DETERMINATION OF LIFE CYCLE INVENTORY AND GREENHOUSE GAS EMISSIONS FOR A SELECTED OIL PALM NURSERY IN MALAYSIA: A CASE STUDY

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ABSTRACT

A case study on a gate-to-gate life cycle assessment (LCA) starting from the delivery of germinated seeds to the production of oil palm seedling in an oil palm nursery was carried out. The oil palm nursery, located in Selangor and licensed by the Malaysian Palm Oil Board (MPOB) was selected for this study. One oil palm seedling was the defined functional unit. The environmental impact from activities in the nursery were determined from the input and output into and from the processing steps in the nursery. The LCA study was conducted in accordance with the procedural framework ISO 14040 – 14044 series of the International Organisation of Standardisation (ISO). The purpose of the study was to obtain a life cycle inventory (LCI) of input and output associated with the production of one oil palm seedling and to provide a comprehensive picture of the environmental impact associated with production of one oil palm seedling in the nursery, by applying the LCA methodology. Inventory data collection consists of the input of raw materials and energy such as polybags, fertilisers, pesticides, diesel, pipes and petrol for transportation and irrigation. Real time measurement of gas and greenhouse gas (GHG) emissions from the pump for irrigation in the nursery was also carried out. The results show that the LCA methodology is suitable for assessing the environmental impact associated with oil palm seedling production.

Keywords: life cycle assessment, LCA, LCI, oil palm seedling, environmental impact, GHG.

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INTRODUCTION

Malaysia is currently one of the world's leading producers and exporters of palm oil. Crude palm oil (CPO) production in Malaysia based on the *Malaysian Oil Palm Statistics* (2012) reached more than 18.7 million tonnes in 2012. As the second biggest exporter, Malaysia has an important role in fulfilling the global demand for edible oils that are produced in an 'environmentally sustainable manner'. The oil palm industry is an export-oriented industry which relies heavily on the access to world market. Therefore, it is vital for the oil palm industry to remain competitive in order to increase its long-term profitability. Thus, to produce a large volume of quality products, the cost-effective application of chemicals such as fertilisers for nutrient requirements and pesticides for crop protection. To ensure the sustainability and competitiveness of the Malaysian palm oil industry, the emphasis on environmental management is very important.

To address this issue, life cycle assessment (LCA) methodology is used as a tool to systematically evaluate the environmental effects of a product, process or activity (Awang *et al.,* 1998). Recently, the LCA of the Malaysian palm oil including palm biodiesel was completed by the MPOB researchers (Halimah *et al.,* 2010; Zulkifli *et al.,* 2010; Vijaya *et al.,* 2010a,b; Yew Ai *et al.,* 2010; Puah *et al.,* 2010). It was a cradle-to-grave analysis starting from production of oil palm seedlings to the production and use of biodiesel. From the study, it was found that the main environmental impacts for the production of palm biodiesel were from upstream activities such as fresh fruit bunch (FFB) production. A study on LCA for gate-to-gate case study of an oil palm seedling and determination of greenhouse gas (GHG) contributions by subsystems in the oil palm supply chain using the LCA approach were also published (Halimah *et al.,* 2012; Yuen May *et al.,* 2011). LCA is also a tool that can be used to evaluate the environmental load of a product, process, or activity throughout its life cycle. LCA identifies and quantifies the amount of energy and materials used and wastes released to the environment and evaluates opportunities to effect environmental improvements. LCA assesses the impact of the energy and materials used and released to the environment, and identifies as well as evaluates opportunities to effect environmental improvements. The assessment includes the entire life cycle of a product, process or activity, encompassing the extraction and processing of raw materials, manufacturing, transportation and distribution, use, reuse, maintenance, recycling and final disposal (Birkved and Hauschild, 2006; Yusoff and Hansen, 2007; Avraamides and Fatta, 2008). It focuses on an area which cannot be covered by risk assessment, environmental impact assessment or other non-integrative tools. LCA has a unique role to play in furthering sustainable development.

