



COVID-19 and Its Implications to the Assessment of Sustainable Palm Oil Supply Chain Management: An Indonesian Perspective

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Motivated by the low sustainability index and pressure to meet the global demand for eco-friendly crude palm oil (CPO) in the pandemic-ridden environment, this research aims to investigate the implications of the COVID-19 pandemic to assess the drivers of sustainable supply chain management (SSCM) of the Indonesian CPO sector to tackle supply chain disruptions. To achieve this aim, the study seeks to determine the sustainability drivers to accommodate the pandemic-ridden environment and if sustainability indicators can help improve the supply chain management of the CPO sector. A methodology is divided into two interrelated parts: first, based on a careful review of extant literature of the CPO sector and sustainable supply chain in the light of pandemic. The proposed methodology is then tested using the response data of 108 oil mills' representatives collected through survey questionnaires and analyzed using statistical tools of reliability, distribution, Kaiser–Meyer–Olkin (KMO), Confirmatory Factor Analysis (CFA), and diagnostic tests of CFA. The findings designate the environmental costs, rapidity, and adaptability as core economic indicators; the social and workforce development, health, and safety workforce development and consumer issues as crucial social indicators; while energy and material efficiency, management of waste and emissions, and sustainable suppliers as the best environmental indicators. This study provides a holistic platform on the implications of the pandemic to assess the SSCM of the CPO sector. These findings are expected to aid the industrial managers in employee skills and health protocols, customer service, and environmental management. The study is also anticipated to guide the supply-chain partners and government policymakers to take initiatives on SSCM in the context of the pandemic.

Keywords: assessment, COVID-19, palm oil, sustainable, supply chain management

INTRODUCTION

The pressure to meet the global demand for eco-friendly and equitable crude palm oil (CPO) by Indonesia that has already been condemned for its low sustainability index of CPO (Papilo et al., 2018), escalates the gravity to adopt sustainable production of CPO by Indonesia (Khatun et al., 2017). The tropical produce, Oil palm (OP), has met the growing demand for bio-energy, cosmetics, food ingredients, and animal feed globally. The CPO industry faces several threats: deforestation,

biodiversity loss, environmental degradation, pollution, and scarce environmental know-how. Recently, the entire supply chain has been adversely affected by the COVID-19 pandemic (Ivanov and Das, 2020; Kilpatrick and Barter, 2020), which caused severe health, labor market, and economy worldwide. The crises exacted the businesses to reconsider their global supply chain strategy to endorse and hasten various sustainable measures to combat a disruptive business environment (Ivanov, 2020a; Remko, 2020) of the covid-ridden economy.

In order to meet the sustainability needs, the OP companies need to adopt the highest sustainability approaches (Sajjad et al., 2020) and at the same time align with the stakeholders' conjecture and expectations. To explore new drivers to support the supply chain, the supply chains need to make necessary changes in the management to enhance their resilience capabilities and competitiveness (Hobbs, 2020). Previous studies revealed the gravity of adopting a sustainable supply chain management (SSCM) crucial for an industry's survival. Zeng et al. (2017) formulated a sustainable supply chain framework in a circular economy to accommodate the bureaucratic pressure from legal, economic, and social bodies. Li and Mathiyazhagan (2018) explored the key sustainable supply chain determinants to boost the sustainability performance of the automobile sector. According to Munny et al. (2019), customer needs and employees' health and safety, wages, and other benefits the effective social sustainability practices (Karmaker et al., 2021). Gupta et al. (2020) explored the challenges of supply chain sustainability innovation and offered solutions and strategies to adopt sustainable supply chains.

Unfortunately, the extant literature on assessing sustainable supply chain drivers is not adequate for the present context as the novel and unique COVID-19 pandemic with anonymous attributes has changed old assumptions about supply chain sustainability (Choi, 2020; Ivanov, 2020a). Also, studies emphasizing all three dimensions, namely environment, economic, and social transformations in diverse sustainability challenges, are inadequate. In addition, despite several calls for research on OP development and transformations concerning a particular supply chain management and the impact of COVID-19, no research was conducted. Thus, this present study seeks to fulfill the research gaps by assessing the implication of pandemic on sustainable SCM of the CPO sector. This study has two objectives. First, to find the sustainability drivers to accommodate the pandemic-ridden environment. Second, to investigate if sustainability indicators can help improve the sustainability of the supply chain management of the CPO sector.

