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Life cycle assessment and life cycle costing analysis for uncertified and Malaysia sustainable palm oil - MSPO-certified independent smallholders

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ABSTRACT

The Malaysian Sustainable Palm Oil (MSPO) Scheme was established by the government of Malaysia to mandate MSPO certification on all palm oil stakeholders within the country by year 2019 as an initiative for sustainable palm oil production. However, independent smallholders (ISH) who account for 16.71% of the total palm oil plantation area in Malaysia have shown a low MSPO registration rate of 24.82% by midyear 2020. Therefore, it is vital to encourage MSPO certification and incorporation of sustainable production practices in ISHs in order to maintain the supply of certified palm oil. The current study has compared the environmental life cycle assessment (LCA) and life cycle costing (LCC) on the uncertified and MSPO-certified fresh fruit bunches (FFB) production among independent smallholders to determine the impacts of MSPO implementation. Based on the LCA findings using ReCiPe 2016 Endpoint (H), a net decline in environmental impacts will result when independent smallholders adopt MSPO certification. With at least 10.116% decrease in all impact categories except the Mineral Resource Scarcity category (18.065% increase), the endpoint results indicate that MSPO implementation in independent smallholders can overall reduce the environmental impacts from Human Health (99.913%), Ecosystem Quality (99.958%), and Resources (90.223%) categories. The study also finds out that certified ISH systems can further improve by replacing mineral fertilizers with organic fertilizers. In terms of LCC, the net present value in MSPO-certified ISHs (127,092.56 USD) for a 3.94 ha plantation and 25-year life cycle was found to be approximately 39% higher than uncertified ISHs (91,017.84 USD), indicating an increased economic profitability in an ISH system when MSPO is implemented.

1. Introduction

In recent years, the palm oil industry has raised several environmental concerns and is criticized by international groups, including Greenpeace and World Wildlife Fund (WWF) for unsustainable production practices (Lim et al., 2015). The public is increasingly aware of the negative impacts that have resulted from the palm oil production processes, specifically deforestation and losses in biodiversity for the cultivation and expansion of palm oil plantations (Bernet and Berge, 2019). Despite that the land use change impact is relatively low in palm oil plantation with respect to the other oil crops (Tapia et al., 2021), the palm oil market has shifted its demand towards procuring certified

Abbreviations: DALY, Disability Adjusted Life Years; FELCRA, Federal Land Consolidation and Rehabilitation Authority; FELDA, Federal Land Development Authority; FFB, Fresh Fruit Bunches; FFA, Free Fatty Acid; ISH, Independent Smallholders; LCA, Life Cycle Assessment; LCC, Life Cycle Costing; LCIA, Life Cycle Impact Assessment; MPOB, Malaysian Palm Oil Board; MSPO, Malaysian Sustainable Palm Oil; NPV, Net Present Value; PP, Payback Period; RISDA, Rubber Industry Smallholders Development Authority; SPOC, Sustainable Palm Oil Clusters; TUNAS, Tunjuk Ajar dan Nasihat Sawit.

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sustainable palm oil (CSPO), a palm oil produced by certified-sustainable palm oil stakeholders (Kannan et al., 2021). Importers of palm oil, specifically from the European countries and the United States of America, have enforced to only import palm oil produced from certified sustainable supply chains (Shahida et al., 2019).

The Malaysian Sustainable Palm Oil (MSPO) certification is a certification system made mandatory by the government of Malaysia for the palm oil stakeholders within the country. It promotes sustainable palm oil production by establishing sustainable and responsible global practices as its certification criteria. Palm oil entities within Malaysia are required to follow the sustainable practices underlined by the MSPO certification standards in order to get certified. The MSPO certification scheme is directed toward oil palm plantations, independent smallholders, organized smallholders, palm oil mills and other processing facilities. It aims to certify all palm oil companies in Malaysia by December 2019 (Kumaran, 2019). However, as of May 31, 2020, the Malaysian Palm Oil Board (MPOB) has only reported a low percentage of 24.82% MSPO certification amongst the independent smallholder (ISH) sector, covering only 234,666 ha out of 1,015,524 ha of oil palm land owned by independent smallholders within the country (Malaysian Palm Oil Council, 2020). The lack of initiatives taken to comply with the compulsory certification may be caused by insufficient awareness, lack of understanding among smallholders on the effects of the certification, or unclear economic benefits from the certification process. Therefore, it is important to effectively study the cost and sustainability impacts of the MSPO certification scheme to promote a higher adaptation rate, especially among ISHs.

1.1. Background of Malaysia sustainable palm oil certification scheme

The MSPO certification scheme was established in 2013 to serve as an initiative to certify the palm oil industry in Malaysia. It was initially a voluntary implementation scheme, but was later announced as mandatory by the government in 2017 for palm oil companies to get the certification by December 31, 2019. The MSPO certification process is done through an audit that is performed by an independent third-party Certification Body (Kannan et al., 2021). With MSPO made mandatory nationwide in the palm oil industry, a branding foundation can be formed, where Malaysian palm oil can be labelled with confidence as a sustainable and safe product when marketed globally.

The Malaysian palm oil cultivators are categorized into private-business-owned estates, organised smallholders, independent smallholders, and government-owned plantations. The plantation area distribution as of December 2020 is summarized in Fig. 1. Historically,

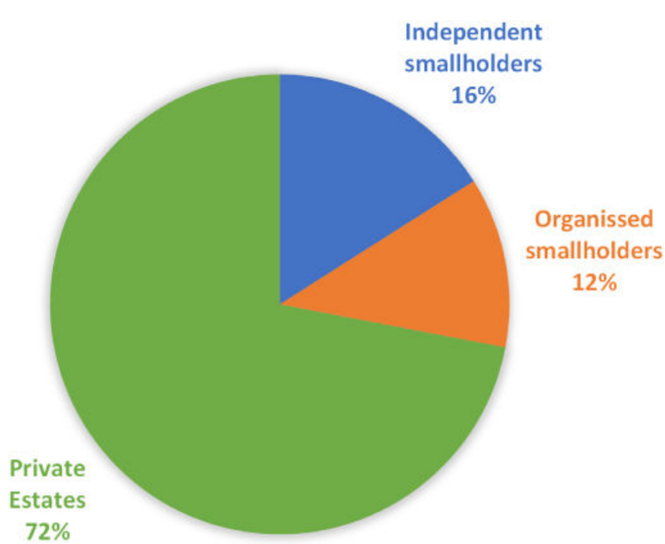

Fig. 1. Oil palm producer land distribution in Malaysia (Hirschmann, 2021).

palm oil smallholders are responsible for up to 40% of Malaysia's total palm oil yield (Senawi et al., 2019), therefore, it is crucial that their production is to be certified to keep up with the increasing demand for certified palm oil for exportation. Uncertified palm oil entities may be penalised, suspended or disallowed from renewing their business licence by MPOB (Shahida et al., 2019). In Malaysia, financial support was given to stakeholders to adapt to the certification in the form of tax deduction, incentive for fertilizer and auditing fees (MPOCC, 2022).

The low number of registrations for the sustainability certification is mainly caused by the high cost of certification incurred to the palm oil entities, on top of the lukewarm demand and sales (Yusof and Yew, 2016). The cost of the certification subscription is approximately 715.99 USD per hectare of land, including the audit fee, membership fees and man-day cost for the audit (Ganeshwaran, 2017). On the contrary, Bursa Malaysia reported a 2% increase in profitability for the firms with certification in a sustainability certification study among 39 palm oil companies (Hafizuddin-Syah et al., 2018). In order to more effectively certify independent smallholders, MPOB has taken the initiative to establish Sustainable Palm Oil Clusters (SPOC) across the country, where ISHs are grouped into numbers of 1000–2000 to allow the smallholders to be certified in a cluster instead of individual certification (Kannan et al., 2021). SPOCs operate within specified plantation boundaries, with the main focus being to produce FFB under the supervision of MPOB (Senawi et al., 2019). Grouping into SPOCs also relieves the high cost of individual MSPO certification, especially for ISHs in Peninsular Malaysia possessing small oil palm plantations at an average area of 2.3 ha (Kannan et al., 2017b). In view that the low MSPO adaptation is caused by the ISHs among the oil palm farmers, the subsequent sections would only focus on the sustainability and economic evaluation of the ISHs palm oil cultivation.