The overall aim of conducting this LCA study was to measure GHG associated with the production of one oil palm seedling. This was done to establish the scientific basis for improvement analysis towards the sustainability of the palm oil production chain. High quality and representative data are critical for reliable LCA results (UNEP, 1996). Mungkung *et al.* (2006) have also observed that in developing countries, baseline data, especially describing background systems, are not always available and thus LCA practitioners have to supplement the missing data by using the databases provided in commercial LCA software. This practice sometimes adds to the low confidence level of LCA results. Lack of awareness of the LCA approach in this country has also been seen as a barrier. Concerted educational effort had to be made to introduce and explain the concept of LCA to the nursery operators during data collection. There is a need to further develop and promote its application in the priority areas such as LCA of any product, water footprint, green procurement and also eco-labelling considering the potential of this method for strengthening sustainable development in the country. This will require a substantial effort to develop a simplified language that would communicate the concepts, tools and benefits of LCA methodology to policy and decision-makers and the development of a database relevant to domestic conditions (Ramjeawon *et al.,* 2005). Current LCA methodologies address only the environmental aspects and impact, therefore recommendations based on LCA's failure to address possible trade-offs between environmental protection and both social and economic concerns in the product life cycle (Guine´e, 2001; Dreyer *et al.,* 2006) are needed. This raises questions about the ability of LCA to support actual decision-making in companies, which aim for sustainability, and it also creates an incentive for developing an LCA methodology to include other dimensions of sustainability (Dreyer *et al.,* 2006).

Despite these general limitations regarding the application of the LCA tool in developing countries like Malaysia, one cannot underestimate the environmental perspective offered by a method which makes it possible to identify key environmental issues in support of sustainability measures. For this case study, the LCA tool proved to be successful in identifying and quantifying the significant impact associated with oil palm seedling production in Malaysia.

Life cycle inventory (LCI) is the heart of a LCA study (Narayanaswamy *et al.,* 2002). An LCI consists of data which are extrapolated to quantify the input and output of a product based on its functional unit (Awang *et al.,* 1998; Sanchez, 2003). This study attempts to obtain a LCI of input and output associated with the production of a single oil palm seedling and to measure GHG emissions from the pump for irrigation in the nursery.

MATERIALS AND METHODS

The study was conducted in accordance with the ISO procedural framework for performing LCA in the ISO 14040-14044 series. According to the ISO Standards, an LCA study has four main phases, namely: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation of results. This LCA study associated with GHG emissions study, was modelled using the System for Integrated environMental Assessment of PROducts (SimaPro, Version 7) and the Eco-indicator methodology (Goedkoop and Spriensma, 2001). Validations of data were carried out by on-site visits, on-site measurements, discussions and communications with the nursery operators.

The goal and scope definition phase states why an LCA is being conducted and describes the system to be studied. The objective of this study was to obtain an LCI of input and output associated with the production of oil palm seedling; to identify and quantify the GHG contribution for process; and then to measure GHG emissions from the pump for irrigation in the nursery. A gate-to-gate study was carried out whereby the system boundary was set to only include the production of oil palm seedling in the nursery (*Figure 1*). LCA is a relative approach which is structured around a functional unit. The functional unit for this study is one oil palm seedling.

The measurement of GHG emissions which included carbon monoxide (CO), nitrous oxide (N_2O), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) was carried out using the MRU Vario Plus Air Emission Monitoring Systems. This analyser was used for the measurement of smoke and flue gases, of combustion air and gas temperature, differential pressure measurement, stack pressure measurement and flow velocity. The measurement principle of toxic gases was based on the electrochemical principle or optionally on infrared bench (non-dispersive infrared). The oxygen content of the sample gas was measured with two electrodes electrochemical sensor while toxic gases like CO, SO_2, nitric oxide (NO), NO_2 and H_2S were measured with three-electrodes sensors. The electrochemical sensors were based on the gas diffusion technology with the advantages of permanent generated signal being directly proportionally and linearly to the volume concentration (% or ppm) of the analysis gas components. Emissions from the 33HP diesel water pump and 15HP petrol water pump were measured for 20 min with a 2-min interval using the metal probe which was placed in exhaust of water pump.

RESULTS AND DISCUSSION

Life Cycle Inventory

Annual inventory data collected from a selected nursery over a four-year period was analysed. *Table 1* shows the LCI average input for the production of a single oil palm seedling. This input comprised the foreground data which was collected directly from the oil palm nursery operators. Most of the foreground data was collected from this selected nursery and apportioned over the typical life span of oil palm of 25 years.

This phase involved the most intensive work and was the most time-consuming compared to other phases in an LCA study, mainly because of data

TABLE 1. LIFE CYCLE INVENTORY FOR THE PRODUCTION OF A SINGLE OIL PALM SEEDLING

Input	Amount
Electricity (kWhr)	0.000226
Diesel (litre)	0.0009
Petrol (litre)	0.000541
Water	0.03226
Unspecified pesticide (kg)	0.0000001965
Maneb (kg)	0.00002264
Organophosphorus (kg)	0.00001445
Glyphosate (litre)	0.00003713
N fertiliser (kg)	0.000476
P fertiliser (kg)	0.000480
K fertiliser (kg)	0.000366
Polyethylene bag (kg)	0.0005

