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ORIGINAL PAPER

Environmental sustainability practices among palm oil millers

Halima Begum[1] · A. S. A. Ferdous Alam[2] · A. C. Er[1] · Ahmad Bashawir Abdul Ghani[2]

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Abstract

Considering the global palm oil production, it can be identified as the second largest vegetable oil. Palm oil is a natural resource that is favorable for the Malaysian climate. In 2017, Malaysia had a total of 454 palm oil mills with a production capacity of approximately 112 million tonnes of fresh fruit bunches. A sustainable environment denotes high income, value addition and zero waste. Nonetheless, palm oil mills are being associated with the discharge of untreated effluent water stream pollution, solid wastes, air pollution, etc. The important objective of this study is to measure the level of sustainable environmental practices parameters and awareness of millers. The primary data were collected through questionnaire survey and interviews from 71 millers in Malaysia. This study used confirmatory factor analysis to describe the relationships between the environmental parameters for measuring environment sustainability. This study found that most of the millers employ positive practices for environmental sustainability, and the highest environment parameter is disposal of solid wastes. However, this study can be implemented in Malaysian palm oil mills for identifying the lowest parameters. This study suggested to the industries that the new national sustainable policies for palm oil mills, especially for small and medium players, may enhance the environmental parameters.

Keywords Environmental sustainability · Palm oil millers · Fresh fruit bunch · Sustainable production · SEM · Peninsular Malaysia

Introduction

It is substantiated that the milling sector is one of the important sectors for earning income in the oil palm industry (Begum et al. 2019), and this sector has been generating profits for the past decades (MPOB 2001, 2011, 2016). However, the sector is divided into three segments such as upstream, midstream and downstream sectors (Sime Darby 2009) in order to perform the operation shown in Fig. 1. The major players in each segment are directly involved in the palm oil production such as growers or planters, millers, refiners, processors, manufacturers, retailers, etc. (Teoh 2000). However, in Fig. 1, the upstream process is to involve with cultivation for producing Fresh Fruit Bunches (FFB). The midstream sector such as the palm oil mill is also known as palm oil manufacturing mills under the midstream sector which mainly processes the oil palm Fresh Fruit Bunches (FFBs) to produce crude palm oil (CPO) from the fibrous mesocarp and crude palm kernel oil (CPKO) from the kernels after receiving the FFB from the smallholders (Wicke et al. 2008; Subramaniam et al. 2010, 2013; Sisbudi et al. 2013). However, the FFB has to be processed in the mill within 24 h as palm fruits consist of a lot of fatty acid enzyme, which would hydrolyze palm oil. Finally, the crude oil is further treated to purify in downstream sector and dry it for storage and export to the market.

Nevertheless, it is asserted by EPU (2010) and Basiron (2007) that given the fast production by the POM, the Malaysian oil palm industry has become one of the largest exporters and the second largest producers of CPO supplying half of the world's production after Indonesia (Basiron and Weng 2004; Basiron 2007; USDA 2016). Besides, next to Indonesia, Malaysia is the world's second largest producer of palm oil. As of 2015, Malaysia (31.67%) and Indonesia (53.33%) both account for 85% of the global palm oil production (MPOB 2016), and the GNI (Gross National Income) of Malaysia indicates that

✉ A. S. A. Ferdous Alam
ferdous@uum.edu.my

[1] Faculty of Social Sciences and Humanities, National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia

[2] School of International Studies, Universiti Utara Malaysia, 06010 UUM Sintok, Kedah, Malaysia

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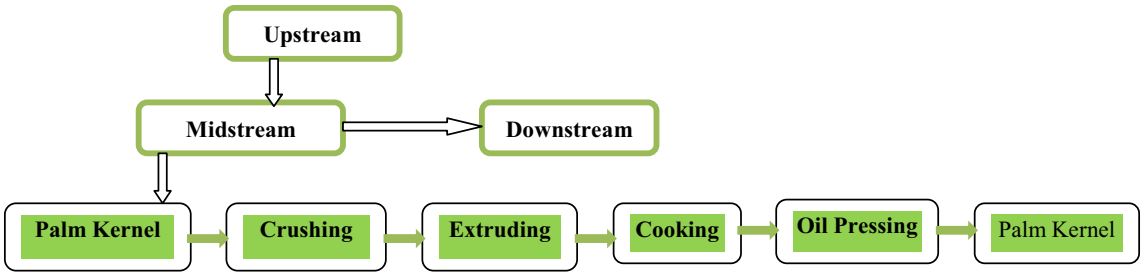

Fig. 1 Crude palm kernel oil pressing production line. *Source*: Authors' adopted from Sime Darby (2009)

the fourth largest contributor to the Malaysian economy is the palm oil industry (EPU 2017).

Moreover, the oil palm industry is opening tremendous potential opportunities in Malaysia to increase the national average through a combination of environmental monitoring and quality control, production efficiencies and societal development through sustainability practices in the new period (Begum et al. 2014a, b, c, 2016, 2018, 2019; Alam et al. 2015, 2016). It is quantified that the country had 19 oleo-chemical plants, 53 refineries, 454 mills and 45 palm kernel crushers, Malaysian Palm Oil Board (MPOB) (see Table 1 for details) and palm oil plantation in almost 5.10 million ha of land area in 2017 (MPOB 2017). Table 1 also shows that according to MPOB (2017), a total of 244 mills are located in Peninsular Malaysia, 130 mills in Sabah and the remaining 80 mills in Sarawak and all these mills have the capacity to produce 112,187,800 tons of palm oil.

However, the market situation has been experiencing a sudden decline since 2014 due to several reasons, for example several recent palm oil statistics show that the production, supply and prices are decreasing (Oil World 2014; MPOB 2014a, b). Figure 2 delineates the yearly yield and increase rate of the palm oil industry from 2005 to 2015, and it demonstrates that the production was decreasing in Malaysia between 2014 and 2015, whereas the CPO production was comparatively high in 2007 (USDA 2017). However, the issue directly affects the economic sustainability performances.

Therefore, the government has undertaken several plans and initiatives to address the concerning issues in this sector (EPU 2017) and issue of sustainability under the long-term concern of the Malaysian Palm Oil Industry (MPOI), in order to enhance their credibility, brand value and images (EPU 2017). Therefore, the practice of sustainability is

Table 1 Number and capacities of palm oil mills in operation as at December 2017 (tonnes/year). *Source*: Din (2017)

Sector	Peninsular Malaysia		Sabah		Sarawak		Malaysia	
	No.	Capacity in operation	No.	Capacity in operation	No.	Capacity in operation	No.	Capacity in operation
FFB Mills	244	56,803,600	130	33,775,200	80	21,609,000	454	112,187,800
PK Crushers	28	4,475,300	13	2,097,200	4	697,200	45	7,269,700
Refineries	35	15,475,200	12	8,738,000	6	3,115,000	53	27,328,200
Oleochemicals	19	2,668,929					19	2,668,929

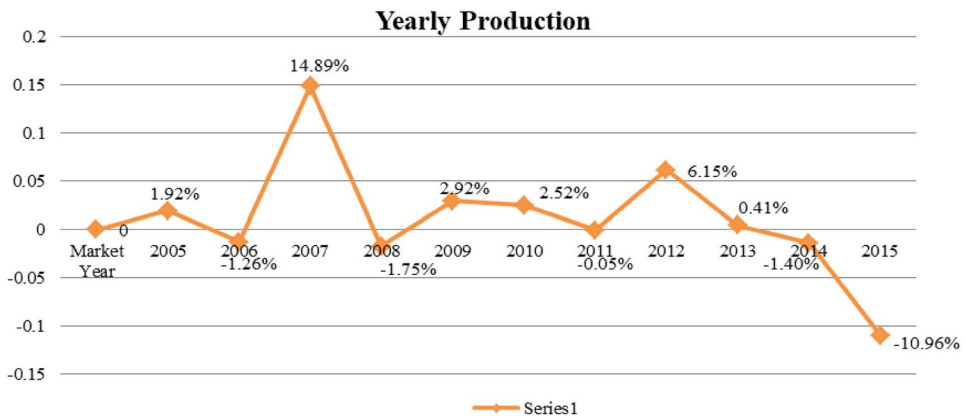

Fig. 2 Yearly production of CPO. *Source*: USDA (2017)

the ultimate goal of the oil palm industry (Palm oil World Online) for long-term environmental conservation, economic growth and social development (Begum et al. 2014c, 2015a, c, 2018; Abazue et al. 2015). Hence, Malaysia is an active member of the Malaysian Sustainable Palm Oil (MSPO) and the Roundtable on Sustainable Palm Oil (RSPO), which are instrumental to the continuous development of independent and supported palm oil millers (Arif and Tengku Mohd Ariff 2001; RSPO 2007; Dompok 2010; MSPO 2014). However, there is a big challenge on how to enhance the production toward sustainability and create awareness of its potential in the global vegetable oil market, consumer demands for certification of products and processes (Guan et al. 2016).

