.51**	**1.44**	**1.44**	**1.36**

The major contribution to GHG emissions comes from Scope 1: field emissions, peat emissions and avoided emissions due to nature conservation. Scope 2 emissions (purchased electricity) account for a small share of the total emissions. Electricity is mainly used in the refineries. Scope 3 emissions are dominated by iLUC, purchased CPO and CPKO, purchased crops (FFB), assets (machinery, buildings etc.), and production of fertilisers.

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

UP's palm oil has been compared with industry averages RSPO certified and non-certified palm oil (Malaysia/Indonesia), rapeseed oil (Europe) and sunflower oil (Ukraine). The industry averages are based on Schmidt and De Rosa (2020) and Schmidt (2015). **Figure 5.4** shows results excluding iLUC, and **Figure 5.5** shows results including iLUC and both iLUC and nature conservation. **Figure 5.5** shows separately the effect of nature conservation – see bars 'UP ex nature' and 'UP incl nature'. The data used for the industry averages are associated with large uncertainties for emissions of pesticides and heavy metal contaminants in fertilisers. Therefore, the contributions to toxicity are not included in the comparison.

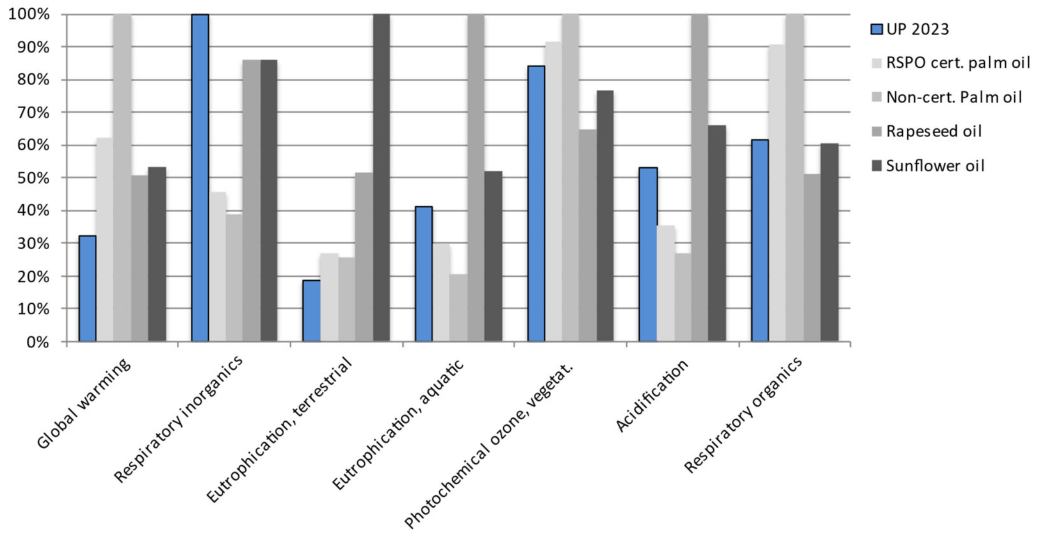

Figure 5.4: Comparison of LCIA results (excluding iLUC) for 1 kg NBD palm oil at United Plantations Berhad in 2023 with industry averages for 2016 for palm oil (Malaysia and Indonesia), rapeseed oil (Europe) and sunflower oil (Ukraine).