1.2. Independent smallholders in Malaysia and their shortcomings

Palm oil smallholders are entities that possess oil palm lands that are not more than 40.46 ha in area, and can be divided into organised smallholders and independent smallholders (Kannan et al., 2021). ISHs are located in all states of Malaysia, and manage their oil palm production independently without adhering to strict government regimes. Unlike organised smallholders, ISHs do not receive exclusive technical, marketing, processing provision, and financial aid from government agencies like the Federal Land Development Authority (FELDA), Rubber Industry Smallholders Development Authority (RISDA), and Federal Land Consolidation and Rehabilitation Authority (FELCRA) (Rahman, 2020). Instead, they are assisted through an extension service established by MPOB, known as *Tunjuk Ajar dan Nasihat Sawit* (TUNAS). TUNAS provides assistance to improve FFB production for smallholders that are grouped into the SPOCs. However, the availability of this extension service for the huge number of independent smallholders is at a ratio of 1:1500, making it challenging to provide assistance to every smallholder (Kannan et al., 2021).

Studies have shown concerns about ISHs having diverse levels of agricultural management, such as palm oil productivity, yield management, and pest and disease control (Khatun et al., 2017). This has attributed to the vulnerability of these smallholders towards fluctuations in crude palm oil and fertilizer prices, pest and disease occurrences, and environmental changes, among other factors. The vulnerability of the smallholder groups is also attributed to insufficient knowledge of proper farm maintenance, as well as a lack of financial support (Hidayat et al., 2015).

1.3. Palm oil cultivation process and its sustainability assessment

The palm oil cultivation process can be sectioned into five stages, including the nursery, land preparation, palm planting, plant maintenance, and fruit harvesting. In the oil palm nursery, palm oil pre-germinated seedlings are grown in polyethylene bags for 12–15 months while being provided with 1.5–2.5 L of water every day. Fertilizers, fungicides, and pesticides are applied in adequate amounts for crop protection (Schmidt, 2007). At the same time, the agricultural land is prepared by the removal of vegetation via machinery and the decomposition of residual biomass, which will involve CO_2 emissions. The soil will be ploughed and covered with *Mucuna bracteata* legume in advance to prevent soil erosion and nitrogen fixation.

The seedlings are then transferred to the field for planting. The immature palm tree will bear its first fruits in two to three years and continue for another 20–25 years. Potassium chloride, ammonium sulfate, magnesium sulfate monohydrate, and phosphorite are commonly used as fertilizers (Zulkifli et al., 2010), while other fertilizer blends of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and boron (B) are also used (Rodrigues et al., 2014). The palms are maintained by applying herbicides and pesticides to clear the weeds and for bagworm control. The use of insecticide is minimal in matured palms. After 25–30 years, the oil palm tree is felled and chipped to be left to decompose within 2 years. It is then replanted to keep up with the decreasing yield of old palm trees (Schmidt and De Rosa, 2019a). The freshly harvested FFB from the oil palm plantation gets transported immediately to the palm oil processing mill as free fatty acid (FFA) content can build up in the fruit once harvested. Typical transport vehicles used are lorries and tractors with tippers (Ashrad et al., 2017).

Upon the understanding of the palm oil cultivation process, a systematic approach is required to assess the sustainability of the process and to evaluate the performance of the MSPO certification. To the best of the authors' knowledge, there is no available literature to evaluate and compare the sustainability impacts of certified and non-certified MSPO among the ISHs. In this work, Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) were used to assess the impacts of the MSPO certification on the ISHs from the environmental and economic aspects, respectively. The analyses can benefit palm oil stakeholders by highlighting the potential impacts of implementing MSPO through a comparative analysis between non-certified (pre-MSPO) and certified (post-MSPO) fresh fruit bunch (FFB) cultivation by ISHs. In addition, stakeholders and decision makers are able to evaluate the sustainability of certified palm oil production based on the assessment results, and utilize them as a reference point for future studies (Omran et al., 2021). It would also help government agencies for policy drafting, and ISHs to have an improved understanding of the differences and potential benefits of getting certified as an MSPO practitioner.

2. Methodology

Following sections discuss the methodology and scope of LCA and LCC used in this work to compare the impact of MSPO certification.

2.1. Life cycle assessment (LCA)

The life cycle assessment is a tool that can be applied to a product or a process to evaluate quantitatively its environmental impacts in a life cycle manner. It follows the standards of the International Organization for Standardization (ISO), ISO 14040:2006 and ISO 14044:2006 and is widely used as a sustainability assessment method to identify the environmental impacts of a product or process throughout its entire life cycle, therefore facilitating the effectiveness in the management and optimization of the environmental quality of a system (Subramaniam et al., 2010). The assessment tool is essentially executed through the evaluation of the inputs and outputs of a system boundary defined by the user (Heijungs and Guinee, 2012) and is usually performed using LCA software. It evaluates the environmental impacts linked to the different stages of a product or process from cradle (resource extraction) to grave (disposal) in the system boundary. An LCA study is divided into four phases: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and life cycle interpretation (Schmidt and De Rosa, 2019a). The goal and scope definition of the current study will be discussed in Subsection 2.1.1, whereas the LCI, LCIA and life cycle interpretation will be illustrated in Subsections 2.1.2, 2.1.3, and 3.1, respectively.

This study focuses on a cradle-to-gate LCA case study carried out on the palm oil production line, where only the processes at the palm oil cultivation stage by ISHs were considered. The study was focused on the cultivation stage only to highlight the sustainability impact due to the low adaptation rate of the MSPO scheme as stated above. A LCA was performed on an uncertified ISHs system and a MSPO-certified ISHs system in order to compare the environmental impacts of both systems and evaluate the effects of implementing MSPO certification.

2.1.1. Goal and scope definition

The goal of the current study is to evaluate the differences in the impacts on the environment between MSPO-certified and non-certified palm oil ISHs using the LCA approach. As discussed in Subsection 1.1, the main reason of the low MSPO registration rates is from the ISH sector; therefore, the current study is adapting the cradle-to-gate concept to focus the evaluation on the independent smallholder sector only. The functional unit was defined as 1 tonne of FFB produced from a plantation site by ISHs. The boundary system was limited to the oil palm cultivation by smallholders, which consists of two stages; growing of seedlings at the nursery, and the planting and harvesting of FFB in the palm oil field. The system also included the transport of FFBs to palm oil dealers by the smallholders. This paper would assess and compare the pre- and post-MSPO certification for ISHs in terms of life cycle inventory (LCI), life cycle impact assessment (LCIA), and life cycle costing (LCC) using an attributional modelling approach.

2.1.2. Life cycle inventory (LCI)

The life cycle inventory is described as the total exchange of natural elements between the boundary systems in the techno-sphere and the eco-sphere. The determination of a life cycle inventory requires the identification and quantification of the materials, including resources, products, or wastes, that enter and leave the boundary. Capital goods such as building structures and equipment were left out of the inventory as they have no significant environmental impacts as reported by other studies (Chee et al., 2021).