The present study provides evidence from Indonesia, taking representatives of the OP mills as a unit of analysis, where no significant research has been conducted. It may help the researchers, policymakers, and practitioners of OP-producing

countries by offering insights on the subject. The study aims to open up the corridors to assess the sustainability of equitable palm oil by presenting a comprehensive analysis. It is expected that there might be new findings on the sustainable SCM of OP, especially on the issues of implications of the COVID-19 pandemic.

The remainder of this study is organized as follows. Section Literature Review details the theoretical background to develop the skeleton of the analysis. Section Methodology discusses the sampling methods and measurement procedures. The study results are presented in section Results. Findings and discussion are elaborated in the subsequent sections, which are Findings and Discussion respectively. Section Conclusion concludes the study.

LITERATURE REVIEW

Oil Palm (OP) Supply Chain Structure

Oil palm (OP), with the scientific title of *Elaeis guineensis*, stands as one the most promising global oil crops that covers almost 40% of the exported volume of vegetable oils. Palm oils and their downstream harvests have been profoundly imported all over the world. Palm oils are widely consumed by more than three billion people of Asia as a primary dietary constituent. Palm kernel oil has also been popular for non-edible purposes, such as cleaning, sanitizing, cleanings, hygiene, and personal care products, such as cleansing agents, lathers, and surface cleaners (Central Point of Expertise on Timber, 2015). OP is crucial to the economies of the two South East (SE) Asian countries, namely Indonesia and Malaysia, from which it has been exported worldwide in the forms of oil, food additive, and other derivatives (Ommelna et al., 2012). Key locations of global oil palm cultivation are highlighted in (Table 1).

Regardless of the local or global level, the entire supply chain is affected and faces challenges in ensuring logistics and manufacturing operations (Statista, 2020). Businesses have been badly damaged by the pandemic named COVID-19 with its deadly, transmittable, and unpredicted symptoms. This caused severe disorders to human lives and the circular economy (Klande et al., 2019). The global supply chain is faced with considerable risk, and trading and distribution activities have been reduced significantly. The sprawl of COVID-19 affected most countries and territories with an increasing rate of active cases and deaths (Farooq et al., 2021). Though during early-2020, the lockdown initially affected the trade of the vital OP importers, the OP supply chain has been demonstrating resilience to the early shock of lockdown and continued transporting millions of tons of palm oils with minimum disruption from the major importing hubs of South-East Asia and Europe. While OP supply chains of Indonesia were comparatively less affected by the pandemic followed by localized lockdown and insufficient workers, a 10% reduction in palm oil production is predicted in the upcoming years from the previous year (MPOC, 2020).

Sustainable Supply Chain and COVID-19

Sustainability involves the notion of how humans should carry responsibility for the natural environment and future generations (Clark, 2007). Sustainable development seeks to cover the needs

Abbreviations: CPO, Crude Palm Oil; SSCM, Sustainable Supply Chain Management; KMO, Kaiser-Meyer-Olkin; CFA, Confirmatory Factor Analysis; FFB, Fresh fruit branches; OP, Oil Palm; TBL, Triple Bottom Line; ECS, Economy Sustainability; SS, Social Sustainability; ENS, Environmental Sustainability; KPI, Key Performance Index; COVID-19, Coronavirus Disease 2019; NGOs, Non-governmental organizations.

of the existing cohort without negotiating the capacity of the impending cohorts (World Commission on Environment Development, 1987). As sustainability is achievable by addressing social, environmental, and financial objectives in the supply chain (Mitchell and Walinga, 2017; Raut et al., 2017), a sustainable supply chain will be better able to minimize the adverse effects of supply chain operations and enhance the performance and value of supply chain management (Vargas et al., 2018). Other benefits of adopting sustainability in the supply chain would be to supplement the brand identity and socially conscious image. It also reduces time and expense associated with potential environmental pollution and other damages. Companies are eventually better off (Bai et al., 2019).