Therefore, Malaysian palm oil mills have had to abide by the standards and principles of RSPO since 2004 (RSPO 2006) to be a certified sustainable palm oil (CSPO) globally and avoid international criticism. Besides, the Malaysian own body led the sustainability policies such as the MSPO which has also imposed a mandatory government-led certification scheme since 2019 toward sustainable oil palm industry (MSPO 2014). However, the assurance of the palm oil sustainability in long terms with continuous trust of consumers and brand value can be ensured along with the improvement and safeguarding of the environment (Abdullah et al. 2017). Hence, ENGOs keep claiming that the production sector of palm oil is highly responsible for creating environmental pollutions (Er 2007, 2011). Moreover, despite the developmental initiative of mills for sustainability, ETP (2009); stated that there are still lacks in research and investment, limited study in the palm oil milling area in Malaysia as the majority of the research is merely focused on the palm oil plantation area. Thus, ongoing research via random sampling may help to embellishment and identify the issues in the sector (Abdullah et al. 2017).

However, in order to address the problem in the palm oil milling sector, it was announced that based on the Environmental Quality (Prescribed Premises) (Crude-Palm Oil) Regulations of 1977, the mills will need to apply for the license from the Department of Environment annually (DOE 1991). Due to the enforcement action taken by this authority, a significant improvement was achieved by the mills. Eventually, the mills drastically reduced their pollution to comply with the regulations in order to avoid their licenses being suspended. For instance, in 1981, the total BOD loads discharged was 58 tons per day, and in 1991, the loads reduced dramatically to 6 tons per day. The compliance rate of palm oil mills following the implementation of the regulation was impressive in the first decade with rates going up to 75% (DOE 1991). In relation to the compliance rate, it was seen that 80% of the mills complied with the regulation from 1991 to 1998 (DOE 1998). Moreover, a few palm oil mills that were found flouting the environmental regulations have been reported in the media and ENGOs.

Table 2 Effluent discharge standards for CPO and CPKO Mills by EQA (1974). *Source*: Ahmad et al. (2003) and Pierzynski et al. (2005)

Units (MG/L)		
Parameters	Concentration limit	Standard limit
pH	4.7	5–9
Oil and grease	4000	50
Biological oxygen demand (BOD)	25,000	100
COD	50,000	–
Total solids	40,500	–
Suspended solids	18,000	400
Total nitrogen	750	150

In 1997, the DOE suspended the licenses of two palm oil mills for not complying with the effluent discharge limits as stipulated in their licenses. The DOE also took 27 palm oil mill operators to court for the same offense (Tan 1999). However, there are rules and regulations for the concentration and standard limits of pH, oil and grease, biological oxygen demand (BOD), COD, total solids, suspended solids and total nitrogen by DOE for effluent discharge standards for CPO mills (Environmental Quality Act 1974, Pierzynski et al. 2005) mentioned in Table 2. However, the unit limits has to follow for controlling emissions during wastages treatment and ponding system methods.

Although some progress has been noted by the implanted policies and inspections by DOE and local authorities, the performance records on the whole show that despite the promulgation of the laws over the last three decades, the issue has remained unresolved despite the attempt to become sustainable palm oil mills (Mohd Rafi 2007). Nonetheless, the issue has not been resolved yet, as it is asserted that palm oil mills create air, water and soil pollution due to their practice of using chemical fertilizers and palm oil milling activities (Danielsen et al. 2009; Tan et al. 2009; McCarthy 2010). Hence, Guan et al. (2016) mentioned that for sustainability, the environmental preservation is a great challenge among palm oil production sector as large production has a definite positive effect on the good environmental practices and awareness of the ecosystem. Therefore, the objective of this study is to measure the level of sustainable environmental practices and awareness with their adopted policies, and methods among surveyed palm oil mills.

Literature review

"Environmental sustainability (ENVS)," in accordance with "Malaysian palm oil manufacturing" is defined as the awareness of ecological conservation for economic escalation and human welfare by the technological advancement and sector

of regulatory policies (Abdullah et al. 2017; Begum et al. 2019). Among three factors of sustainability, the conservation of environment is one of the integral parts to assess sustainability (Er 2007; Begum et al. 2014a, b, 2015a, b). It has been defined by several authors, as asserted by Morelli (2011), as a natural system on human impact, and it is an "ecological subset" (Vivian et al. 2006; Morelli 2011).

More specifically, sustainable manufacturing practices in Malaysia involve several dimensions of environmental conservations with their factors, such as environment legislation compliance with international standard (ISO 14001), green policies (KETTHA), Malaysian standards and regulations, carbon footprint labeling policy, waste management and pollution control with reverse logistic, Life Cycle Assessment (LCA), Green House Gas emissions (GHGE), technological advancement with waste treatment and energy generation (Abdullah et al. 2015b). Previous studies on improving sustainability in palm oil milling have been conducted in the area of environmental impacts of palm oil production (Shirai et al. 2003), renewable energy applications of palm oil (Yusoff 2006), utilization of palm oil waste, wastewater treatment, and sustainable development and practices as detailed in the current research on the POM (Zhang et al. 2019).

To follow the sustainability practices framework, Malaysia's efforts to promote sustainable development have resulted in her being ranked number 38 among 146 countries worldwide (EIA 2005). In addition, a follow-up study in 2006 ranked Malaysia ninth among 133 countries in terms of efforts taken to reduce environmental stress on human health and protecting ecosystem vitality. This example shows that the regulatory measure was the main motivator for the adoption of environmental management practice in the country. Another new development in environmental legislation in Malaysia in this period was the introduction of the Environmental Impact Assessment (EIA) legislation in 1988 (Peter 1998). On the other hand, practicing environmental sustainability is one of the greatest issues in the palm oil sector. Unfortunately, its activities are not without environmental costs (Er 2007).

Moreover, for enhancing sustainability performances, environmental conservations are one of the key issues (Salwa Hanim et al. 2008) and they improve the quality of human life (Salwa Hanim et al. 2017). Undoubtedly, competitive advantages can be gained by sustainable business practices and the implementation of green technologies (Ramayah et al. 2013). Thus, industries create a positive impression for creating further competitive advantages for organizations and boost organizations' status among the society (Mahmood et al. 2014). Thus, it is important to enhance environment sustainability practices in order to gain the production benefits and images (Liyanage 2007), while Malaysian palm oil mills are facing the international criticisms continuously around the globe due to unsustainable green practices (Emily 2018).

Besides, to identify the issue of environmental sustainability practices among palm oil mills in Malaysia, the existing findings revealed that adopted methods during FFB processing for palm oil production by the mills remain controversial, as they created environment pollution and social conflicts (Lim and Biswas 2015, 2018); and undeniably, rapid increase in activities by mills was responsible for environmental pollution (Abdullah et al. 2015a). It was reported that the country's worst source of water pollution in 1975 was by POMs (DOE 1991). Likewise, another milling process is POME by palm oil mill which contains very high organic matter and the method is the most voluminous and environmentally unfriendly (Saifudin and Fazlili 2009). Er (2011) also revealed that independent mills need further developed methods during the discharge of POME for sustainability. Besides, conventional palm oil mills in Malaysia are identified as the largest source of pollution and destruction of natural resources (Vairappan and Yen 2008; Oosterveer 2014) and the mills cause gas emissions due to the waste treatment plant (Abdullah and Sulaiman 2013).

