Tropical Life Sciences Research, 23(1), 15–23, 2012

A Gate-to-gate Case Study of the Life Cycle Assessment of an Oil Palm Seedling

[1]Halimah Muhamad, [2]Ismail Bin Sahid*, [2]Salmijah Surif, [1]Tan Yew Ai and [1]Choo Yuen May

[1]Malaysian Palm Oil Board, Kuala Lumpur, Malaysia
[2]School of Environmental and Natural Resource Sciences,
Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia

Abstrak: Industri minyak sawit memainkan peranan yang penting di dalam pembangunan ekonomi Malaysia dan telah meningkatkan kebajikan ekonomi rakyat. Untuk menentukan impak alam sekitar bagi anak pokok sawit di peringkat nurseri, maklumat mengenai input dan output perlu dinilai. Nurseri sawit merupakan rangkaian pertama dalam rantaian bekalan minyak sawit. Kajian *gate-to-gate* telah dijalankan di mana sempadan sistem telah ditetapkan untuk memasukkan hanya proses anak pokok sawit. Titik permulaan bagi proses ini adalah biji benih cambah sawit, disemai di dalam beg polietilena kecil (6 in x 9 in) dan dibiarkan sehingga anak pokok mencapai 3 hingga 4 bulan. Kemudian, anak pokok itu akan dipindahkan ke dalam beg polietilena yang lebih besar (12 in x 15 in) dan dibiarkan sehingga anak pokok mencapai 10–12 bulan, sebelum anak pokok itu ditanam di ladang. Unit fungsi bagi inventori kitaran hayat (LCI) adalah berdasarkan penghasilan satu anak pokok sawit. Secara amnya, dalam sempadan sistem, penghasilan anak pokok sawit hanya mempunyai dua impak alam sekitar yang utama iaitu polibeg yang digunakan semasa penanaman anak pokok dan juga racun kulat (ditiokarbamat) yang digunakan untuk mengawal kulat patogen, yang mana kedua-dua polibeg dan ditiokarbamat diperolehi dari bahan api fosil.

Kata kunci: Nurseri, Anak Pokok, Inventori Kitaran Hayat, Input Alam Sekitar, Penilaian Impak Kitaran Hayat

Abstract: The palm oil industry has played an important role in the economic development of Malaysia and has enhanced the economic welfare of its people. To determine the environmental impact of the oil palm seedling at the nursery stage, information on inputs and outputs need to be assessed. The oil palm nursery is the first link in the palm oil supply chain. A gate-to-gate study was carried out whereby the system boundary was set to only include the process of the oil palm seedling. The starting point was a germinated seed in a small polyethylene bag (6 in x 9 in) in which it remained until the seedling was approximately 3 to 4 months old. The seedling was then transferred into a larger polyethylene bag (12 in x 15 in), where it remained until it was 10–12 months old, when it was planted in the field (plantation). The functional unit for this life cycle inventory (LCI) is based on the production of one seedling. Generally, within the system boundary, the production of an oil palm seedling has only two major environmental impact points, the polybags used to grow the seedling and the fungicide (dithiocarbamate) used to control pathogenic fungi, as both the polybags and the dithiocarbamate are derived from fossil fuel.

Keywords: Nursery, Seedling, Life Cycle Inventory, Environmental Input, Life Cycle Impact Assessment

*Corresponding author: ismail@ukm.my

INTRODUCTION

Life cycle inventory (LCI) data are the most important when conducting a life cycle assessment (LCA) to determine the environmental impact of a product at all stages, "from the cradle to the grave". LCA is a process used to evaluate the environmental impact associated with a product, process or activity by identifying and quantifying the energy and materials used and the waste products released into the environment. LCA takes into consideration the impact of the energy and materials used and released to the environment, and it identifies and evaluates opportunities for environmental improvement. The assessment includes the entire life cycle of the product, process or activity, and it encompasses the extraction and processing of the raw material, manufacturing, transportation and distribution, use, reuse, maintenance, recycling and, finally, disposal (Birkved & Hauschild 2006; Yusoff & Hansen 2007; Avraamides & Fatta 2008).