Fig. 2 illustrates the system boundary to be applied in the case study, divided into a foreground and a background system. The foreground system consists of the ISH activities, which are palm oil cultivation and transport of FFB products. The material flow for FFB production includes palm oil seedling, fertilizer, pesticide and weedicide, diesel, land use change, and water; while the output material flows from the foreground system are the FFB product and emissions to air, water, and soil (Silalertruksa et al., 2012). As most palm oil smallholders do not practise farm record-keeping, the foreground system primary data was scarce (Kannan et al., 2017a). Therefore, the main data used in the LCA were secondary data retrieved from various scientific publications, government websites, and data gaps filled with assumptions. Whereas, the background production systems were computed using existing data from LCA databases (Schmidt and De Rosa, 2019b). The main reference used to obtain the inventory data of the FFB production in uncertified and MSPO-certified ISHs for the case study was based on Ashrad et al. (2020), summarized in Table 1. The average land holding area of the 257 respondents who are ISHs from several states across Malaysia is 3.94 ha. The material input data from the reference case study (which is based on 1 ha of land) was then converted to obtain values that are based on the functional unit of 1 tonne of FFB produced.

Table 2 summarises the material flow used in the case study of MSPO-certified and uncertified ISHs. The case study considered inorganic fertilizer as the default option for both groups of ISHs. The inorganic fertilizer formulation is a ratio of nitrogen, phosphorus, potassium and magnesium of 12:17:10:3 (Rodrigues et al., 2014). The effect of using organic fertilizer will be discussed in Section 3.2. Under the MSPO certification scheme, stakeholders are to avoid the use of high

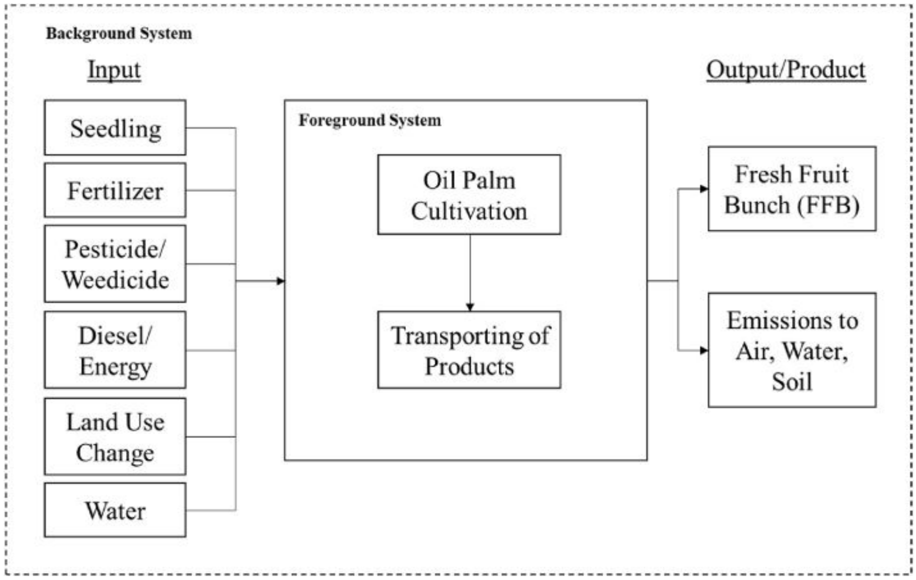

Fig. 2. System boundary for LCA of ISHs.

Table 1
Material flow data for life cycle inventory based on 1 ha planted area.

Parameter	Uncertified ISHs	MSPO-Certified ISHs	Reference
Average Fertilizer Used (kg/palm)	4.18	6.53	Ashrad et al. (2020)
Average Weedicide Used (L)	6.96	8.83	Ashrad et al. (2020)
Average Distance from Plantation to Palm Oil Dealer (km)	5.77	5.77	Kannan et al. (2017a)
Average FFB Yield (t/y)	17.88	21.24	Ashrad et al. (2020)

Table 2
Material flow data for life cycle inventory based on 1 tonne FFB produced.

Flow Type	Material	Uncertified ISHs	MSPO-Certified ISHs	Reference(s)
Input	Average Fertilizer Used (kg/t FFB)	33.196	43.656	Ashrad et al. (2020)
	N Component	9.485	12.473	
	P Component	13.436	17.670	
	K Component	7.904	10.394	
	$MgSO_4$	2.371	3.118	
	Average Weedicide Used (L/t FFB)	27.42	34.79	Ashrad et al. (2020)
	Diesel (kg/t FFB)	0.0824		Ashrad et al. (2017)
	Land Use Change (ha)	3.94	0 (Continued Land Use)	Ashrad et al. (2020)
	Carbon Dioxide from Fixation (kg/t of FFB)	2200	1850	Rodrigues et al. (2014)
	Water Usage for nursery and plantation (m^3/t FFB)	35.03		Sabli et al. (2020)
	Average Seedling	0.26		Ashrad et al. (2017)
Output	Average FFB Yield (t)	1.00		Ashrad et al. (2020)
	GHG Emissions (kg CO_{2eq}/t FFB)	1016.77	1038.98	Rodrigues et al. (2014)

biodiversity value land. Currently, there is no detailed record on the land use change by ISHs in Malaysia. The proposed case study assumed that land use changes were applied to uncertified ISHs based on the average plantation size of ISH, while continued land use was applied by MSPO-certified ISHs which is enforced by the MSPO Standards. It was also assumed that only mineral soil was used (peat conversion impacts were not included), and the expansion of plantation size was not included in the comparison. The average plant density on a typical oil palm plantation was found to be 142 trees per hectare (Zulkifli et al., 2010). According to Rodrigues et al. (2014), carbon dioxide fixation in palm oil plantations is at a calculated average of 197 tCO_2/ha of palm oil trees, over a basis of 25 years. By assuming that the fixation amount is evenly distributed across the entire palm oil cycle and with the consideration of the differences in production yield, the sequestration levels in palm oil cultivation for non-certified ISH and certified ISH are estimated to be at 2.20 tCO_2/tFFB and 1.85 tCO_2/tFFB, respectively. Note that the difference in carbon fixation between certified and non-certified ISH was based on the variation of FFB yield. The fate of other carbon sources was assumed to be identical as MSPO does not mandate biomass management at the time of study. The supply of water is only considered for manual irrigation water sources and excludes the water from rain feed, and the values are suggested by Sabli et al. (2020). The production of polyethylene bags used to contain the seedlings in the nursery stage was factored into the background system. The seedling polyethylene bags were assumed to be reused again in the nursery after the seedlings are planted in the field, and therefore, not consumed in the production system.

The greenhouse gas (GHG) emissions from the foreground FFB production system are outputs that are sourced from diesel consumption for transportation of FFB, land preparation, fertilizer consumption, and biomass decomposition of chipped trunks. The GHG emissions of the background systems are indirectly computed using the LCA software database. The carbon dioxide emission from diesel consumption was calculated using a basis of 0.12 $kgCO_2$/km (Ecoscore, 2022), and the pollutant emissions, which constitute 1% of the exhaust gas composition were assumed to be negligible (Resitoglu and Altinisik, 2015). The average distance from the plantation to palm oil dealers recorded by Kannan et al. (2017a) is 5.77 km. A 16-tonne lorry was recommended to be the land transport vehicle, and as the delivery of harvested FFB to palm oil dealers is a round-trip with the vehicle loaded only for half the trip, a load factor of 50% was used when calculating the amount of diesel used for FFB transport (Ashrad et al., 2017). Land preparation as a result of biomass decomposition emits 6 t CO_{2eq}/ha (Rodrigues et al., 2014). GHG emission from fertilization is expected to be 4.96 kg CO_{2eq}/kg for N fertilizer, 1.35 kg CO_{2eq}/kg for P_2O_5 fertilizer, 0.58 kg CO_{2eq}/kg for K_2O fertilizer (Kazlauskas et al., 2021), and 0.30 kg CO_{2eq}/kg for $MgSO_4$ fertilizer (Winnipeg, 2022).