In 2007, Hansen (2007) conducted a feasibility study of performing a Life Cycle Assessment (LCA) on CPO in Malaysia. The result showed that LCA activities created a significant environmental impact due to vast CPO production quantities (Hansen 2007). However, this will allow more industry players to adopt cleaner technology investments in their processing activities (Hansen 2007). However, Chavalparit et al. (2006) asserted that inefficient equipment, defective machinery, leakage (by breakdown or overflow of tanks) may often be the reason for extra oil losses. Besides, there is one important parameter of environmental sustainability among palm oil mills through biodiesel production (Lapola et al. 2010). Additionally, in Malaysia, biofuel or biodiesel has less financial values among the processing mills (Yatim et al. 2017; Greenpeace 2007).

On the other hand, practicing environment sustainability is one of the greatest issues in the palm oil sector (Begum et al. 2015a, b, 2016, 2018). Unfortunately, its activities are not without environmental costs (Er 2007). As with other extractive industries such as logging, rubber, tin and chemical-based agriculture, the Malaysian palm oil industry (MPOI) includes upstream and downstream sectors that are considered environmentally damaging activity in the country (Wong et al. 2009) and it is pressurized by ENGOs due to political interest (Tan et al. 2009). Moreover, another source of air pollution is from greenhouse gas emission (Graboski and McCormick 1998). On the other hand, palm oil is a source of lower emission as has been claimed (Kalam and Masjuki 2002). However, the use of palm oil is also advocated because it is assumed to dramatically reduce

CO_2 emissions (Yusoff 2006). Besides, pollution occurs due to ponding system (Ahmad et al. 2005; Guan et al. 2016).

However, a number of high-profile media and non-government organizations (NGOs) campaign negatively about environmental sustainability. This has led to a close scrutiny of the activities associated with palm oil production and processing (Er 2007). This vigorous campaign to denigrate the palm oil industry is masterminded by NGOs spreading in Australia and European Union's governments, with the aims to pressurize processed food manufacturers and consumers into boycotting palm oil (World Growth 2010). Thus, there is an importance of depth research to embellishment of Malaysian cheapest and valuable green product of palm oil (Begum et al. 2019; Abdullah et al. 2017).

However, this study revealed that environment driving forces are highly relevant in realizing sustainability, but a lesser amount of research has been published in this area. This indicates that there is still a large gap to be bridged. Therefore, researches should address and focus more on environment sustainability practices and its determining factors in the palm oil milling sector like other manufacturing factories in Malaysia. At present, there is only one exploratory study with limited data through an online survey that examined the relationship between current achievements and the levels of priority placed on their practices to compare the implemented environment-sustainable manufacturing practices among POMs in Malaysia. Hence, the aim of this study is to identify the environmental impact of the palm oil mills toward sustainability, and to identify the approaches and mechanisms for mitigating the environmental risks associated with the palm oil industry.

Research methodology

Study area and population

The aim of this study was to examine the environment sustainability practices of Malaysian palm oil mills for measuring sustainability. The data for this study were taken to reflect the current manager of the mills. Therefore, the palm oil mills were chosen for the survey through questionnaire in December, 2014. The interviewers conducted the interviews with the persons who were the operational heads of the mills, for example Managers, Assistant Managers, Executives, Engineers, etc. as well as the persons responsible for the sustainability decision for their mills. This study used primary data collected from Malaysia such as Sabah and Sarawak State and Peninsular Malaysia. The data collected through a questionnaire survey and interviews with 71 out of 123 were found completed with useful information and were accepted for further analysis. However, the targeted populations reviewed from the previous study of Er (2011).

Questionnaire development

This study adopted questionnaire as the main instrument for data collection to conduct survey, and survey is the best method which can cover large population and ensure a more accurate sample size to gather data from other than focus group discussion. The questionnaire for this study was developed based on comprehensive review of past relevant studies. The entire questionnaire was divided into four sections A, B, C and D. Section "C" contains the environment sustainability practices by palm oil millers in Malaysia. In order to measure these variables, several items were adapted from the most relevant studies. Several studies noted that the sustainability concept has been used too extensively and that the concept should be "reclaimed" (Santillo 2007), but indicators, limited to environmental impacts, are not sufficient in the analysis of palm oil mills. However, the research methodology was also mainly adopted from other studies related to sustainability manufacturing practices and survey questionnaires were developed considering Malaysian palm oil environment sustainability context from the existing studies of such as Er (2007), Vinodh and Joy (2012) and Begum et al. (2014a, b, c, 2015a). Section "A" considered the socio-demographic variables of the respondents such as age, sex, education and economic position and production capacity. These variables were adopted from the survey questionnaire of Danielsen et al. (2009) and Er (2007). The overall survey instrument had undergone pre-test in an effort to purify and refine the pilot survey instrument for further field survey.

Sampling technique and data collection

The data of this study used a five-point Likert scale that ranged from "Low Extent (1)" to "High Extent (5)." The data used in this study were collected through a questionnaire survey, and interviews with 71 were found completed with useful information and were accepted for further analysis. The remaining 52 out of 123 distributed questionnaires, which had incomplete answers, were excluded from the analysis. The "Cluster Sampling technique" was used to collect samples. The survey was conducted during "4 December to 6 December" 2014 at the time of the annual seminar of palm oil milers which was organized by Malaysian palm oil council (MPOC). This study chose cluster sampling technique because it confirms that each subgroup within the population obtains proper representation within the sample. The palm oil millers are Malaysian citizens mainly. Moreover, data were obtained in the form of questionnaires that were distributed and completed through personal interviews. Target respondents were the palm oil millers engaged in palm oil mills, and at the same time, a special attention was given by the MPOB to increase the environment sustainability in this area.

Statistical analysis

Analysis of environmental issues was derived from data analysis undertaken through IBM SPSS statistical software in order to calculate the missing data, data reliability and frequency distribution. This study also used Confirmatory Factor Analysis (CFA) with Analysis of a Moment Structures (AMOS) to identify the Cronbach's alpha (CA) that describes the relationships between the environmental factors, i.e., national policy, waste management, protected ecosystem, environmental pollution, environmental conservation and safety and welfare of the environment. CFA was carried out in explorative, clustering groupings-related variables into dimensions for environment sustainability programs and practices at Malaysian Palm Oil Mills (POM). The Kaiser–Meyer–Olkin (KMO) test by SPSS assesses sampling adequacy and evaluates the correlations among variables (Urban and Naidoo 2012). The reliability construct is independent and calculated separately from other constructs. However, it is very important to assess data reliability for the diagnosed CFA.

Variables of the study

The sustainability of the palm oil mills is mainly defined by the combination of environment and social and economic aspects (Abdullah et al. 2015b). In this study, the environmental aspects were discussed only because of its significance for palm oil processing mills. However, Fig. 3 illustrates the observed variables of the study to assess the LV of environment sustainability practices. The environment sustainability driver generally consists of certifications certified by CSPO and committed to the RSPO (RSPO 2007), modern technology (Mohd-Lair et al. 2012), international, national, state and local policies implications (Er 2007). They also include waste management treatment and disposal (Chin et al. 2013), environmental auditing by Department of Environment (DOE) and Environment Management System (Er 2007), Environment and Quality Act (EQA 1974), international and national training participation, Green House Gas Emission and Pollution Control Activity (GHGP) (Winroth et al. 2016), internal budget for environment training, environment awareness for community welfare and Green Manufacturing Practices (GMP) (Er 2007). Those variables will assess for diagnosis of CFA in order to identify the relation between LV (environment sustainability) and observed variables (X_1, X_2, X_3…X_{15}).

Results

Reliability test

The collected data were analyzed for this study. The internal consistency and reliability of the pilot survey were tested using the Cronbach's α-reliability test as in Ogunbiyi et al.