The oil palm industry has played an important role in the economic development of Malaysia by enhancing the welfare of the people. To determine the environmental impact of the palm oil supply chain, information on inputs and outputs within the chain must be quantified. The oil palm nursery is the first link in the palm oil supply chain. In 2006, 2007 and 2008, the average production of germinated oil palm seedlings in Malaysia was 66.7, 65.2 and 88.2 million, respectively. The productivity of an oil palm plantation depends on many factors. The most important starting point is the quality of the oil palm seedlings derived from the cross-pollination of selected parent palms. The production of high quality oil palm seedlings is dependent on good nursery management and practices.

A nursery stage is required because the palm seedlings require close supervision during the first 10 to 12 months of their life, and this activity is easier when a smaller area is involved, as it facilitates pest control and the culling of unhealthy/diseased palms. In some organisations, there are two nursery stages: in the first three months, the seedlings grow in a small polybag; in the remaining nine months, they are transplanted into a larger polybag. This transplanting is done so that healthy seedlings with optimum vigour at the time of field planting will be established faster, thus minimising the immature period in the field, resulting in earlier and higher yields.

The Malaysian oil palm industry is the core business in the Malaysian economy. In 2010, the total exports of oil palm products, consisting of palm oil, palm kernel oil, palm kernel cake, oleochemicals, biodiesel and finished products, increased by 2.8% (or 0.63 million tonnes), from 22.43 million tonnes in 2009 to 23.06 million tonnes in 2010. The total export earnings also increased by 20.4% (or RM10.13 billion) to RM59.77 billion, compared with the RM49.66 billion obtained in 2009, as a result of higher prices (Choo 2011). To produce this large volume of quality products, the use of chemicals, such as fertilisers (for nutrient requirements) and pesticides (for crop protection), as well as the availability of an efficient transportation system are vital. To ensure the sustainability and competitiveness of the Malaysian palm oil industry, emphasis on environmental management is important. The Malaysian Palm Oil Board (MPOB) has completed the LCA for the production of crude palm oil, and other LCA projects are in progress or nearing completion (Vijaya *et al.* 2008, 2009). One of the gaps that need to be filled to obtain a complete LCA of palm oil production from the estate to the refinery is the LCA for the production and establishment of the seedling from the seed.

The objective of this study was to identify the potential environmental impact associated with the production of an oil palm seedling and to evaluate and implement strategies to improve the environmental status during seed processing, germination and nursery management.

MATERIALS AND METHODS

An oil palm nursery licensed by the MPOB was selected for the study. This oil palm nursery is located in Negeri Sembilan (West-central Peninsular Malaysia), and it uses a two-stage polybag nursery. Questionnaires were administered to the personnel of the relevant nursery, and selection criteria were based on the average of 25 years as the time taken for one complete cycle of the oil palm tree (Corley & Tinker 2003). Inventory data were collected from the oil palm nursery over a period of 4 years, from 2004 to 2007. The inventory data for the nursery stage were collected, and calculations were made to quantify the input from the environment and the output to the environment by one oil palm seedling. The LCA study was carried out using established guidelines under the ISO 14040/14044. The SimaPro (PRé Consultants, Netherlands) software was used for the study, and the life cycle impact assessment (LCIA) was carried out using the Ecoindicator 99 methodology (Goedkoop & Spriensma 1999).

System Boundary and Functional Unit

The LCA study is a gate-to-gate system boundary beginning with the germinated seed up to the planting and management of the nursery and, finally, the transport of the seedling to the specified field in the plantation. The system boundary is for the production of pre-plantation inputs that comprise the oil palm seedling and all the input/output processes in the nursery. The system boundary determines which unit processes are included or excluded in the LCA. The functional unit for this system boundary is one oil palm seedling. A flow chart of the process to produce seedlings is shown in Figure 1. The inputs of the nursery are materials and energy, while the outputs are emissions into the atmosphere, water and soil that leave the system boundary.

Limitations/Constraints

The SimaPro software used was obtained from Europe; therefore, it was designed based on European data. However, the software is generic, and Malaysian data were entered (as additional inputs) into the database wherever possible for the purpose of the study. However, the background data were adopted from the database itself (e.g., diesel, chemicals) due to lack of relevant Malaysian data. This was one of the main constraints in determining the LCIA, as Malaysia lacks much-needed background data. Therefore, the LCIA for an oil palm seedling in the nursery was carried out with the above constraints taken into account.