OpenLCA was used to perform the LCA for this study due to the various databases available and manuals available for users without monetary charges. Among the available LCA databases by openLCA, the AGRIBALYSE v3.0.1 database was preferred as it focuses on the agriculture and food sectors, comprising inventories for 2500 products. The database permits the user to assign the materials from either a production-based or consumption-based approach (openLCA Nexus, 2021). The LCI data summarized in Table 2 was then utilized as inputs in the openLCA software.

2.1.3. Life cycle impact assessment (LCIA)

The current study implements ReCiPe 2016 Endpoint (H) as the life cycle impact assessment method. The ReCiPe method is a combination of the Eco-Indicator and CML methods, and is versatile as it allows for both midpoint-based and endpoint-based assessments. An endpoint-based impact assessment was used in this case study as the main goal was to determine the impacts or outcomes resulted from the FFB production in the two different systems. ReCiPe also gives users the choice to select the assessment perspectives based on the level of uncertainty of the data. ReCiPe (H) was selected over its alternatives (E) and (I) since the *hierarchist* (H) perspective is based on the most commonly used policy principles, and strikes a balance between the *individualist* (I) perspective that is based on optimism and the *egalitarian* (E) perspective that is pessimistic-based (Goedkoop et al., 2013). The full list of midpoint impact categories of the LCIA method is given in Table 3.

Table 3
Impact categories of ReCiPe 2016) Endpoint (H) in openLCA.

Endpoint Impact Category	Midpoint Impact Category	Reference Unit (Huijbregts et al., 2017)
Human Health	Fine particulate matter formation Global warming, Human health Human carcinogenic toxicity Human non-carcinogenic toxicity Ionizing radiation Ozone formation, Human health Stratospheric ozone depletion Water consumption, Human health	DALY[a]
Ecosystem Quality	Freshwater ecotoxicity Freshwater eutrophication Global warming, Freshwater ecosystems Global warming, Terrestrial ecosystems Land use Marine ecotoxicity Marine eutrophication Ozone formation, Terrestrial ecosystems Terrestrial acidification Terrestrial ecotoxicity Water consumption, Aquatic ecosystems Water consumption, Terrestrial ecosystem	species.yr[b]
Resources	Fossil resource scarcity Mineral resource scarcity	USD2013[c]

[a] Disability Adjusted Life Years; Years that are lost due to diseases or accident.
[b] Local Species Loss in Terrestrial, Freshwater, and Marine Ecosystems.
[c] US Dollars Based on Year 2013; Extra costs incurred for future mineral and fossil resource extraction.

These impact categories can be further categorized into three endpoint impact categories: human health, ecosystem quality, and resources. The midpoint categories are useful in interpreting the potential contributors to the endpoint category results during the interpretation stage of the LCA analysis.

2.2. Life cycle costing (LCC)

Similar to the LCA methodology, LCC is considered an accounting method that assesses the life cycle of a product or service, but from the economic point of view which follows ISO 15686:2008 (Corti et al., 2019). It evaluates the cost-effectiveness and economic viability of a system over its economic lifetime (Norris, 2001). Unlike LCA which analyses material flow, LCC takes the flow of cash and revenue entering and leaving a user-defined boundary system of a process, including the development costs, utility or service costs, and recycling or reprocessing costs. The LCC can be approached via the same methodology applied to an LCA study, including the goal and scope definitions, and the choice of the functional unit used (Van Ostaeyen et al., 2013). Apart from being able to assess the difference between the cost contributions of the two systems, LCC analysis in this study also considers the Net Present Value (NPV) and Payback Period (PP), which are useful financial indicators for comparative assessments. The NPV considers the total net cash flow of the system across the study period and applies an annual discount rate to more accurately gauge the cash flows of the future periods in the present time (Svatoňová et al., 2015). The positive value of NPV would signify the total profit across the study period of the system. The PP value indicates the amount of time, usually in years, that is required for the system to achieve its initial investment worth.

This work has performed a comparative LCC assessment on an uncertified ISH and a MSPO-certified ISH system. The goal of the LCC was to determine the differences in the inventory cost data between the two systems and evaluate the economic impacts of the MSPO certification on ISHs. The literature case study executed by Ashrad et al. (2020) was used as the main reference for cost data and as the base case to perform LCC, with a study land area of 3.94 ha for both uncertified and MSPO-certified ISH systems. In this case study, all of the production costs and revenue enclosed within the cradle-to-gate boundary system (Fig. 2) were taken as the main data for analysis. In other words, the costs of the life cycle inventory of uncertified ISHs and certified ISHs were used as the economic assessment data. The foreground system cash flow was considered while the background system materials, such as the cost of producing fertilizers, were not taken into account. The cost categories used for LCC are the initial investment costs, operational costs, maintenance costs, and disposal or end-of-life costs (Omran et al., 2021). The economic data gathered was converted into annual costs in order to perform the two financial appraisal analyses, NPV and PP, which are commonly used in LCC methodologies as financial performance indicators (Omran et al., 2021). These indicators were calculated based on the cash flow of the system, which in-turn was calculated from the revenue and costs on an annual time-step (Svatoňová et al., 2015).

Equation (1) shows the calculation for the cash flow, CF_t based on the revenue, R_t, capital cost, C_t and operating cost, T_t at operating year, t; and Equation (2) shows the net present value, NPV based on CF_t and discounted rate, r (Svatoňová et al., 2015). In this case, the annual revenue and costs were estimated based on the duration of the typical life cycle of an oil palm, which is usually 25 years ($t = 25$), from seedling to old and poor-yielding palm that is felled or cut down (Zulkifli et al., 2010). The annual discount rate used in the case study is 5%. Equation (3) shows the payback period, PP which is expressed as the total capital cost, C_t divided by the net annual cash flow, CF_t, signifies the amount of time, t (in years) that is needed to recover the initial investment cost and generate net profit (Javed, 2021).

$$CF_t = R_t - (C_t + T_t) \tag{1}$$

Table 4
Typical FFB yield for oil palm (Foong et al., 2019).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
FFB Yield (t)	0	0	0	2	7.5	12	17	18	22	25	28	28	28
Year	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
FFB Yield (t)	28	27	26	26	26	26	25	25	24	23	22	21	

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \quad (2)$$

$$PP = \frac{C_t}{CF_t} \quad (3)$$

2.2.1. Cost and revenue data gathering

The cost data are secondary data obtained from several sources, including Ashrad et al. (2020), the main reference used in the environmental LCA. Each of the cost data was converted from MYR to USD based on a conversion rate of 4.19 MYR to 1 USD. The annual FFB revenue was derived using the annual FFB yield that varies across the entire 25-year life cycle of the oil palm. The average FFB yield reported by Ahmad et al. (2019) indicates that the FFB yield from the uncertified ISH system (17.88 t/ha/year) is lower than the FFB yield from the certified ISH system (21.24 t/ha/year) by approximately 15.819%. The typical FFB yield profile of an oil palm for a 25-year life cycle is presented in Table 4 (Foong et al., 2019). By assuming conservatively that the MSPO-certified system follows the typical FFB yield profile, the uncertified counterpart was projected to produce the same yield profile but 15.819% lower in value.