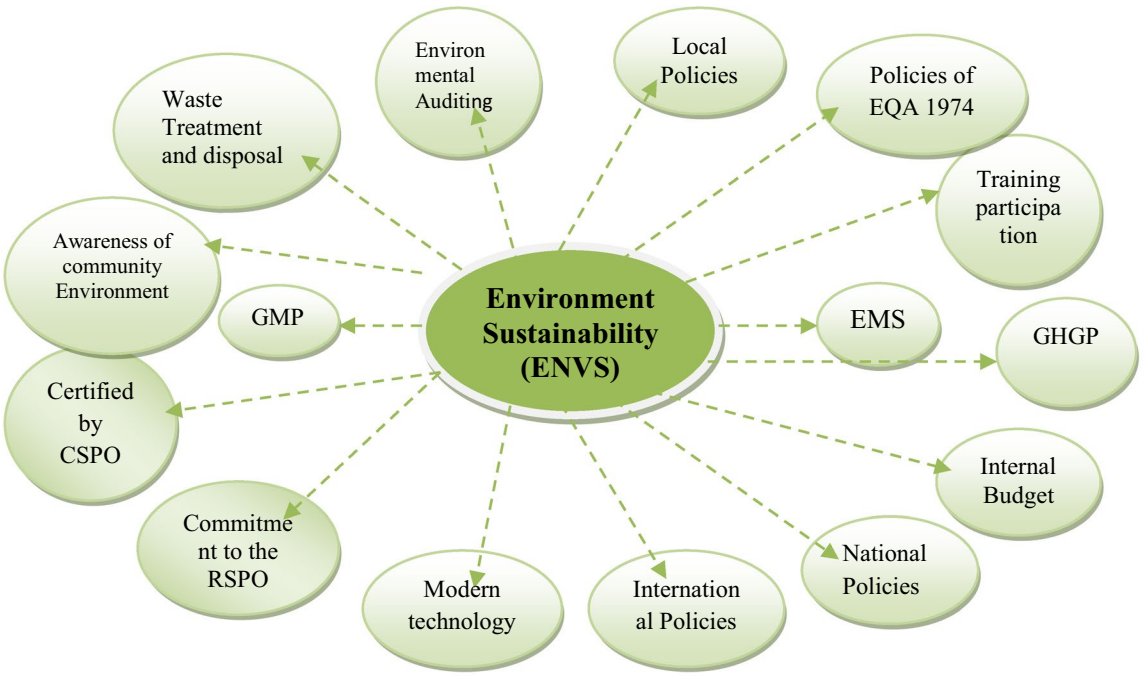

Fig. 3 Research framework of this study. *Source*: Adopted from Er (2007), Singh et al. (2012), Abdullah et al. (2015a, b), Lim et al. (2015) and Lim and Biswas (2015)

(2014). According to Gliem and Gliem (2003), an α-value of less than 0.6 is considered to be poor, and one in the range of 0.7 is considered to be acceptable and any one above 0.8 is reckoned to be good. However, the reliability of data was 0.819 with 71 sample sizes which was good and acceptable (Table 3). Besides, the growth rates by primary survey of latent variables (LVs) are given as follows:

Demographic profile of the respondents

During 2013, a total of 434 palm oil mills existed in whole Malaysia (MPOB 2014b). Most of the Palm oil mills are established in Pahang state according to the previous statistics of MPOB 2014. The respondents such as mangers and assistant mangers of POM are from different states in Peninsular Malaysia such as Selangor, Pahang, Perak, Negeri Sembilan—Port Dickson, Malacca and Kedah. The majority of the respondents were from Pahang areas. The demographic background of the respondents shows the percentages of the respondents (Millers) according to their age, sex, education and economic position. About 55.6% of the respondents are aged between 25 and 44 years old mainly. Undeniably, majority of the executive positions are held by males (91.7%), whereas few are females (8.3%). Moreover, majority of the respondents (48.6%) completed their degree levels. Most of the respondents have service lengths of more than 10 years. The past study revealed that the person who are minimum 2 years of experiences considered as maturity period of experiences in order to get reliable information about a company (Dustmann and Meghir 2005). Besides, the studied palm oil mills hired staff with workers below 200 (51.4%) in order to perform their operations.

Table 3 Reliability analyses of 71 sample sizes

Reliability Statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.819	0.819	71

own calculation

The frequency distribution of sustainable environment

The frequency distribution of the palm oil miller's level of practices for environmental sustainability is described in Table 4. Regarding the section on "Certified by CSPO O (X_1)," 71.9% of the respondents indicated that they follow the regulation to be certified by CSPO "very frequently." About 38% of the respondents agree that the mills frequently use "modern technology (X_3)." Most of the respondents (77.5%) agree that the mills maintain a "level of compliance (X_4)," such as adequate "facilities of disposal wastage (X_5)" and "treatment and disposal of effluent (X_6)," wherein 78.8% and 69% of the respondents indicated "agree," respectively.

About 70.4%, 71.8%, 77.4%, 77.4% and 54.9% of the respondents indicated that they implement "environmental auditing (X_7)," "EMS (X_8)," "EQA 1974 (X_9)," "local policies (X_{10})" and "Environmental awareness training participation (X_{11})," respectively. About 66.2% of the respondents mentioned that they have controlled "greenhouse gas emission and pollution (X_{12}) by adopting environment policies and technological advancement" regularly. About 47.9%

Table 4 Factors of sustainable environmental issues of palm oil industries. *Source*: Primary Survey data of "December 2014"

Environmental issues	1	2	3	4	5	Mean	SD
Certified by CSPO (X_1)	3 (4.2)	0 (0)	17 (23.9)	20 (28.2)	31 (43.7)	4.07	1.033
Commitment to the RSPO (X_2)	1 (1.4)	1 (1.4)	34 (47.9)	9 (12.7)	26 (36.6)	3.82	1.004
Modern technology (X_3)	6 (8.5)	1 (1.4)	37 (52.1)	14 (19.7)	13 (18.3)	3.38	1.074
International policies (X_4)	0 (0)	1 (1.4)	15 (21.1)	30 (42.3)	25 (35.2)	4.11	0.785
National policies (X_5)	0 (0)	0 (0)	15 (21.1)	28 (39.4)	28 (39.4)	4.18	0.762
Treatment and disposal of effluent (X_6)	5 (7.0)	1 (1.4)	16 (22.5)	26 (36.6)	23 (32.4)	3.86	1.112
Environmental auditing (X_7)	2 (2.8)	2 (2.8)	17 (23.9)	27 (38.0)	23 (32.4)	3.92	1.066
Environmental management system (EMS) (X_8)	2 (2.8)	3 (4.2)	15 (21.1)	25 (35.2)	26 (36.6)	3.96	1.101
EQA, 1974 (X_9)	1 (1.4)	1 (1.4)	14 (19.7)	29 (40.8)	26 (36.6)	4.01	1.089
Local policies (X_{10})	6 (8.5)	2 (2.8)	7 (9.8)	29 (40.8)	26 (36.6)	3.87	1.340
Training participation (X_{11})	1 (1.4)	6 (8.5)	25 (35.2)	22 (31.0)	17 (23.9)	3.55	1.228
GHGP (X_{12})	2 (2.8)	6 (8.5)	16 (22.5)	17 (23.9)	30 (42.3)	3.77	1.436
Internal budget for environmental training (X_{13})	0 (0)	4 (5.6)	33 (46.5)	22 (31.0)	12 (16.9)	3.21	1.473
Awareness of community environment (X_{14})	0 (0)	4 (5.6)	19 (26.8)	32 (45.1)	16 (22.5)	3.46	1.538
GMP (X_{15})	6 (8.5)	4 (5.6)	16 (22.6)	31 (43.7)	14 (19.7)	3.31	1.564

1 = not at all, 2 = hardly, 3 = moderate, 4 = frequently, 5 = very frequently; percentage in the parenthesis

of the respondents indicated that they had "Internal budget for environmental training (X_{13})", and 67.6% "concerned of awareness of community environment (X_{14})." "Majority of the respondents (63.4%) agree that sustainable mills practice GMP to be environmentally sustainable (X_{15})." However, there is a national scheme in Malaysia issued by the RSPO in 2010 called the Malaysia National Interpretation Working Group (MY-NIWG), which is reviewed periodically. Scheme managers should ensure that their organized mills are aware of environmental issues and they comply with the relevant legal requirements (MY-NIWG 2010). About 49.3% indicated that they have "Commitment to the RSPO (X_2)" to maintain the national policies for the environment. Majority of the respondents observe a considerable improvement in terms of environmentally friendly operations practices over the last decades compared with the earlier years of the industry in the country.