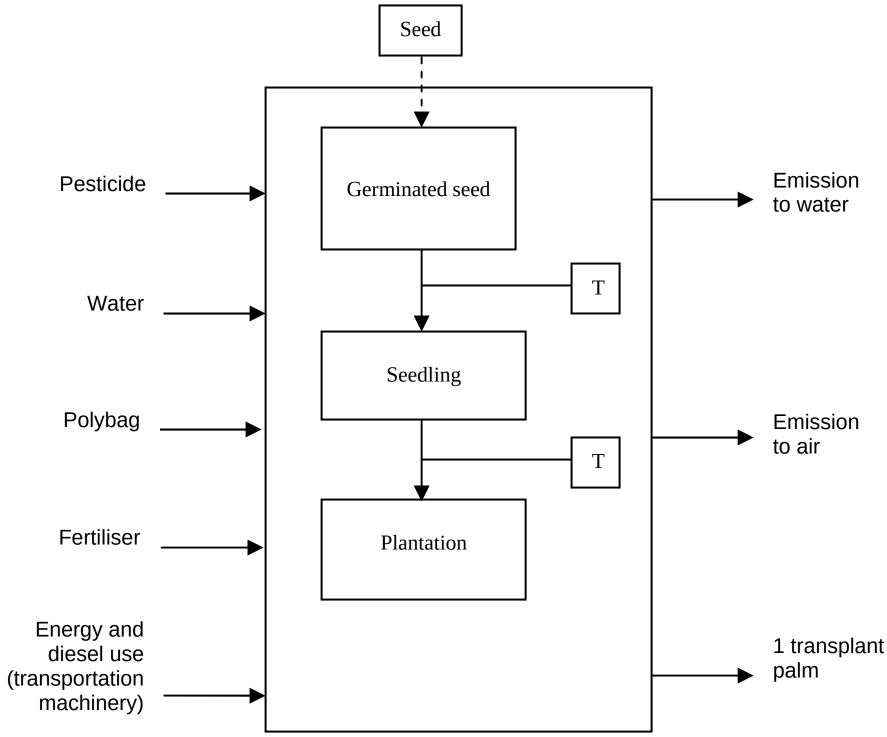

Figure 1: A flow chart diagram for the system boundary for the production of a seedling.

RESULTS AND DISCUSSION

The study began with the transportation of the germinated seed to the nursery and ended with the transportation of the seedling to the field (plantation). In the study, all processes were considered relevant unless they were excluded based on the exclusion criteria. Several inflows and outflows were found to be difficult, if not impossible, to quantify. The criteria that had to be excluded are shown in Table 1. In addition, a mass-based threshold limit of less than or equal to 3% was not considered for input contribution. In the production of the seedling, the processing category included agricultural inputs (e.g., polybags, fertilisers, insecticides, herbicides and fungicides), transportation of the germinated seed to the nursery and diesel used for running the water pump. Meanwhile, capital goods such as polyvinyl chloride for pipes and water pumps were excluded. In addition, the transportation of the topsoil to the nursery and the seedling to the plantation, agricultural inputs (e.g., polybags) and the application of fertilisers, insecticides, herbicides and fungicides, were also excluded from the study. In this particular nursery, diesel instead of electricity was used to run the water pump. The pesticides used at the nursery were grouped under their common chemical class according to the availability of the data in the Simapro software, and those not listed were considered as unspecified pesticides.

The LCI for the production of one seedling as calculated at an oil palm nursery is shown in Table 2. The nursery received the germinated seed from a seed producer licensed by MPOB. The environmental inputs to obtain one oil palm seedling were energy (e.g., fossil fuel), material (polybags), plant nutrition products (fertilisers) and plant protection chemicals (herbicides, fungicides and insecticides).