Table 5 summarises the cost data used in this study. The average price of FFB was retrieved from the MPOB website based on the period between January and June 2021 at 10.21 USD per 1% Oil Extraction Rate (OER). The average OER of FFB across Malaysia from the same period is given at 19.78% (Malaysian Palm Oil Board, 2021a). This yields a price of 210.96 USD/t FFB for the certified FFB. The price of uncertified FFB, however, is quoted to be 7% less than certified FFB (Shahida et al., 2019), thus having a price of 187.79 USD/t FFB. The FFB revenue can then be calculated for each year for the entire life cycle. It was assumed that the first three years of the cycle are the growth period of the palm oil into mature palm oil, therefore no fruit can be harvested. The cost of fertilizers, cost of weedicide, fertilizer quantity, and weedicide quantity before and after MSPO were collected from 257 ISHs through interviews. The average cost of palm oil seedlings for single- and double-stage nurseries was reported to be 3.10 USD per seedling (Ahmad et al., 2019). Other costs associated with the foreground system include the cost of water and transportation. The cost of water was divided into premature palm (nursery, year 1–3) and mature palm (on field, year 4–25), also excluding the amount of water sourced from rainwater. The cost of transportation was obtained by determining the amount of diesel fuel and the price of diesel which is 0.51 USD/L. Due to data scarcity, only the initial investment (or capital) cost, operational cost, and maintenance cost were taken into account. Data that are excluded from the study include the cost of land and cost of labour, by assuming that the piece of land is wholly owned by the smallholder and that the labour requirement is fulfilled by the smallholders themselves. The revenue was computed with the assumption that all of the produced FFB was sold.

In Table 5, several additional MSPO certification costs were added to the cost pool under the ‘maintenance costs’ cost category for the certified palm oil smallholders, including the certification audit fees, annual surveillance fee, and training costs. These costs vary according to the number of ISHs placed under the SPOC, as more man-days are required for the auditing of a SPOC that contains a larger number of smallholders. Certified ISHs are required to pay for training fees prior to MSPO audits, which is 8.35 USD (35 MYR) per ISH. The MSPO certification includes an audit process that is carried out by MSPO certification bodies to verify the FFB production standards. The audit is divided into two stages, each bearing an audit fee. The Stage-1 audit is carried out first, followed by the Stage-2 audit that will be carried out six months later. The MSPO certificate has a validity of 5 years and requires recertification once the validity period ends. An annual surveillance audit fee is also applicable to certified ISHs. The certification audit fee and surveillance audit fee are based on the working man-days required to conduct the audits, which depends on the number of smallholders in the SPOC group. The fee is usually divided by the number of smallholders in that SPOC group. These certification costs were provided by MPOB and were summarized in Table 6. The certification costs given are based on a SPOC group containing 500 ISHs, and an auditor team of 2 auditors. Each auditing man-day costs approximately 358 USD (1500 MYR) and additional charges for the accommodation and transportation fees of the auditors are also taken into account. However, through the aid of the government, MPOB is currently able to provide financial support to fully cover the certification fees, training, chemical racks and personal protection equipment (PPE) to the smallholders towards obtaining MSPO certification. Therefore, it is assumed that no certification cost is borne by the certified ISHs in this study.

Table 5
Life cycle costing data for 3.94 ha uncertified and MSPO-certified ISHs.

		Units	Uncertified ISH	Certified ISH	Source
Price of FFB		USD/t	187.79	210.96	(Malaysian Palm Oil Board, 2021b; Shahida et al., 2019)
FFB yield		t/y	Refer to Table 4		Foong et al. (2019)
Capital cost	Land	USD	13,632.40	13,632.40	Svatoňová et al. (2015)
Operation costs	Fertilizer	USD/y	2005.67	2599.92	Ashrad et al. (2020)
	Weedicide	USD/y	859.75	180.17	Ashrad et al. (2020)
	Seedling	USD	56.83	67.51	Ahmad et al. (2019)
	Diesel	USD/y	7.09	8.42	Ashrad et al. (2020)
	Water	USD/y			(Sabli et al., 2020; Toriman and Mohktar, 2012)
	Pre-mature		113.40	134.72	
	Mature		475.57	564.94	
Maintenance costs	Certification fees (Stage 1 and 2 Audits)	USD/ISH/5 y	–	(16.95; Waived)	Provided by MPOB in 2021
	Surveillance fees	USD/ISH/y	–	(12.08; Waived)	Provided by MPOB in 2021
	MSPO training fees	USD/ISH	–	(8.35; Waived)	Provided by MPOB in 2021

Table 6
Certification audit fee per ISH based on SPOC with 500 ISHs.

	Unit	Certification Audit	Surveillance Audit
Number of auditors	persons	2	
Number of ISH in SPOC	ISH/SPOC	500	
Audit cost	USD/day	358.00	
Accommodation	USD/day	47.73	
Audit Cost			
Stage 1	day	6	12
Stage 2	day	12	–
Stakeholder consultation	day	1	1
Total	day	19	13
	USD	6801.91	4653.94
Additional Cost			
Accommodation for 2 auditors	day	20 (10 days/auditor)	14 (7 days/auditor)
	USD	954.65	668.26
Transportation	USD	715.99	715.99
Total cost	USD	8472.55	6038.19
Cost per ISH	USD/ISH	16.95	12.08

3. Results and discussion

Sections below discuss the main findings from the comparison of MSPO certification using the proposed LCA approach.

3.1. LCIA and life cycle interpretation for uncertified and MSPO-certified system

Figs. 3 and 4 illustrate the comparative life cycle impact assessment (LCIA) results between an uncertified ISH system and a MSPO-certified ISH system from the endpoint impact category and midpoint impact category, respectively. The results represent the extent of negative impacts on the environment in each category, where a higher value signifies a more harmful emission from the system into the environment. The results were compared on a logarithmic scale as large differences in the magnitude of the computed discrete data were indicated. When viewed from the endpoint impacts (Fig. 4), the MSPO-certified ISH system has reduced effects on all three categories (Human Health, Ecosystem Quality, and Resources) than the uncertified ISH system, inferring that the MSPO-certified system is the more sustainable alternative overall. The most significant impacts are from the Resources category, followed by the Human Health, and lastly the Ecosystem Quality category. The endpoint impacts also indicate 99.913%, 99.958%, and 90.223% reductions in the Human Health, Ecosystem Quality, and Resources categories, respectively, of an ISH system with MSPO-certified. This suggests that MSPO certification would result in a net positive improvement in the environmental aspect of the FFB production system when MSPO is implemented and MSPO practices are in place.

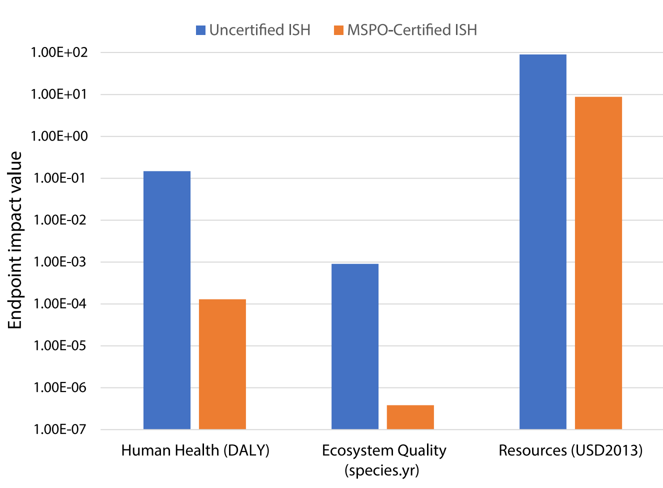

Fig. 3. Comparative LCIA results for uncertified and MSPO-certified ISHs system using endpoint impact category.

Fig. 4 indicates the detailed breakdown of the LCIA results from the midpoint impact categories extracted from the LCA database calculation. The midpoint impact categories that are most significant are the Fossil Resource Scarcity category, followed by the Mineral Resources Scarcity category, both contributing to the Resources endpoint impact category. This finding is in line with that reported by Subramaniam et al. (2010), where the fossil fuel impact category has the highest weighted score. Although the use of N-type fertilizers can lead to the release of nitrous oxide gases, which cause damage to human health by causing respiratory diseases, and are also a huge contributor to global warming (Norfaradila et al., 2014), the impact assessment results of the two systems show insignificant impact values in the Global Warming category when compared with the Fossil and Mineral Resource Scarcity impact categories.