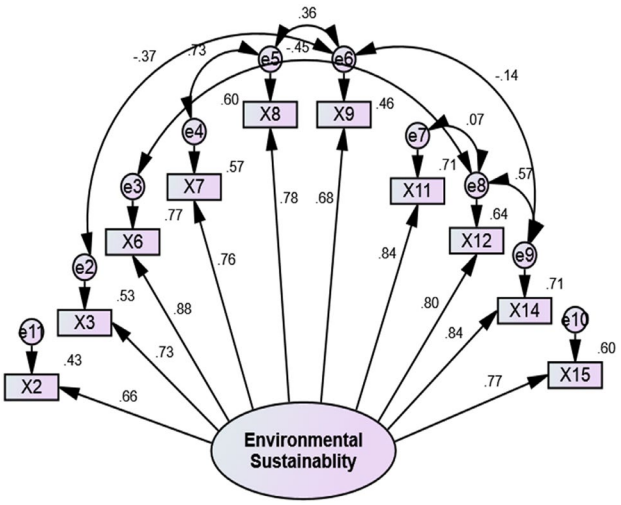

Fig. 4 Confirmatory factor analysis (CFA) for measuring sustainable environment

Confirmatory factor analysis (CFA)

The CFA model was used to examine the hypothesized relationships between the constructs (factors) in the model (Fig. 4). A relatively insignificant result was found about the implementation of the criteria and principles of the RSPO, but institutional and individual documents are lacking (Diana and Riantri 2014). There is a lack of knowledge and practice in sustainable palm oil plantation management. Such a condition is influenced by the size of the palm oil industry and by the participation in farmer groups. The present study was developed from previous studies. The findings of the present study indicate a positive significant relationship between the palm oil industry and its sustainable environmental factors.

Convergent validity test results included coefficient and variance estimates between factors and variable loadings on the factors for each variable (Table 5). Among the environmental latent variables, this study found that the path coefficient of the "waste treatment and disposal of effluent" obtained the highest value (0.88), followed by "awareness of community environment" (0.84), "environmental awareness training participation" (0.84), "GHGP" (0.80), "environmental management" (0.78), "good manufacturing practices (GMP)" (0.77), "environmental auditing" (0.76), "modern technology" (0.73), "policies of EQA 1974" (0.68) and "commitment to the RSPO" (0.66). However, X_1 = Certified Sustainable Palm oil (CSPO), X_4 = International Policies, X_5 = National Policies, X_{10} = Local Policies and X_{13} = Internal Budget for Environmental Training have been deleted due to lower and negative values.

Table 5 Output summary of the confirmatory factor analysis (CFA)

Latent variables	Observed variables	Correlation (coefficient)	Effect (variance)
Sustainable environment	X_2 = commitment to the RSPO	0.66	*0.43*
	X_3 = modern technology	*0.73*	*0.53*
	X_6 = treatment and disposal of effluent	*0.88*	*0.77*
	X_7 = environmental auditing by DOE	*0.76*	*0.57*
	X_8 = EMS	*0.78*	*0.60*
	X_9 = Policies of EQA 1974	0.68	*0.46*
	X_{11} = Environmental awareness training participation	*0.84*	0.71
	X_{12} = GHGP	*0.80*	0.64
	X_{14} = Awareness of community environment	*0.84*	0.71
	X_{15} = Green manufacturing practices(GMP)	*0.77*	0.60

The path coefficient > 0.6 consider significant

Diagnostic tests of CFA

To determine the goodness fit of the model, several types of indicators and conditions were tested. Cronbach's alpha is used to determine the reliability of the environmental factors. The latent variable in this model have high Cronbach's alpha values for the environment at 0.949. Therefore, the reliability level for the attitude toward the environment meets the critical value of 0.7, as suggested by Nunnally and Bernstein (1994).

Discussion

This study had given more importance on the level of ranking of environment sustainability practices parameters of Malaysian palm oil mills through CFA. The findings of the study suggest that out of the three main standpoints that drive Malaysian palm oil mills for sustainability are based on environmental consciousness. The study found that most mills are unable to be certified by CSPO. The dissimilar Yusoff (2006) studies examined that most Malaysian POMs are CSPO-certified, and Malaysian POMs are more certified than those of Indonesia and other countries. Besides, the POMs in Malaysia cannot adopt fully the international, national policies and local policies for environment conservations during processing due to stringent policies and bureaucratic barriers. Thus, there are lots of improvements essential for the policies and regulations through the depth research while considering employees and local communities as respondents. The similar findings are asserted by Winroth et al. (2016) that the stringent policies created impediments for following environmental sustainable policies. More surprisingly, the current study reported allocation of fewer internal budgets for environmental training among the employees. However, there is a dissimilar study by Abdullah et al. (2017). The study also examined that the wastages treatment by empty fruit bunches (EFB) and the managing effluent from that disposal were given as one of the highest priorities for achieving environment sustainability among Malaysian palm oil mills. The study was parallel to the findings of Lapola et al. (2010); Er (2011). They added that independent POMs discharge treated palm oil mill effluent in accordance with environmental parameters. As a result, biomass energy from solid wastes became potential and profitable sources of renewable energy in Malaysia (Yatim et al. 2017; Yiin et al. 2018).

However, the wastages need more careful treatment to decrease the environment pollutions though this is of the highest priority among studies Malaysian palm oil mills. Lim and Biswas (2018) also identified similar findings as asserted that it needs lots of improvement till for wastages treatments. More, another similar study asserted that composting is considered as one of the sustainable ways to minimize the waste as well as preventing pollution into the mills (Yaser et al. 2007). Secondly, it is also highlighted that creating environmental awareness through training and community environment by studied palm oil mills also generated positive environment sustainability. The parallel study examined that environment awareness training (Mohd Rafi 2007) and awareness of community environment (Abdullah et al. 2017) added that awareness can boost the environment sustainability among oil palm processing industry. Fan et al. (2014) examined that the sustainable operations for health and safety of employees are found in environmental management. The third ranking level of environment parameter for sustainability is greenhouse gas emission and pollution control activity by POMs in Malaysia, and it is one of the issues of environment conservations. As, the previous studies discussed that another source of air pollution is from greenhouse gas emission dramatically reduce CO_2 emissions (Graboski and McCormick 1998; Yusoff 2006), on the other hand, palm oil a lower emission has been claimed (Kalam and Masjuki 2002). The fourth level is fulfilling the requirements of environmental management system (EMS). As it is, the POMs in Malaysia are given medium importance because of strict policies. The fifth level of environment parameter is Green Manufacturing Practices (GMP) for environment sustainability of palm oil mills. The study found that there is a less concern to practice to produce green product. However, the existing studies revealed that consumers are boycotting CPO because of unsustainable practices and ENGOs keep claiming to boycott palm oil (Tan et al. 2009). The sixth environment parameter for sustainable environment is environmental reporting and auditing by DOE. The study revealed that DOE reported that there is still pollution creation by downstream activities among POMs in Malaysia. There is a similar finding by Alam et al. (2015) and Tan (1999). There is a less use of modern technology rather than conventional technology for producing CPO and CPKO. Therefore, it needs large investment to process with modern technology. However, the similar study opined that defective machinery and inefficient equipment are responsible for CPO losses and pollution during the processing as claimed by Chavalparit et al. (2006). For the policies of sustainable environment conservations, there is less priority of practices of EQA 1974 though the introduction of the Environmental Impact Assessment (EIA) legislation in 1988 (EQA 1974; Peter 1998) was started in this period. Nonetheless, the lowest ranking is fulfilling the requirements by RSPO. Large scale of POMs is only able to follow the principles and compliances by RSPO though it is an expensive method to be certified by RSPO. The parallel Brandi et al. (2012) study asserted that RSPO method is quite expensive and cost oriented. Besides, pollution occurs also due to ponding system (Ahmad et al. 2005; Guan et al. 2016). However,

the previous studies asserted that there are some rules and regulations for the treatment of POME which needs to be fulfilled (Chavalparit et al. 2006) and DOE highly inspected the Malaysian palm oil mills for creating environment awareness (Begum et al. 2019).