The energy needed to produce one seedling from diesel for watering the seedling was 0.000001. The weight of the polybags used to produce one seedling was 0.0004 kg. The amounts of pesticides, namely, carbamate, pyrethroid, organophosphate and dithiocarbamate, were 4.40E-05, 0.20E-6, 0.20E-05 and 0.80E-6 kg, respectively. Glufosinate ammonium was classified as an unspecified pesticide, and the amount needed to produce one seedling in this case study was 0.20E-05 kg. The amount of fertilisers used, namely, K_2O and P_2O_5, was 0.00004 and 0.00002 kg, respectively. The transportation only included that of the germinated seed to the nursery, and the amount of diesel needed for one seedling was 2.02E-04. The highest input to the LCI came from water used for seedling irrigation, followed by the use of the two polybags. Because the water came from the river, the impact on the environment was minimal. However, the input needed to produce 1 seedling at the nursery was quite low. On-site verification of the LCI data of the gate-to-gate study for the production of one oil palm seedling was also carried out.

Table 1: System boundary definition criteria.

Processing category	Included	Excluded	
		Insignificant environmental impact	Difficult to obtain representative data
Production, maintenance and replacement of capital equipment		✓	✓
Transportation of capital goods		✓	✓
Production of agricultural inputs, e.g., polybags, fertilisers, insecticides, herbicides and fungicides	✓		
Disposal of small polybags (15x23 cm)		✓	✓
Water supply		✓	
Transportation of germinated seed to nursery	✓		
Diesel for running water pump	✓		
Production of top soil			✓

Table 2: Input data of one nursery.

Input	Amount
Diesel (l)	0.000001
Polybay (kg)	0.0004
Water	0.013
Fertiliser (kg)	
N	0.00004
P_2O_5	0.00002
K_2O	0.00004
Pesticides (kg)	
Carbamate	4.40E-05
Pyrethroid	0.20E-06
Organophosphate	0.20E-05
Dithiocarbamate	0.80E-06
Unspecified pesticides	0.20E-02
Transportation (l) of germinated seed to nursery	2.02E-04

A paper presented by Choo *et al.* (2009) on an LCIA studied the cradle to gate system boundary. The starting point of their study was from the germination of the seed until the seedling was ready to be sent to the plantation, where the oil palm was grown, and fresh fruit bunches (FFB) were harvested and transported to the mill until the production of the crude palm oil (CPO) at the palm oil mills. At the plantation phase, a land use change scenario of 20 years from the logged forest was used for the production of the FFB. For the present study, the LCI for nurseries was included; however, the LCIA study for the nursery from the germinated seed to the seedling in the polybag was not carried out. A poster paper was presented by Halimah *et al.* (2010) that outlines the environmental impacts identified using LCA associated with the production of one seedling and the proposed mitigation measures.

A case study of the LCI and real-time measurements on greenhouse gas (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 infrared gas analyser (Germany). Emissions from the 33 horsepower (HP) diesel water pump and 15 HP petrol water pump were measured for 30 minutes with a 2-minute interval (Rawaida *et al.* 2009).

An environmental impact assessment for the production of refined palm oil, beginning with the oil palm seedlings, carried out using the life cycle approach, was reported by Tan *et al.* (2009). The assessment was also applied to the fractionation process for obtaining palm olein and palm stearin from refined palm oil. The system investigated the production of oil palm seedlings in nurseries, agricultural practices in oil palm plantations, the extraction of palm oil from palm fruits and the refining and fractionation stage in refineries. The consumption of raw materials, including energy and emissions, was evaluated using site-specific inventory data to identify the processes along the palm oil supply chain, which gave rise to a significant environmental burden. The material input and output from the system was quantified on the basis of a functional unit of 1 tonne of refined palm oil, refined palm olein or palm stearin. The production and use of fertilisers in the cultivation of the palms, the generation of palm oil effluents from mills and the consumption of fossil fuels for the production of polybags (for holding the seedlings) and for the transportation of crude palm oil to the refineries were found to be "hotspots" that require further attention.

Puah *et al.* (2009) reported an LCA for the production of palm biodiesel, and the system boundary started from the nursery and moved to the oil palm plantation, palm oil mill, palm oil refinery, biodiesel factory and, finally, to combustion in a vehicle. Palm biodiesel has been shown to contribute to greater GHG emission saving compared with biodiesels produced from other vegetable oils. The study provided a quantifiable measure that showed that palm biodiesel is environmentally friendly, and it enhances the image of palm oil as an environmentally friendly product.