For the uncertified ISH system, the high value of 87.95 USD2013 in the Fossil Resource Scarcity impact category is mainly attributed to the diesel consumed in machinery in the background system for i) land use change or forest clearing during perennial crop cultivation (83.04 USD2013 or 94.419%) and for ii) the production of mineral fertilizers (4.78 USD2013 or 5.435%). The certified ISH system, on the other hand, results in a lower Fossil Resource Scarcity impact (6.42 USD2013) than that of the uncertified system, as MSPO certified ISH does not practice deforestation under the MSPO Standards and deploys continued land use. In turn, the production of mineral fertilizers in the background system has contributed 97.881% of the Fossil Resource Scarcity impacts for the certified ISH system. The diesel burned in the transport lorry in the foreground system has contributed to the Resources category only 0.052% for the uncertified system and 0.711% for the MSPO-certified system, which are relatively insignificant when compared to the background contributors. This explains why the uncertified system has a higher environmental impact in the Fossil Resource Scarcity category than the certified system even though both systems consume equal amounts of diesel for the transportation of 1 tonne of FFB in the foreground system.

Similarly, the main contributing factor to the Mineral Resource Scarcity midpoint environmental impact is the manufacturing of mineral fertilizers in uncertified ISHs (1.801 USD2013 or 89.625%) and certified ISHs (2.369 USD2013 or 99.827%), where the highest contributor is from K_2O fertilizer production. This can be explained by the fact that the commercial potassium mineral fertilizers used in the case study are sourced from the extraction of minerals in the form of potash ores from underground (Yager, 2016), which can potentially cause mineral scarcity. The latter of the two systems sees a higher impact on the Mineral Resource Scarcity (18.065% increment) due to the use of higher volumes of mineral fertilizer, as per MSPO Standards (Ashrad et al., 2020).

Apart from the Mineral Resource Scarcity category, the remaining midpoint categories have experienced reduced environmental impacts when MSPO practices were adopted, indicating its effectiveness in achieving sustainability in those midpoint categories. In order to allow for quantitative comparisons, the percentage reduction in the impact category results was calculated and reproduced graphically in Fig. 5. It shows that other than the Mineral Resource Scarcity impact category which has an increment of 18.065%, the post-MSPO system observes reductions between 10.116% and 99.996% in value in all environmental impact categories as compared to the pre-MSPO system. This difference is a result of continued land use change and the higher FFB yield from certified oil palm cultivation in MSPO-certified smallholders, which in turn leads to a lower resource requirement to produce per tonne of FFB.

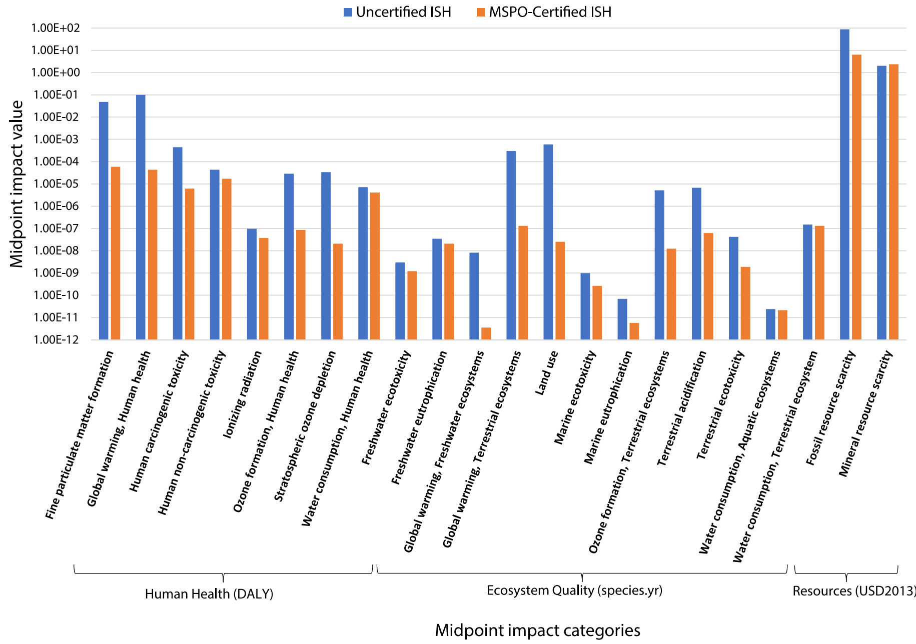

Fig. 4. Comparative LCIA results for uncertified and MSPO-certified ISH system using midpoint impact category.

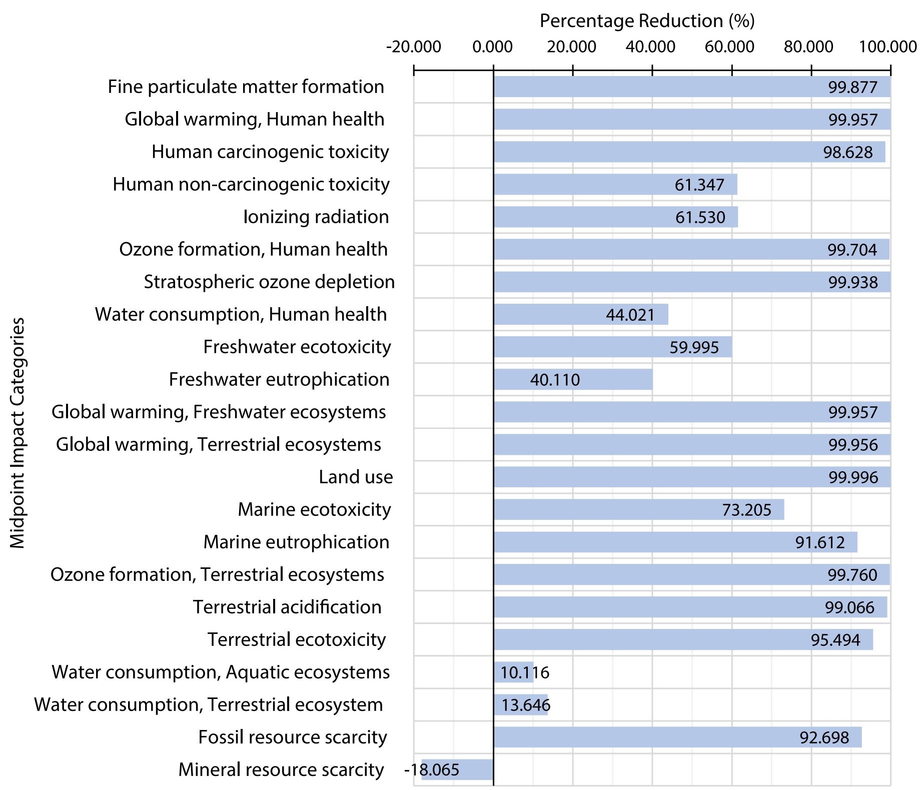

Fig. 5. Percentage reduction in midpoint impact categories after MSPO implementation in ISHs.

3.2. Impact of organic fertilizer in LCIA and life cycle interpretation

Based on the results shown in the previous section, the high usage of inorganic fertilizer to fulfil the MSPO standard is the sole negative impact. This section extends the LCIA and life cycle interpretation to a MSPO-certified system with 100% usage of organic fertilizer to investigate potential improvement of a MSPO-certified system. The use of organic fertilizer that is made of compost or green waste to substitute mineral fertilizers used in palm oil cultivation is suggested in order to overcome the issue of increased mineral resource scarcity in a post-MSPO ISH system. Substituting mineral fertilizers with composts such as palm oil mill by-products can reduce the mineral doses required in palm oil plantations by 43% for potassium, 9% for phosphorus, 85% for nitrogen and 100% for magnesium (Ferreira et al., 1998). The yield of EFB generation is assumed to be unchanged to account for the worst-case scenario. The use of organic fertilizers also allows the reduction of emissions produced by the fertilization production process and the diesel consumption in machinery, thus altogether decreasing the environmental impacts of FFB cultivation.