Conclusion

By considering environmental consciousness, fundamentals of laws, regulations and policy compliance, waste management and pollution control, and advance machinery about palm oil mill perceived a very encouraging field toward sustainability. However, the large numbers of millers have adequate knowledge and focus on environmental conservations. Thus, a small group of millers are still unaware of sustainable environmental concerns of palm oil milling practices. There is a great impact on waste treatment for environmental conservation while it also creates less pollution during processing activity. It creates renewable energy, too. However, during processes wastage needs more careful treatment still, to decrease the environment pollutions. Nonetheless, the international, national as well as local policies should restructure for the palm oil millers, especially RSPO method was suggested to be less cost oriented. Besides, more investment is needed to introduce modern technology at each and every palm oil mill for more environment sustainability. However, due to defects machinery is creating the losses of CPO production. Specialized programs related to sustainable palm oil should be developed through long-term environmental and development planning. Hence, the management enhances the operational knowledge through green manufacturing practices and introduces guidelines for workers environmental consciousness. As a result, the community will not pollute via air and water pollutions. Moving toward environmentally sustainable practices offers no threats to business procedures but more benefits achieved. Subsequently, environmental consciousness parameters can influence the greening images, branding, etc. Moreover, employers participating in environment training can expect reduction in fatalities, injuries and illnesses for creating environment awareness. Nevertheless, a few studies investigated the importance and applicability of environment sustainability toward sustainability performances among the Malaysian palm oil mills. Hence, this study can be one of the academic contributions. Besides, methodology and variables were newly validated for the data analysis in the palm oil milling sector which were adopted from other environment sustainability manufacturing studies. Therefore, the questionnaire was developed for the primary survey. However, this study can be implemented in Malaysian POMs for identifying the lowest parameters for giving importance with the highest parameters also. It is recommended to study that the new national sustainable policies for palm oil mills, especially for small and medium players, may enhance the environmental parameters.

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References

Abazue CM, Er AC, Alam ASAF, Begum H (2015) Oil palm smallholders and its sustainability practices in Malaysia. Mediterr J Soc Sci 6:482–488. https://doi.org/10.5901/mjss.2015.v6n6s4p482

Abdullah N, Sulaiman F (2013) The oil palm wastes in Malaysia. In: Matovic MD (ed) Biomass now sustainable growth and use. InTech, Rijeka. https://doi.org/10.5772/55302

Abdullah I, Mahmood WW, Fauadi MM, Ab Rahman MN (2015a) Benefits of regulatory and voluntary sustainability standards compliance: a review on Malaysian palm oil. J Adv Manuf Technol (JAMT) 9(1):1–12

Abdullah I, Mahmood WHW, Fauadi MHFM, Ab Rahman MN, Jali FAA (2015b) Sustainability in Malaysian palm oil: a review on manufacturing perspective. Pol J Environ Stud 24:1463–1475. https://doi.org/10.15244/pjoes/37888

Abdullah I, Wan Mahmood WH, Md Fauadi HF, Ab Rahman MN, Mohamed SB (2017) Sustainable manufacturing practices in Malaysian palm oil mills: priority and current performance. J Manuf Technol Manag 28:278–298. https://doi.org/10.1108/jmtm-09-2016-0128

Ahmad AL, Ismail S, Bhatia S (2003) Water recycling from palm oil mill effluent (POME) using membrane technology. Desalination 157(1):87–95

Ahmad AL, Ismail S, Bhatia S (2005) Ultrafiltration behavior in the treatment of agroindustry effluent: pilot scale studies. Chem Eng Sci 60:5385–5394. https://doi.org/10.1016/j.ces.2005.04.021

Alam ASAF, Er AC, Begum H (2015) Malaysian oil palm industry: prospect and problem. J Food Agric Environ 13:143–148

Alam ASAF, Er AC, Begum H, Siwar Chamhuri (2016) Smallholders the prominent contributor in oil palm sector for sustainability. Int J Adv Appl Sci 3:20–24

Arif S, Tengku Mohd Ariff TA (2001) The case study on the Malaysian palm oil. Paper presented for the UNCTAD/ESCAP regional workshop on commodity export diversification and poverty reduction in South and South-East Asia, Bangkok, 3–5 April

Basiron Y (2007) Palm oil production through sustainable plantations. Eur J Lipid Sci Technol 109:289–295

Basiron Y, Weng CK (2004) The oil palm and its sustainability. J Oil Palm Res 16(1):1–10

Begum H, Er AC, Alam ASAF (2014a) Sustainability of oil palm smallholders: the environment, social and economic perspectives. Paper presented at the regional network on poverty eradication (RENPER 5), 22–24 October 2014, Banking University, Ho Chi Min City, Vietnam

Begum H, Alam ASAF, Er AC, Siwar C, Suraya I (2014b) Economic sustainability of oil palm cultivations: smallholders perspective. Paper presented at the regional network on poverty eradication (RENPER 5), 22–24 October 2014, Banking University, Ho Chi Min City, Vietnam

Begum H, Alam ASAF, Er AC (2014c) Social sustainability of oil palm settlers. In: National research & innovation conference for graduate students in social sciences (GS-NRIC 2014): empowering sustainable development through knowledge and human advancement, 5–7 December 2014, Corus Paradise Resort Port Dickson, Negeri Sembilan, Malaysia [organized by: Universiti Putra Malaysia (UPM) and Ministry of Education, Malaysia (MOE)], pp 1002–1015. ISBN: 9789832408222

Begum H, Er AC, Siwar C, Alam ASAF, Suraya I (2015a) Smallholder's practices towards environment sustainability. Adv Sci Lett 21:1742–1745. https://doi.org/10.1166/asl.2015.6170

Begum H, Siwar C, Er AC, Alam ASAF, Ishak S (2015b) The issues of practices for sustainable oil palm. Paper presented at the 3rd international conference limit to growth & sustainability: contemporary issues & perspectives. 5th–7th December 2015, Universiti Kebangsaan Malaysia, Kampus Tuanku Abdul Halim Mu'adzam Shah, Pusat Penyelidikan Langkawi (PPL), Langkawi, Kedah, Malaysia

Begum H, Er AC, Alam ASAF, Siwar C, Ishak S (2015c) Oil palm cultivation and environmental sustainability. Civilization, hopes and discontents insights from the social sciences and humanities, chapter 6. E-ISBN 978-967-445-391-6

Begum H, Siwar C, Er AC, Alam ASAF (2016) Environmentally friendly practices of oil palm cultivators. Int J Adv Appl Sci 3:5–19

Begum H, Siwar C, Alam ASAF, Er AC, Ishak S, Alam L (2018) Enhancing sustainability amongst oil palm smallholders in Malaysia. Int J Agric Resour Gov Ecol 14:62–79. https://doi.org/10.1504/ijarge.2018.090853

Begum H, Er AC, Alam ASAF, Siwar C, Ishak S (2019) Sustainability practices framework of palm oil milling sub sector: a literature survey. Int J Environ Sustain Dev **(in print)**

Brandi C, Cabani T, Hosang C, Schirmbeck S, Westermann L, Wiese H (2012). Sustainability certification in the Indonesia palm oil sector—benefits and challenges for smallholders. Deutsches Institut für Entwicklungspolitik (DIE)/German Development Institute, Bonn. Briefing paper. ISBN 978-3-88985-581-7. https://www.die-gdi.de/uploads/media/Studies_74.pdf. Accessed 16 Jan 2016

Chavalparit O, Rulkens WH, Mol APJ, Khaodhair S (2006) Options for environmental sustainability of the crude palm oil industry in Thailand through enhancement of industrial ecosystems. Environ Dev Sustain 8:271–287. https://doi.org/10.1007/s10668-005-9018-z

Chin MJ, Poh PE, Tey BT, Chan ES, Chin KL (2013) Biogas from palm oil mill effluent (POME): opportunities and challenges from Malaysia's perspective. Renew Sustain Energy Rev 26:717–726. https://doi.org/10.1016/j.rser.2013.06.008

Danielsen F, Beukeman H, Burgess ND, Parish F, Bruhl CA, Donald PF, Murdiyarso D, Phalan B, Reijnders L, Struebig M, Fitzherbert EB (2009) Biofuel plantations on forested lands: double jeopardy for biodiversity and climate. Conserv Biol 23:348–358. https://doi.org/10.1111/j.1523-1739.2008.01096.x