Figure 2 shows the characterisation of the LCIA for the production of one oil palm seedling. There are 11 impact categories for the characterisation of the LCIA: carcinogens, respiratory organic/inorganic, climate change, radiation, ozone layer, ecotoxicity, acidification/eutrophication, land use, minerals and fossil fuels. The polyethylene bags contributed to the major impact in the respiratory (inorganic) category followed by the fossil fuel and land use categories. The second and third contributors to fossil fuels were dithiocarbamates and fertilisers. The impact on the ozone layer, radiation, ecotoxicity, mineral and carcinogens were mainly due to the use of pesticides. Meanwhile, the impacts on the respiratory (inorganic/organic), acidification, land use and fossil fuel categories were caused by the use of the two polybags to raise the seedling. Climate change might be affected by fertilisers, polybags and the pesticide thiocarbamate.

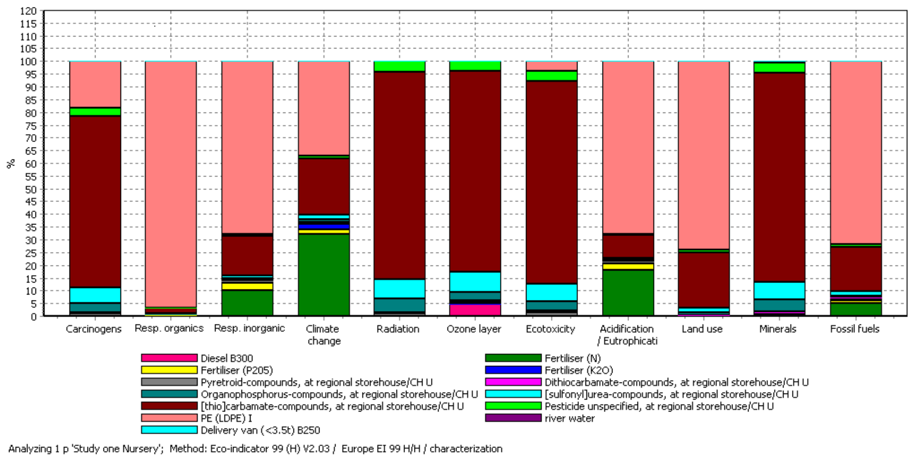

Figure 2: Characterisation of LCIA for the production of an oil palm seedling.

Figure 3 shows the normalisation for the production of one oil palm seedling, and this impact was grouped under the 'three damage' categories, namely, human health, ecosystem quality and resources. It was found that there were two potential impact areas in the production of a seedling. Resource depletion had the highest impact, followed by human health and ecosystem quality. The polybags used for growing the seedling caused the major impact to resource depletion and human health followed by the use of thiocarbamate (pesticide) and fertilisers.

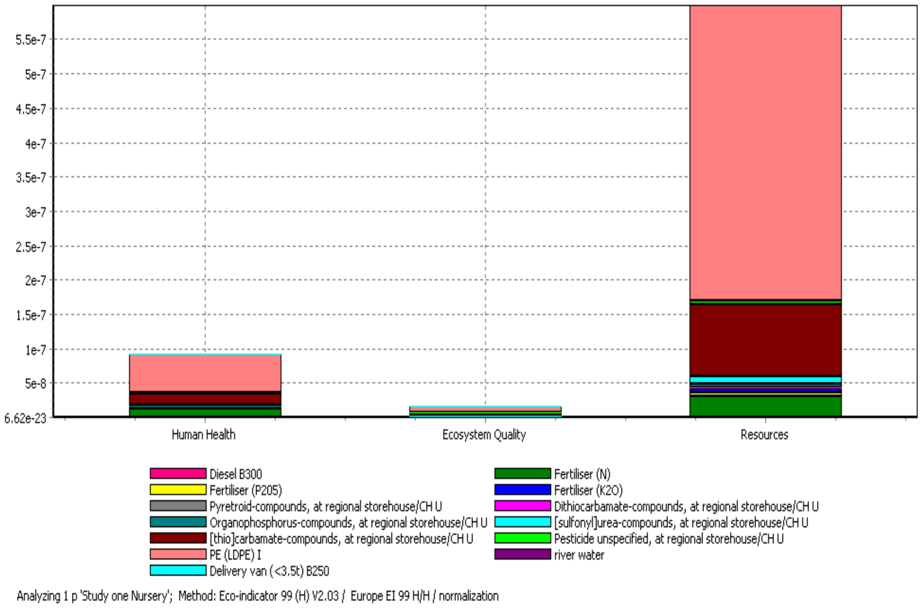

Figure 3: Normalisation of LCIA in the production of one oil palm seedling.