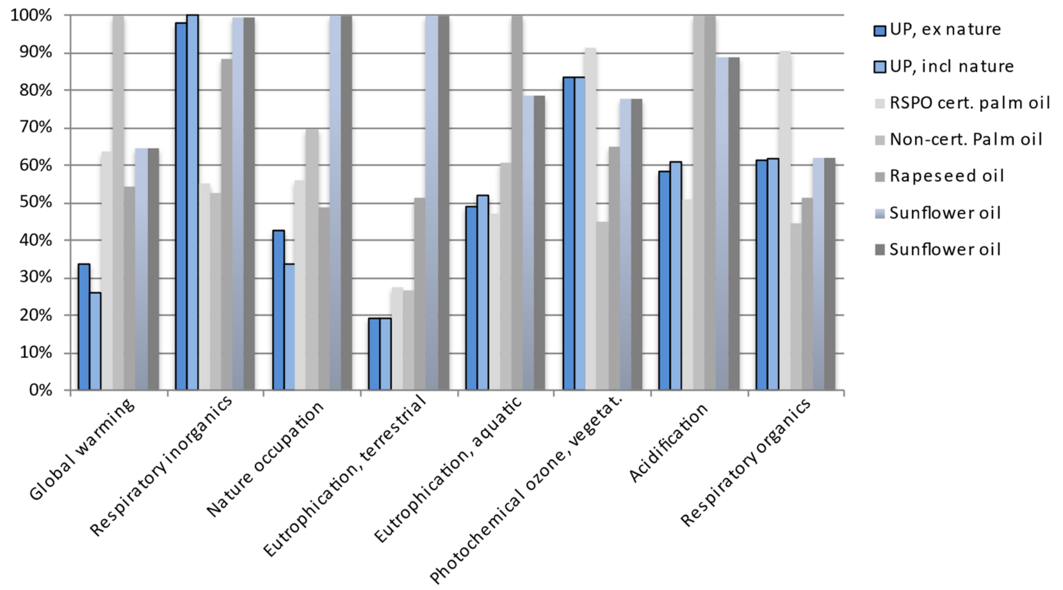

Figure 5.5: Comparison of LCIA results (including only iLUC and both iLUC and nature conservation) for 1 kg NBD palm oil at United Plantations Berhad in 2023 with industry averages for 2016 for palm oil (Malaysia and Indonesia), rapeseed oil (Europe) and sunflower oil (Ukraine).

UP's palm oil performs better than all the other oils for almost all impact categories. In particular, United Plantations' oil shows lower GHG emissions even compared to average RSPO certified palm oil and significantly lower emissions compared to non-certified palm oil.

5.5 Results for UP's total product portfolio in 2023

Product portfolio footprint broken down by life cycle stage

Table 9 shows the results for the entire 2023 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 refineries. The results for the cultivation stage are divided in contributions from oil palm cultivation at United Plantations' estates and external estates, i.e. GHG emissions from imported FFB to the PTSSS mill in Indonesia. Similarly, the results for the oil mill stage are shown separately for United Plantations' mills and for the external production of CPKO. The external CPKO is imported to the Unitata refinery.

The table shows the results with iLUC and nature conservation, with iLUC only and without iLUC and nature conservation.

Table 9: GHG emissions results for UP's total product portfolio in 2023 (1000 t CO2-eq) with iLUC and nature conservation.

			GHG emission (1000 t CO_2-eq)		
			With iLUC		Excluding iLUC
Life cycle stage	Product flow (1000 t)		With nature conservation	Without nature conservation	Without nature conservation
Cultivation stage (UP estates)	1,287	FFB	312	428	350
Cultivation stage (purchased FFB)	53	FFB	29	29	23
Oil mill stage	278	CPO	-13	-23	-14
Oil mill stage (purchased CPKO)	103	CPKO	338	338	299
Refinery stage (UP refineries)	312	refined oils	148	148	148
Refinery stage (refinery of UP ID CPO)	56	refined oils			
UP Total			**814**	**920**	**807**

Product portfolio footprint broken down into scope 1, 2, and 3

Table 10 shows the same results as in **Table 9**, but here broken down into scope 1, 2 and 3 as defined in GHG Protocol (2004, p 25). The table shows the results with iLUC and nature conservation, with iLUC only and without iLUC and nature conservation.

Table 10: GHG emissions results for UP's total product portfolio in 2023 (1000 t CO2-eq), broken down into scope 1 (direct emissions), scope 2 (purchased electricity), and scope 3 (the rest).

	With iLUC		Excluding iLUC
GHG emissions (1000 t CO_2-eq)	**With nature conservation**	**Without nature conservation**	
Scope 1	303	303	303
Scope 2	-1	-1	-1
Scope 3 – iLUC	113	113	n.a.
Scope 3 – nature conservation	-106	n.a.	n.a.
Scope 3 – other	504	504	504
UP Total	**814**	**920**	**807**

Time-series of product portfolio footprint: scope 1, 2, and 3 emissions

Table 11 shows the results for the entire product portfolio of United Plantations in terms of GHG emissions (1000 t CO2-eq.), for the last 4 years: 2020, 2021, 2022 and 2023. The contribution of scope 1, 2 and 3 is specified for the total result in each year.

Table 11: GHG emissions results for UP's total product portfolio 2020-2023 (1000 t CO2-eq), broken down into scope 1 (direct emissions), scope 2 (purchased electricity), and scope 3 (the rest). The results include iLUC and nature conservation.