Diana C, Riantri B (2014) Implementasi pengelolaan sawit yang berkesinambungan pada perkebunan rakyat: studi kasus perkebunan sawit rakyat di Sumatera Utara. Prosiding, semnas Hasil-Hasil Penelitian, Inna Grand Bali Beach Sanur-Bali 27–28 Feb 2014. ISBN 978-602-18622-4-7, pp 32–36

Din AK (2017) Malaysian oil palm industry performance 2016 and prospects for 2017. In: MPOB-palm oil economic review & outlook seminar

DOE (1991) Environmental quality report, 1991. Ministry of Science, Technology, and the Environment, Kuala Lumpur

DOE (1998) Annual report 1998. Ministry of Science, Technology, and the Environment, Kuala Lumpur

Dompok BG (2010) Launching on the use of palm biodiesel by Sime Darby Vehicles. Speech, Carey Island, Selangor, 24 March. http://www.simedarbyplantation.com/media/press-releases/sime-darby-plantation-responds-governments-call-use-of-biodiesel-private-sector. Accessed 5 Feb 2011

Dustmann C, Meghir C (2005) Wages, experience and seniority. Rev Econ Stud 72:77–108. https://doi.org/10.1111/0034-6527.00325

Economic Planning Unit (EPU) (2010) Tenth Malaysia Plan (2011–2015). Percetakan National Malaysia Berhad, Kuala Lumpur. Economic planning unit. The Government of Malaysia. http://onlineapps.epu.gov.my/rmke10/rmke10_english.html. Accessed 27 Jan 2012

Economic Planning Unit (EPU) (2017) The Malaysian economy in figures. Prime Minister's Department. Economic Planning Unit, Ministry of Economic Affairs. http://epu.gov.my/sites/default/files/MEIF_2017.pdf. Accessed 6 Dec 2018

Economic Transformation Programme (ETP), NKEA (2009) A roadmap for Malaysia. Chapter 9: deepening Malaysia palm oil advantage. http://www.palmoilworld.org/PDFs/NKEA-Chapter9-PalmOil.pdf. Accessed 30 Sept 2018

Emily C (2018) Malaysia reviewing palm oil export taxes amid bulging stockpiles, Reuters 26 December, 2018. https://www.reuters.com/article/malaysia-palmoil-outlook/malaysia-reviewing-palm-oil-export-taxes-amid-bulging-stockpiles-idINKCN1OP08M. Accessed 1 Jan 2017

Energy Information Administration (EIA) (2005) US Department of Energy, Country Analysis Brief Malaysia, Update January 2005

Environmental Quality Act (1974) Law of Malaysia. Lawnet Percetakan Nasional Malaysia Berhad

Er AC (2007) A quantitative methodology to test ecological modernization theory in the Malaysian context. Doctoral thesis, Wageningen University, The Netherlands. https://library.wur.nl/WebQuery/wurpubs/358049. Accessed 6 Jan 2018

Er AC (2011) A comparative analysis of the Brazilian bioethanol sector and the Malaysian palm biofuel sector. Asian Soc Sci 7:74–78. https://doi.org/10.5539/ass.v7n2p74

Fan D, Lo CKY, Ching V, Kan CW (2014) Occupational health and safety issues in operations management: a systematic and citation network analysis review. Int J Prod Econ 158:334–344. https://doi.org/10.1016/j.ijpe.2014.07.025

Gliem JA, Gliem RR (2003) Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. In: Midwest research-to-practice conference in adult, continuing, and community education. https://scholarworks.iupui.edu/bitstream/handle/1805/344/Gliem%20%26%20Gliem.pdf?sequence=1&isAllowed=y. Accessed 30 Nov 2015

Graboski MS, McCormick RL (1998) Combustion of fat and vegetable oil derived fuels in diesel engines. Prog Energy Combust Sci 24:125–164. https://doi.org/10.1016/s0360-1285(97)00034-8

Greenpeace International (2007) How the palm oil industry is cooking the climate? Greenpeace International. https://www.greenpeace.org/usa/research/how-the-palm-oil-industry-is-c/. Accessed 3 Nov 2012

Guan CC, Amear S, Ariffin S, McKay A (2016) Environmental sustainability drivers: a study on Malaysian palm oil industry. IAFOR J Sustain Energy Environ 3:65–82. https://doi.org/10.22492/ijsee.3.1.04

Hansen S (2007) Feasibility study of performing an life cycle assessment on crude palm oil production in Malaysia. Int J Life Cycle Assess 12:50–58. https://doi.org/10.1065/lca2005.08.226

Kalam MA, Masjuki HH (2002) Biodiesel from palm oil e an analysis of properties and potential. Biomass Bioenergy 23:471–479. https://doi.org/10.1016/s0961-9534(02)00085-5

Lapola DM, Schaldach R, Alcamo J, Bondeau A, Koch J, Koelking C, Priess JA (2010) Indirect land-use changes can overcome carbon savings from biofuels in Brazil. In: Proceedings of the National Academy of Sciences

Lim CI, Biswas W (2015) An evaluation of holistic sustainability assessment framework for palm oil production in Malaysia. Sustainability 7:16561–16587. https://doi.org/10.3390/su71215833

Lim CI, Biswas W (2018) Development of triple bottom line indicators for sustainability assessment framework of Malaysian palm oil industry. Clean Technol Environ Policy 20:539–560. https://doi.org/10.1007/s10098-017-1453-7

Lim CI, Biswas W, Samyudia Y (2015) Review of existing sustainability assessment methods for Malaysian palm oil production. Procedia CIRP 26:13–18. https://doi.org/10.1016/j.procir.2014.08.020

Liyanage JP (2007) Operations and maintenance performance in production and manufacturing assets: the sustainability perspective. J Manuf Technol Manag 18(3):304–314

Mahmood WHW, Abdullah I, Muhammad Hafidz Fazli MF, Ab Rahman MN (2014) OEE measures for sustainable environment in palm oil mill: a review. Sci Int (Lahore) 26(5):1855–1859

Malaysian Palm Oil Board (MPOB) (2001) Malaysian oil palm statistics, 21st edn. MPOB Bangi, Selangor

Malaysian Palm Oil Board (MPOB) (2011) Malaysian oil palm statistics, 21st edn. Economics and Industry Development Division, Malaysian Palm Oil Board, Bangi, Selangor

Malaysian Palm Oil Board (MPOB) (2014a) Review of the Malaysian palm oil industry, 2013. MPOB Bangi, Selangor

Malaysian Palm Oil Board (MPOB) (2014b) Malaysian oil palm statistics, 33rd edn. MPOB Bangi, Selangor

Malaysian Palm Oil Board (MPOB) (2016) Sectoral status. http://bepi.mpob.gov.my/index.php/statistics/sectoral-status/137-sectoral-status-2015/752-number-a-capacities-ofpalm-oil-sectors-2015.html. Accessed 28 May 2016

Malaysian Palm Oil Board (MPOB) (2017) Economics and industry development division. http://bepi.mpob.gov.my/index.php/en/statistics/sectoral-status/179-sectoral-status-2017/803-number-a-capacities-of-palm-oil-sectors-2017.html. Accessed 10 Sept 2018

Malaysian Sustainable Palm Oil (MSPO) (2014) Malaysian standard. Part 1: general principles, 2013. http://www.msonline.gov.my/default.php. Accessed 27 July 2014

McCarthy JF (2010) Processes of inclusion and adverse incorporation: oil palm and agrarian change in Sumatra, Indonesia. J Peasant Stud 37:821–850. https://doi.org/10.1080/03066150.2010.512460

Mohd Rafi Y (2007) An investigation of the Malaysian palm oil industry's environmental strategies, stakeholders' pressure, environmental effectiveness and competitive advantage. University of Newcastle, NSW, Australia

Mohd-Lair NA, Lee JFM, Liew WYH, Sarbatly R (2012) Simulation based process improvement in palm oil industry: a case study at palm kernel department. In: 2012 IEEE business, engineering & industrial applications colloquium (BEIAC), pp 12–15. IEEE. https://doi.org/10.1109/beiac.2012.6226037

Morelli J (2011) Environmental sustainability: a definition for environmental professionals. J Environ Sustain 1:1–10 **10.14448/jes.01.0002**