CONCLUSION

In general, the production of an oil palm seedling in the nursery in Negeri Sembilan had an insignificant impact on the environment. The major factor that contributed to the environmental load was fossil fuel, which came from the two polybags used to raise the seedling. The impact of the polybags can be mitigated through the use of environmentally friendly biodegradable pots or bags. The other key cause of fossil fuel depletion was the use of the pesticide dithiocarbamate to protect the seedling. As an alternative, biodegradable natural pesticides should be used to replace the chemical pesticides.

ACKNOWLEDGEMENT

This research was financially supported by the Malaysian Palm Oil Board (MPOB) research fund.

REFERENCES

Avraamides M and Fatta D. (2008). Resource consumption and emissions from olive oil production: A life cycle inventory case study in Cyprus. *Journal of Cleaner Production* 16: 809–821.

Birkved M and Hauschild M. (2006). PestLCI - a model for estimating field emissions of pesticides in agricultural LCA. *Ecological Modelling* 198(3–4): 433–451.

Choo Y M, Mohd Basri W, Halimah M and Zulkifli H. (2009). Life cycle assessment of palm oil. Paper presented at *6th International Planters Conference 2009.* Kuala Lumpur, 22–24 June 2009.

Choo Y M. (2011). O*verview of Malaysian oil palm industry 2010.* Selangor, Malaysia: Malaysian Palm Oil Board, 1–3.

Corley R H V and Tinker B. (2003). *The Oil Palm*. Oxford, UK: Blackwell Science Ltd, 562.

Goedkoop M and Spriensma R. (1999). *The Eco-indicator 99. A damage oriented method for Life Cycle Impact Assessment. Methodology Report*. Netherlands: PRé Consultant.

Halimah M, Zulkifli A M, Zulkifli H, Vijaya S, Tan Y A, Puah C W, Choo Y M and Mohd Basri W. (2010). A case study on the environmental assessment of an oil palm nursery. *International Conference on Oil Palm and Environment (ICOPE).* Bali, Indonesia, 23–25 February 2010.

Puah C W, Choo Y M, Ma A N, Halimah M, Zulkifli H, Vijaya S, Tan Y A and Mohd Basri W. (2009). Life cycle assessment of non-food product: Palm biodiesel. *International Conference on Oil Palm and the Environment*. Malaysian Agro Exposition Park Serdang, Selangor, Malaysia, 14–15 August 2009.

Rawaida A, Tan Y A, Zuraiti Z, Zulkifli H, Muzzammil N and Halimah M. (2009). A case study of life cycle inventory (LCI) and green house gas (GHG) emissions in the oil palm nursery. Paper presented at *6th International Planters Conference 2009*. Kuala Lumpur, 22–24 June 2009.

Tan Y A, Chow M C, Halimah M, Zulkifli H, Vijaya S, Putri N, Neo Y P, Norlin H, Chong C L, Choo Y M and Mohd Basri W. (2009). Life cycle assessment of palm oil. Paper presented at *6th International Planters Conference 2009*. Kuala Lumpur, 22–24 June 2009.

Vijaya S, Ma A N and Choo Y M. (2009). A gate to gate assessment of environmental performance for production of crude palm kernel oil using life cycle assessment approach. *American Journal of Environmental Sciences* 5(3): 267–272.

Vijaya S, Ma A N, Choo Y M and Nik Meriam N S. (2008). Environmental performance of the milling process of Malaysian palm oil using the life cycle assessment approach. *American Journal of Environmental Sciences* 4(4): 310–315.

Yusoff S and Hansen S B. (2007). Feasibility study of performing a life cycle assessment on crude palm oil production in Malaysia. *International Journal of Life Cycle Assessment* 12(1): 50–58.