GHG emissions (1000 t CO_2-eq)	2020	2021	2022	2023
Scope 1	287	271	282	303
Scope 2	0.0	0.8	0.5	-1.0
Scope 3	462	434	516	511
Total	**750**	**705**	**799**	**814**

The major contribution to the total GHG emissions comes from Scope 3. While the purchased electricity emissions represented by scope 2 are very low.

6 Highlights

GHG emissions 2023: The GHG emissions per kg NBD palm oil from palm oil production at United Plantations Berhad are calculated as:

- Result with iLUC and nature conservation: 1.36 kg CO_2-eq.
- Result with iLUC and without nature conservation: 1.76 kg CO_2-eq.
- Result without iLUC and nature conservation: 1.52 kg CO_2-eq.

Reductions in GHG emissions 2004-2023: United Plantations Berhad, via their efforts towards a more sustainable production, have achieved remarkable reductions in the GHG emissions per kg NBD oil:

- Reduction 2004-2023 with iLUC and nature conservation: 63%
- Reduction 2004-2023 with iLUC and without nature conservation: 52%
- Reduction 2004-2023 without iLUC and nature conservation: 56%

Comparison of United Plantations palm oil production with average palm oil and other oils: The 2023 GHG emissions from United Plantations' production have been compared with industry averages RSPO certified and non-certified palm oil (Malaysia/Indonesia), rapeseed oil (Europe) and sunflower oil (Ukraine). The industry averages are based on Schmidt and De Rosa (2020) and Schmidt (2015).

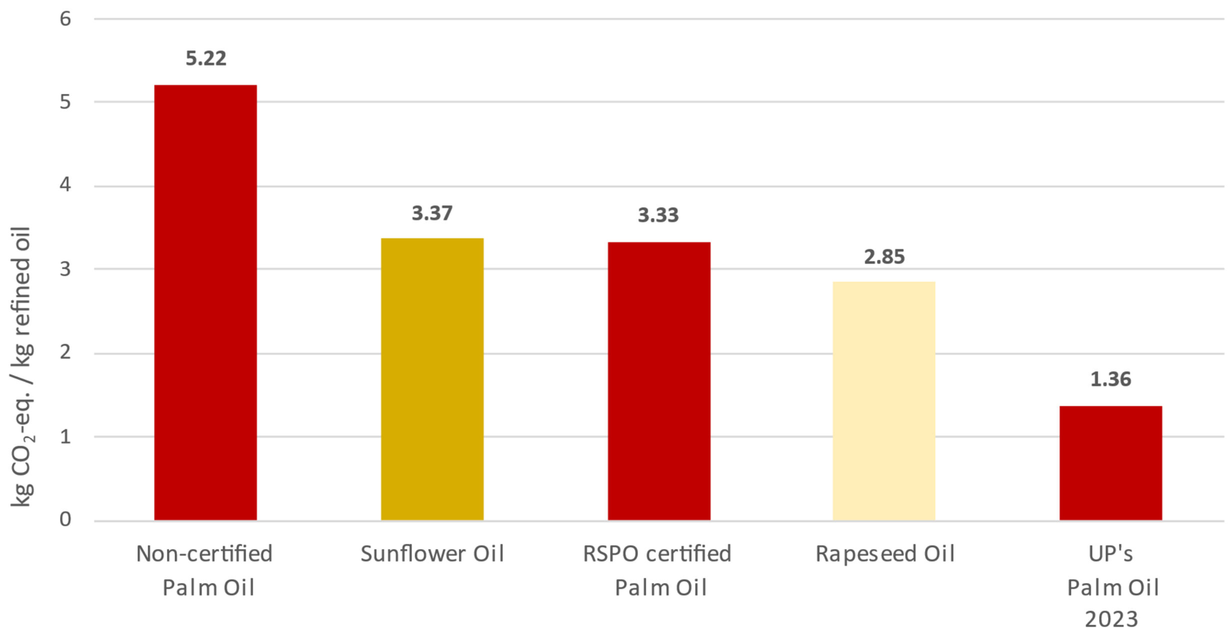

Figure 6.1: GHG emission of UP's palm oil calculate in this report, average palm oil (Schmidt and De Rosa 2020), sunflower oil and rapeseed oil (Schmidt and De Rosa 2020; Schmidt 2015) with iLUC and nature conservation. The chart shows the results for RSPO certified and non-certified RBD palm oil in 2016 and for UP's NBD palm oil in 2023. The results for RSPO certified and non-certified palm oil are slightly different (-2%) than in Schmidt and De Rosa (2020) due to updated values of capital goods and services and dinitrogen oxides emissions.