Nunnally JC, Bernstein IH (1994) Psychometric theory. McGraw-Hill, New York

Ogunbiyi O, Oladapo A, Goulding J (2014) An empirical study of the impact of lean construction techniques on sustainable construction in the UK. Constr Innov Inf Process Manag 14:88–107. https://doi.org/10.1108/ci-08-2012-0045

Oil World (2014) Oil world annual 2014. Oil world. ISTA Mielke GmbH, Hamburg

Oosterveer P (2014) Promoting sustainable palm oil: viewed from a global networks and flows perspective. J Clean Prod 107:146–153. https://doi.org/10.1016/j.jclepro.2014.01.019

Palm Oil World (online) Sustainable palm oil developments in Malaysia. http://www.palmoilworld.org/sustainability.html. Accessed 12 Dec 2017

Peter HC (1998) The EIA process in Malaysia: legal and institutional issues for the future'. In: Hasan MNH, Abdullah LA, Komoo I (eds) National review on environmental quality management in Malaysia: towards the next two decades. Institute for Environment and Development, Universiti Kebangsaan Malaysia, Bangi, pp 266–275

Pierzynski GM, Vance GF, Sims TJ (2005) Soils and environmental quality. CRC Press, Boca Raton

Ramayah T, Mohamad O, Omar A, Marimuthu M, Leen JYA (2013) Green manufacturing practices and performance among SMEs: evidence from a developing nation. In: Green technologies and business practices: an IT approach. IGI Global, pp 208–225

Roundtable for Sustainable Palm Oil (RSPO) (2006) Factsheet: palm oil. http://www.rspo.org/files/pdf/Factsheet-RSPO-AboutPalmOil.pdf. Accessed 3 June 2008

Roundtable on Sustainable Oil Palm (RSPO) (2007) RSPO principles & criteria for sustainable palm oil production—including indicators and guidance. http://www.rspo.org/resource_centre/RSPO%20certification%20systems.pdf. Accessed 11 July 2007

Saifudin N, Fazlili SA (2009) Effect of microwave and ultrasonic pretreatments on biogas production from anaerobic digestion of palm oil mill effluent. Am J Eng Appl Sci 2:139–146. https://doi.org/10.3844/ajeassp.2009.139.146

Salwa Hanim AR, Evans S, Longhurst P (2008) A comparison of four sustainable manufacturing strategies. Int J Sustain Eng 1(3):214–229

Salwa Hanim A-R, Novita S, Raja Ariffin RG, Ramayah T (2017) The impact of sustainable manufacturing practices on sustainability performance: empirical evidence from Malaysia. Int J Oper Prod Manag 37(2):182–204. https://doi.org/10.1108/IJOPM-04-2015-0223

Santillo D (2007) Reclaiming the definition of sustainability. Environ Sci Pollut Res 14:60–66. https://doi.org/10.1065/espr2007.01.375

Shirai Y, Wakisaka M, Yacob S, Hassan MA, Suzuki SI (2003) Reduction of methane released from palm oil mill lagoon in Malaysia and its countermeasures. Mitig Adapt Strateg Glob Change 8:237–252. https://doi.org/10.1023/b:miti.0000005641.97009.14

Sime Darby (2009) Palm oil industry in Malaysia. Unpublished presentation. http://siteresources.WorldBank.org/EDUCATION/Resources/278200-1121703274255/1439264-1242337549970/Malaysian_Palm_Oil_Industry.pdf. Accessed 3 August 2012

Singh RK, Murty HR, Gupta SK, Dikshit AK (2012) An overview of sustainability assessment methodologies. Ecol Ind 15:281–299. https://doi.org/10.1016/j.ecolind.2011.01.007

Sisbudi S, Grundman P, Hang L, Hansen A, Amran M, Salleh M, Ghazi M (2013) Resources, conservation and recycling energy balances, greenhouse gas emissions and economics of biochar production from palm oil empty fruit bunches. Resour Conserv Recycl 77:108–115. https://doi.org/10.1016/j.resconrec.2013.04.005

Subramaniam V, Choo YM, Muhammad H, Hashim Z, Tan YA, Puah CW (2010) Life cycle assessment of the production of crude palm oil (part 3). J Oil Palm Res 22:895–903

Subramaniam V, Menon NR, Sin H, May CY (2013) The development of a residual oil recovery system to increase the revenue of a palm oil mill. J Oil Palm Res 25:116–122

Tan E (1999) DOE compliance target for palm oil, rubber sector. New Straits Times, 1 Feb 1999, p 6

Tan KT, Lee KT, Mohamed AR, Bhatia S (2009) Palm oil: addressing issues and towards sustainable development. Renew Sustain Energy Rev 13:420–427. https://doi.org/10.1016/j.rser.2007.10.001

Teoh CH (2000) Land use and the oil palm industry in Malaysia. Report of WWF

United States Department of Agriculture (USDA) (2016) Global consumption of vegetable oils from 1995/1996 to 2014/2015, by oil

type (in million metric tons). United States: Statista, USDA, Foreign Agricultural Service. Oilseeds: World Markets and Trade. Vegetable Oils: Global Consumption by Oil Type 55:1995–2015

United States Department of Agriculture (USDA) (2017) https://www.indexmundi.com/agriculture/?country=my&commodity=palm-oil&graph=production. Accessed 12 Dec 2017

Urban B, Naidoo R (2012) Business sustainability: empirical evidence on operational skills in SMEs in South Africa. J Small Bus Enterp Dev 19:146–163. https://doi.org/10.1108/14626001211196451

Vairappan CS, Yen AM (2008) Palm oil mill effluent (POME) cultured marine microalgae a supplementary diet for rotifer culture. J Appl Phycol 20:603–608. https://doi.org/10.1007/s10811-007-9305-1

Vinodh S, Joy D (2012) Structural equation modelling of lean manufacturing practices. Int J Prod Res 50:1598–1607. https://doi.org/10.1080/00207543.2011.560203

Vivian WY, Tam CMT, Zeng SX, Chan KK (2006) Environmental performance measurement indicators in construction. Build Environ 41:164–173. https://doi.org/10.1016/j.buildenv.2005.01.009

Wicke B, Dornburg V, Junginger M, Faaij A (2008) Different palm oil production systems for energy purposes and their greenhouse gas implications. Biomass Bioenergy 32(12):1322–1337. https://doi.org/10.1016/j.biombioe.2008.04.001

Winroth M, Almström P, Andersson C (2016) Sustainable production indicators at factory level. J Manuf Technol Manag 27:842–873. https://doi.org/10.1108/jmtm-04-2016-0054

Wong YS, Kadir MOA, Teng TT (2009) Biological kinetics evaluation of anaerobic stabilization pond treatment of palm oil mill effluent. Biores Technol 100:4969–4975. https://doi.org/10.1016/j.biortech.2009.04.074

World Growth (WG) (2010) Palm oil and food security: the impediment of land supply. World Growth Organization

Yaser AZ, Rahman RA, Kalil MS (2007) Co-composting of palm oil mill sludge-sawdust. Pak J Biol Sci 10:4473–4478. https://doi.org/10.3923/pjbs.2007.4473.4478

Yatim P, Lin NS, Lam HL, Er AC (2017) Overview of the key risks in the pioneering stage of the Malaysian biomass industry. Clean Technol Environ Policy 19:1825–1839. https://doi.org/10.1007/s10098-017-1369-2

Yiin CL, Yusup S, Quitain AT, Uemura Y, Sasaki M, Kida T (2018) Life cycle assessment of oil palm empty fruit bunch delignification using natural malic acid-based low-transition-temperature mixtures: a gate-to-gate case study. Clean Technol Environ Policy 20(8):1917–1928. https://doi.org/10.1007/s10098-018-1590-7

Yusoff S (2006) Renewable energy from palm oil e an innovation on effective utilization of waste. J Clean Prod 2006(14):87–93. https://doi.org/10.1016/j.jclepro.2004.07.005

Zhang P, Huang G, An C, Fu H, Gao P, Yao Y, Chen X (2019) An integrated gravity-driven ecological bed for wastewater treatment in subtropical regions: process design, performance analysis, and greenhouse gas emissions assessment. J Clean Prod 212:1143–1153. https://doi.org/10.1016/j.jclepro.2018.12.027