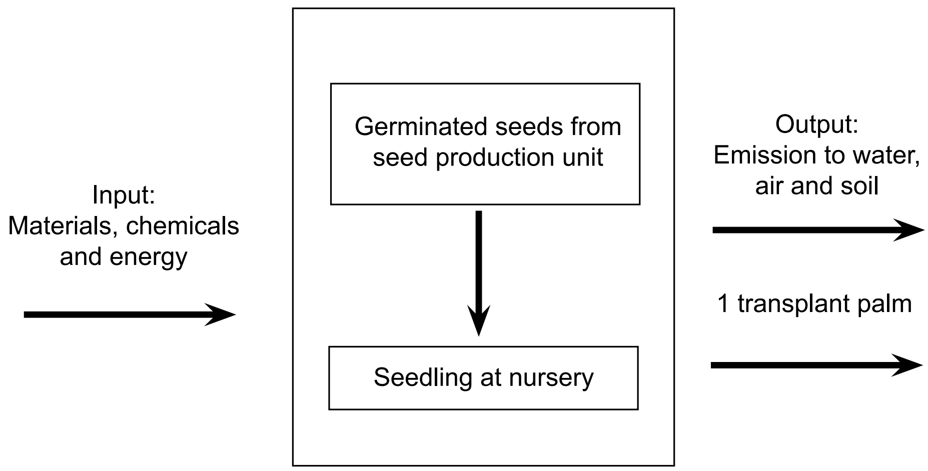

Figure 1. Boundary of life cycle assessment study.

collection and verification of the data obtained. The input needed to produce a single oil palm seedling in this case study included energy (diesel, electricity and petrol), raw materials (water, polybag), chemicals (insecticide, fungicide and fertiliser).

Emissions

Irrigation pump. In this particular nursery, the irrigation of water to oil palm seedling was carried out using a diesel water pump and a petrol water pump. The actual measurement of emissions emitted by the diesel and petrol pump for watering the oil palm seedling was carried out. *Table 2* shows the amount of emissions from the diesel-run and petrol-run water pump for the production of a single oil palm seedling. The CO emission from the diesel-run water pump was 4.21E-07 kg per seedling and this was followed by $NO_{x,}$ at 3.93E-07 kg per seedling; NO at 2.28E-07 kg per seedling and SO_2 at 1.30E-08 kg per seedling.

The amount of CO, NO_x, NO and SO_2 emitted by the petrol-fueled water pump were 2.06E-10 or 2.26E-10 kg per seedling, 2.98E-07 kg per seedling, 1.94E-07 kg per seedling and 3.10E-08 kg per seedling, respectively. The results showed that CO, NO_x and NO emissions from the diesel water pump were higher than the emissions from the petrol water pump. However, the SO_2 emission was lower for the diesel water pump.

Production of raw material, energy and chemicals. *Table 3* shows the GHG emissions to air contributed from the production of input (material and energy) for the production of one oil palm seedling (Ecoinvent database). The CO_2 emissions came from the production of diesel/petrol for running the pump and pesticides. The N_2O was contributed by pesticide, fertiliser, electricity, diesel and petrol. The total amount of carbon dioxide equivalent (CO_2 eq) for the production of one seedling from the production of input (Ecoinvent database) was 0.0284 kg CO_2 eq.

TABLE 2. EMISSIONS FROM FUEL CONSUMPTION OF DIESEL WATER PUMP PER SEEDLING

Emission	Amount (kg) diesel	Amount (kg) petrol
CO	4.21E-07	2.26E-10
NO_x	3.93E-07	2.98E-07
NO	2.28E-07	1.94E-07
SO_2	1.30E-08	3.10E-08

Note: CO - carbon monoxide.
NO_x - nitrogen oxide.
NO - nitric oxide.
SO_2 - sulphur dioxide.

TABLE 3. GREENHOUSE GAS EMISSIONS FOR THE PRODUCTION OF INPUT FROM SIMAPRO

Source	Amount of CO_2 eq (kg)	Source
CO_2	0.0045	Ecoinvent
Methane	0.000324	Ecoinvent
N_2O	1.00E-08	Ecoinvent
Sulphur hexafluoride (SF_6)	1.81E-06	Ecoinvent
Tetrafluroethane	0.01161	Ecoinvent
Polybags (up to production of polybag)	0.01197	Malaysian database
Total	0.0284	-

CONCLUSION

Based on the results obtained in this study, the total amount of CO_2 eq for the production of one oil palm seedling from the production of input was 0.0284 kg CO_2 eq, was very minimal. The main contributor of the 0.0284 kg CO_2 eq was due to CO_2, followed by polybags, tetrafluroethane, methane, SF_6 and N_2O. This emission comes from the materials such as chemicals used in the production of oil palm seedlings. It can be concluded that the GHG emissions for the production of a single oil palm seedling has an insignificant impact on the environment.

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