7 References

Greenhouse Gas Protocol (2004). Corporate Accounting and Reporting Standard. World Business Council for Sustainable Development (WBCSD) and the World Resource Institute (WRI). https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf (Accessed June 2023).

Haberl H, Erb K-H, Krausmann F, Gaube V, Bondeau A, Plutzar C, Gingrich S, Lucht W, Fischer-Kowalski M (2007). Quantifying and mapping the global human appropriation of net primary production in Earth's terrestrial ecosystem. Proceedings of the National Academy of Sciences of the USA. 104: 12942-12947. Maps are available at:

http://www.uni-klu.ac.at/socec/inhalt/1191.htm (Accessed July 2014)

IPCC (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York.

IPCC (2014). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Prepared by Hiraishi T, Krug T, Tanabe K, Srivastava N, Baasansuren J, Fukuda M and Troxler T G (eds). Published: IPCC, Switzerland.

http://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_Supplement_Entire_Report.pdf (Accessed August 2014)

IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidlines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use. https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html (Accessed May 2023)

IPCC (2020). Climate Change and Land - An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems Summary for Policymakers. Intergovernmental Panel on Climate Change.

Muñoz I, Schmidt J (2016). Methane oxidation, biogenic carbon, and the IPCC's emission metrics. Proposal for a consistent greenhouse-gas accounting. International Journal of Life Cycle Assessment 21:1069–1075.

Schmidt J (2017). Life cycle assessment of Palm Oil at United plantations Berhad 2017 - Results for 2004-2016. United Plantations Berhad, Teluk Intan, Malaysia.

Schmidt (2015). Life cycle assessment of five vegetable oils. Journal of Cleaner Production 87:130‐138.

Schmidt J, de Saxcé M (2016). Arla Foods Environmental Profit and Loss Accounting 2014. Environmental project No. 1860, 2016. Danish Environmental Protection Agency, Copenhagen https://lca-net.com/p/2343

Schmidt J, De Rosa M (2018). Enhancing Land Use Change modelling with IO data. Presentation at the SETAC Europe 28th Annual Meeting, Rome 13-17 May 2018. http://lca-net.com/p/3036

Schmidt J and De Rosa M (2020). Certified palm oil reduces greenhouse gas emissions compared to non-certified. Journal of Cleaner Production 277 (2020) 124045.

Schmidt J, Weidema B P, Brandão M (2015). A framework for modelling indirect land use changes in life cycle assessment. Journal of Cleaner Production 99:230‐238.

Schmidt J, Muñoz I (2014). The carbon footprint of Danish production and consumption – Literature review and model calculations. Danish Energy Agency, Copenhagen. https://vbn.aau.dk/ws/portalfiles/portal/196725552/_dk_carbon_footprint_20140305final.pdf (Accessed May 2023).

United Plantations (2023). https://unitedplantations.com/overview/#Landbank (Accessed May 2023).

Appendix 1: Characterized results for all impact categories

This appendix presents the characterized results for palm oil produced at United Plantations per functional unit of 1 kg NBD palm oil. The results are presented without iLUC, with iLUC and with iLUC & nature conservation.

Appendix figure 1: Characterised results for production of 1 kg NBD palm oil at United Plantations in 2023.

Impact category	Unit	Without iLUC	With iLUC	With iLUC & nature cons.
Global warming	kg CO_2-eq	1.52	1.76	1.36
Respiratory inorganics	kg $PM_{2.5}$-eq	0.0039	0.0043	0.0044
Nature occupation	m^2 agr.land	n.a.	1.225	0.968
Ecotoxicity, terrestrial	kg TEG-eq s	1.8	1.9	1.9
Human toxicity, non-carc.	kg C_2H_3Cl-eq	0.028	0.028	0.028
Eutrophication, terrestrial	m2 UES	0.99	1.46	1.54
Eutrophication, aquatic	kg NO_3-eq	0.054	0.080	0.085
Human toxicity, carcinogens	kg C_2H_3Cl-eq	0.008	0.008	0.009
Photochemical ozone, vegetat.	m^2*ppm*hours	18.5	18.8	18.9
Acidification	m^2 UES	0.29	0.39	0.41
Ecotoxicity, aquatic	kg TEG-eq w	63	63	63
Respiratory organics	pers*ppm*h	0.00154	0.00157	0.00158
Mineral extraction	MJ extra	0.001	0.001	0.001
Ozone layer depletion	kg CFC-11-eq	0.0E+00	0.0E+00	0.0E+00
Ionizing radiation	Bq C-14-eq	0.000	0.00	0.00
Non-renewable energy	MJ primary	37.0	45.1	46.6

Appendix 2: Explanation of units in the Stepwise LCIA method

This appendix briefly explains the impact categories included in the applied LCIA method: Stepwise 2006 (version 1.6). The original version is described in Weidema et al. (2008). Updates regarding nature occupation are described in Schmidt and de Saxcé (2016). If no literature reference is given in the table, this means that the information is obtained from Weidema et al. (2008).