Fig. 6 compares the LCIA results between an uncertified ISH system and a certified system with organic fertilizers. From the endpoint categories, the MSPO-certified ISH system with organic fertilization exhibits reduced environmental impacts post-MSPO of 99.998% in Human Health, 99.987% in Ecosystem Quality, and 99.844% in Resources, respectively. These environmental improvements are more pronounced than those produced by the certified ISH system that applies inorganic fertilizers, suggesting that an organic fertilization system is a more environmentally sustainable approach. All midpoint impact categories indicate a drop in negative environmental impact when compared to the uncertified system. This is due to the reason that the resources including water, fuel, electricity, and raw mineral materials required and the emissions in the manufacture of mineral fertilizers are omitted and reduced when replaced with organic fertilizers. The impact on Mineral Resource Scarcity has been reduced from the original 2.01 USD2013 in the uncertified system to 0.004 USD2013, signifying a 99.796% decrease due to organic fertilization. This overcomes the issue of MSPO-certified ISH system having increased scarcity in mineral resources as a result of increased fertilizer application, producing a system that provides improvement in all environmental aspects.

3.3. Comparison of LCC for uncertified and MSPO-certified system

Table 7 presents the total cost of each cost contributor, NPV and PP for both uncertified and certified systems with 3.94 ha of land over a 25-year study period. The results show that independent smallholders with MSPO certification have approximately 7% higher total cost (134,774.04 USD) than those without MSPO certification (125,889.74 USD), with the fertilizer costs, water costs, and capital costs being the major contributors to the total cost in both systems. Fertilizer costs occupy the largest fraction of the total cost in both systems, with percentages of 39.830% (50141.65 USD) in uncertified ISHs and 48.227% (64,998.02 USD) in MSPO-certified ISHs. This is attributed to the frequent and high quantity of fertilizer application throughout the oil palm life cycle. The total cost of fertilizers has seen an increase after the system is MSPO-certified, due to the reason that the frequency and amount of fertilizer application have increased through MSPO practices. In addition, the use of higher-quality fertilizers in the certified system, which are pricier, has also led to an increase in fertilizer costs. Water costs incurred are 10,802.69 USD (8.581%) in uncertified ISH systems and 12,832.73 USD (9.522%) in certified systems, respectively. The moderately high cost of water has resulted from the high water consumption that is required to assimilate inorganic fertilizer pollutants in the cultivation stage (Sabli et al., 2020), which has corresponded to the elevated water costs. Since the water volume is dependent on the FFB yield, the water cost has increased post-certification as the yield of FFB is higher than pre-certification. Meanwhile, the capital costs in both systems are equivalent, as equal land areas of 3.94 ha were considered. The costs of diesel as fuel are also relatively low, at only 0.124% and 0.138% of the total cost of each system, which may be due to the small land holding area of ISHs that require shorter distances to be travelled by the transportation vehicle. Meanwhile, the costs of seedling and weedicide are also low in both systems as seedling is a one-off activity and weedicides are used minimally in the cultivation of oil palms.

The NPV values were calculated using a 5% discount rate for a study period of 25 years has increased from 91,017.84 USD before MSPO to 127,092.56 USD post-MSPO, which is equivalent to a 39.635% increment. This signifies a higher total profitability for independent smallholders who adopt MSPO. This outcome is explained by the higher FFB yields under the practice of MSPO guidelines, with about 18.79% more yield on average. Furthermore, certified FFB is more widely accepted by palm oil mills and is valued at a higher selling price than uncertified FFB, around 7% difference (Shahida et al., 2019). As the ISH system with

Table 7
Total cost profile, net present value and payback period of FFB production in uncertified and MSPO-certified ISHs.

Cost impact category	Uncertified ISH		Certified ISH	
	USD	(%)	USD	(%)
Capital cost	13,632.40	18.02	13,632.40	14.17
Water	10,802.69	14.28	12,832.73	13.34
Seedling	56.83	0.08	67.51	0.07
Weedicide	859.73	1.14	4504.18	4.68
Fertilizer	50,141.65	66.28	64,998.02	67.55
Fuel/Diesel	156.01	0.21	185.33	0.19
Total cost	125,889.74	100.00	134,774.04	100.00
Total FFB revenue	286,333.62		384,675.90	
NPV (USD)	91,017.84		127,092.56	
PP (years)	7.95		7.51	

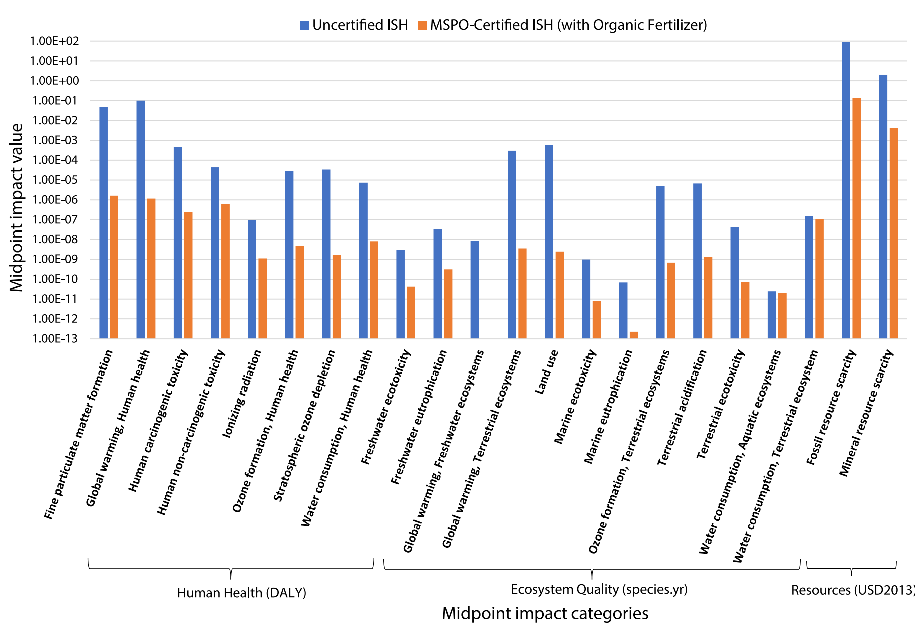

Fig. 6. Comparative LCIA results for uncertified and MSPO-certified ISHs system with organic fertilizer using midpoint impact category.

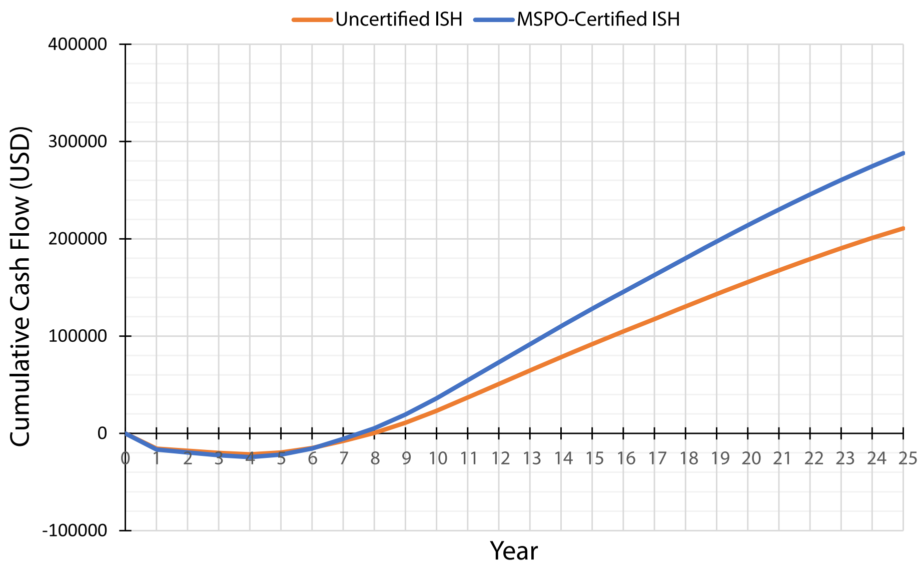

Fig. 7. Cash flow curve of comparative LCC in uncertified and MSPO-certified ISHs systems.