Appendix table 2: Explanation of the impact categories in the LCIA method Stepwise 2006.

Impact category	Unit	Original source		Explanation
		EDIP 2003	Impact 2002+	
Global warming	kg CO_2-eq.	x		The unit is GWP100 (kg CO_2 equivalents) based on the fifth IPCC Assessment report (IPCC 2013).
Nature occupation	m^2 agr.land		x	The unit 'm^2-equivalents arable land', represents the impact from the occupation of one m^2 of arable land during one year. According to Schmidt et al. (2015), a change in demand for 1 ha*year land has the effect that denaturalisation of one hectare is moved one year closer. According to Weidema et al. (2008, p 157), arable land hosts only 20% of the species compared to the number in nature at full relaxation. Therefore, one ha*year arable land corresponds to 0.8 BAHY (biodiversity adjusted hectare years).
Acidification	m^2 UES	x		The unit expresses the area of the ecosystem within the full deposition area (in Europe) which is brought to exceed the critical load of acidification as a consequence of the emission (area of unprotected ecosystem = m^2 UES). The impact indicator is based on modelling of deposition in Europe. (Hauschild and Potting 2005, p47)
Eutrophication, aquatic	kg NO_3-eq.	x		The aquatic eutrophication potentials of a nutrient emission express the maximum exposure of aquatic systems that it can cause. The aquatic eutrophication potentials are expressed as N- or P-equivalents. (Hauschild and Potting 2005, p 73-74)
Eutrophication, terrestrial	m^2 UES	x		Same as for acidification.
Photochemical ozone, vegetat.	m^2*ppm*h	x		The impact is expressed as the accumulated exposure (duration times exceed threshold) above the threshold of 40 ppb times the area that is exposed as a consequence of the emission. The threshold of 40 ppb is chosen as an exposure level below which no or only small effects occur. The unit for vegetation exposure is m^2*ppm*hours. (Hauschild and Potting 2005, p 93)
Respiratory inorganics	kg $PM_{2.5}$-eq.		x	The impact on human health related to respiratory inorganics is expressed as equivalents of particles ($PM_{2.5}$).
Respiratory organics	pers*ppm*h	x		The category covers the impact on human health from photochemical ozone formation. The impact is expressed as the accumulated exposure above the threshold of 60 ppb times the number of persons which are exposed as a consequence of the emission. No threshold for chronic exposure of humans to ozone has been established. Instead, the threshold of 60 ppb is chosen as the long-term environmental objective for the EU ozone strategy proposed by the World Health Organisation, WHO. The unit for human exposure is pers*ppm*hours. (Hauschild and Potting 2005, p 93)
Human toxicity, carcinogens	kg C_2H_3Cl-eq.		x	The impact on human health related to carcinogens is expressed as equivalents of chloroethylene (C_2H_3Cl). The Impact2002+ method determines the damage on human health in terms of DALY (disability adjusted life years). Since there is no real mid-point for human toxicity, the Impact2002+ method has chosen C_2H_3Cl-eq. as a reference substance. (Jolliet et al. 2003)
Human toxicity, non-carc.	kg C_2H_3Cl-eq.		x	Same as for human toxicity, carcinogens
Ecotoxicity, aquatic	kg TEG-eq. w		x	The impact on ecosystems related to ecotoxicity is expressed as equivalents of chloroethylene triethylene glycol (TEG) into water. The Impact2002+ method determines the damage on ecosystems in terms of PAF (potentially affected fraction). Since there is no real mid-point for ecotoxicity, the Impact2002+ method has chosen TEG-eq. into water as a reference. (Jolliet et al. 2003)
Ecotoxicity, terrestrial	kg TEG-eq. s		x	Same as for ecotoxicity, aquatic
Ozone layer depletion	kg CFC_{11}-eq.		x	The unit is equivalents of CFC11 which is an important contributor to ozone layer depletion.
Non-renewable energy	MJ primary		x	Total use of primary non-renewable energy resources measured in MJ.