MSPO certification has a higher NPV, the payback period is expected to be shorter than that of the uncertified system.

The cash flow curve in Fig. 7 illustrates the cash flow trend of the two systems throughout the 25-year study period. Both trend lines have negative gradients from the 1st to 4th year, indicating that the net cash flow is negative and that the annual cost exceeds the revenue. This is because both systems bear capital and operating costs, and the palms are unable to provide fruit in the first three years due to prematurity. Year 4 also exhibits a negative cash flow because of its low initial FFB yield, which cannot generate sufficient revenue to cover the annual costs. The palm matures further and starts producing more FFB to generate enough revenue to cover the operating costs, turning the trendline to a positive gradient from the fifth year. The trend continues until both systems break-even after 7.51 years and 7.95 years, also known as the payback period. The cash flow curve of certified ISHs is predominantly higher than the curve for non-certified ISHs since mid-sixth-year, due to having higher NPV or economic profitability. Both trendlines do not show linear cash flow growth as the annual revenues follow a FFB yield profile. The trendline gradient increases from the 4th year as the young palm slowly matures and increases its annual FFB yield until it reaches its maximum yield in the 10th year. The gradient is then maintained between years 10th and 13th as the fully matured palm stabilizes its FFB production yield. This is followed by a decreasing gradient between 13th - 25th year due to the slow ageing of the oil palm, which causes its FFB yield and annual revenue to decrease.

3.4. *Cost impact of MSPO certification, organic fertilizer and economic potential*

The economic results discussed in the previous section were based on the current scenario where MSPO certification costs were subsidised using MSPO funds provided by the Malaysian government. In the case where the MSPO certification cost funding is lifted by the government, the MSPO-certified smallholders will need to bear the certification costs, which will affect the profitability of the system. If the certification costs (in Table 6) are factored into the LCC calculation, the total NPV value for an MSPO-certified ISH will decrease from 127,092.56 USD (39.635% profitability) to 126,861.87 USD (39.381% profitability), which translates to a 0.24% decrease in overall profitability. Correspondingly, the payback period increases only slightly from 7.51 years to 7.53 years. It shows that the certification costs do not substantially impact the profitability of ISHs as the costs are significantly lower than the annual costs of the other inputs.

According to the comparative LCA results, the application of inorganic mineral fertilizers can lead to an increase in negative environmental impact in the Mineral Resources Scarcity midpoint impact category after ISHs get MSPO-certified due to the increased fertilizer volume required. The substitution of the commercially used mineral fertilizer with organic fertilizer was investigated and has shown to reduce these impacts and improve the system and is thus encouraged. The average cost of organic fertilizer is reported to be 1.19 USD/kg (Noordin, 2020), which is 67.785% costlier than the price of mineral fertilizer used in the default LCC study at 0.72 USD/kg. The NPV of the MSPO-certified system is reduced by 19.515% from 127,092.56 USD to 102,290.74 USD, and the payback period lengthens from 7.51 years to 8.29 years from the fertilizer transition. The net profitability of implementing organic fertilizers may have been reduced, but these extra costs can be outweighed by its environmentally sustainable benefit in the long run. However, it is worth noting that utilization of organic fertilizer is not mandated in the MSPO certification scheme.

In terms of the economic potential of the MSPO certification scheme, the economic impacts can be viewed on a national supply chain scale. From this study, the revenue from a 3.94 ha MSPO-certified ISH system is approximately 384,675.90 USD for a 25-year cycle, normalising to approximately 3905.34 USD/ha.y. Using a similar estimation approach, an uncertified ISH system would rake in 2906.94 USD/ha.y. This results in a situation where every uncertified hectare of land would result in a revenue loss of 998.40 USD/y. As of year 2021, the percentage area of MSPO certification in independent smallholders has reached about 62.649% (MPOB Trace, 2021), which covers 540,890.54 ha of the 863, 360.00 ha of land owned by the ISH sector. Therefore, the hypothetical revenue lost or the lost chances resulting from the fraction of uncertified ISHs in Malaysia every year can be estimated at 32,193,567.30 USD, which is detrimental to the financial aspect of the independent smallholder FFB supply chain. It is worth noting that the hypothetical revenue lost is subjected to the success of selling the uncertified FFBs. The revenue lost would be more significant considering all uncertified FFBs are not able to be part of the trading system.

4. Conclusions

A comparative life cycle assessment (LCA) was performed on an uncertified ISHs system and an MSPO-certified ISHs system to investigate the environmental impacts of the MSPO certification. The life cycle results show an overall decline in the environmental impacts from the Human Health (99.913%), Ecosystem Quality (99.958%), and Resources

(90.223%) categories when the ISH system is MSPO-certified, suggesting that certified palm oil cultivation is more sustainable than uncertified cultivation. Meanwhile, the substitution of mineral fertilizers with organic fertilizers can further reduce the environmental impacts of palm oil cultivation, which are 99.998%, 99.987%, and 99.844% in the human health, ecosystem quality, and resources categories, respectively. The economic impacts resulted from the implementation of MSPO were also investigated using LCC, which shows that although the MSPO certification has led to a higher overall cost than the uncertified system, its increased FFB yield is able to compensate and moreover, generate higher profits in the long run. This was evident as the NPV of the certified ISH system was approximately 39% higher than that of the uncertified ISH system. In conclusion, the implementation of MSPO certification in ISHs would bring about improvements in both the environmental and economic aspects, and should be recommended among independent smallholders to allow for the improved sustainability of palm oil production, and at the same time ensure a continuous supply of certified FFB within the country from the smallholders. This paper also demonstrated a quantifiable approach to MSPO certification impact using LCA tool. It can be used by ISHs and government agencies as one of the monitoring tools for sustainability improvement and for policy drafting to support and encourage MSPO certification.

Nevertheless, this study has incorporated several assumptions in the LCA inventory input due to the lack of detailed recording of differences in operation between MSPO-certified and non-certified ISHs. The result could be revised and verified in the future once ISHs adopt systematic data recording tools. Besides, the current study has only assessed the impacts of MSPO from the environmental and economic viewpoints. An improvement that can be considered in future work includes the conduct of a social LCA study, in addition to the economic and environmental perspectives presented in this study. This triple-bottom-line assessment approach is also known as the life cycle sustainability assessment (LCSA), which feasibly enables decision-makers to identify environmental, economic, and social hotspots that can be improved. Furthermore, the current research has mainly focused on evaluating the effects of MSPO certification on independent smallholders in Malaysia. Extending the scope of the research to other downstream palm oil processes can help in gauging the impacts of MSPO implementation on the palm oil supply chain in Malaysia more comprehensively, thereby providing the opportunity to encourage downstream palm oil stakeholders (such as palm oil mills and palm oil processing facilities) to obtain MSPO certification willingly.

CRediT authorship contribution statement

Chia Hoi Bok: Writing – original draft, Formal analysis, Software, Methodology. **Chun Hsion Lim:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration. **Sue Lin Ngan:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Bing Shen How:** Conceptualization, Writing – review & editing. **Wendy Pei Qin Ng:** Conceptualization, Writing – review & editing. **Hon Loong Lam:** Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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