Unfortunately, neither the need to adopt sustainability has been recognized nor the competency required for administering sustainability practices has been adequate by the firms of the developing economies (Luthra et al., 2017). Therefore, it is imperative to adopt sustainability in the supply chain to corroborate various prospects for sustainable performance of the businesses. The COVID-19 pandemic has left unfavorable effects on the sustainability of value chains worldwide (Govindan, 2018) and created substantial detrimental effects on sales revenue, return on investment, procurement strategies, materials supply, logistics service (Bag et al., 2020; Majumdar et al., 2020; Sharma et al., 2020), production, distribution, or logistics (Ivanov, 2020a). Following the interruption and bottleneck of the supply chain caused devastating consequences (Ivanov, 2020b; Karmaker et al., 2021).

It is not surprising that the existing supply chain strategies and practices designed for a regular operation in the supply chain will not be practical and feasible to tackle a global pandemic like COVID-19. The supply chain managers need to reconsider designing their strategies and practices to accommodate the pandemic era. The businesses are wrestling with formulating a supply chain incorporating the features of sustainability (Sharma et al., 2020) and extra-resilient approaches (de Sousa Jabbour et al., 2020) to combat the challenges offered by the COVID-19 consequences. With the gigantic outburst of COVID-19 continuing worldwide, various organizations shift to work-from-culture, laboratories constantly work to innovate vaccines, medications, and healthcare facilities with relentless research.

Adoption by the affected companies in emerging economies of socially distanced working environments, community lockdown, isolation (Majumdar et al., 2020) and adequate personal protective equipment (PPE), ventilators, masks, face shields, and hand sanitizers (Sharma et al., 2020; Karmaker et al., 2021) to prevent the transmission of COVID-19 disease is inadequate. The terrible health hazards, unemployment, and economic turmoil have triggered economic and social sustainability trials during the pandemic (Majumdar et al., 2020). It is a timely need to rethink a viable resistance level of the supply chain (Ivanov and Dolgui, 2020) to halt the disintegration of the economy.

Sustainability Drivers of SCM in the Context of COVID-19

Supply Chain Management (SCM) refers to ensuring a synthesized approach across the supply chain, starting from

sourcing raw materials, constructing or assembling a product, dispatching it to retail outlets, and actual consumers' end. The oil millers need to restructure their supply chain practices with "tailor-made indicators to enhance sustainable supply chain management performance, especially in the pandemic era (Kusrini and Maswadi, 2021). The key drivers of SSCM ultimately benefit the stakeholders from seven sectors: oil palm producers, processors or traders, consumer goods manufacturers, retailers, banks/investors, and environmental and social non-governmental organizations (NGOs).

In the research of Kusrini and Primadasa (2018), the weighted key performance indicators (KPI) of the SSCM palm oil industry have been identified by combining literature reviews. It is imperative to improve sustainable supply chain management to remain competitive in the COVID-ridden business environment and enhance performance (Sutawidjaya et al., 2021). Proactively detecting disruptions and quick remedial actions can allow industries to lower the impact of current and future shocks (Farooq et al., 2021). Addressing the consequences of diseases under a unanimous framework in the current timeline can be the first step. Some 26 published literature have been observed relating sustainable supply chain management to formulate the essential indicators to assess the performance of sustainable supply chain management from economic, social, and environmental dimensions, specially catered to the pandemic-ridden business environment.

Evolving from sustainability, sustainable supply chain management (SSCM) aims at managing the supply chain relationship and the flow of materials and information to maximize operational performance and the profitability of the supply chain. Compared with supply chain management, the sustainability feature in the sustainable supply chain management (SSCM) has more multiple dimensions ensuring long-term profitability without adversely affecting natural systems (Seuring and Müller, 2008).

SSC drivers ensure efficient operational and economic performance, contingency planning implementation in uncertain environments, and availing sustainability practices (Tseng et al., 2019; Sajjad et al., 2020; Karmaker et al., 2021). Acknowledging such drivers would help establish the SSC initiatives for sustainable management of the CPO sector. The espousal of SSC would depend on several critical indicators (drivers) that contribute significantly to a successful implementation. Nevertheless, inadequate attention on sustainability drivers to execute the SSC has been exhibited (Munny et al., 2019). Amid the pandemic era, it is crucial to investigate the drivers of sustainability on supply chains that will enhance the post-covid performance of the CPO sector. The essential drivers for SSC well-adapted with pandemic have been mainly derived from the extant literature presented in **Table 2**.

In **Table 2**, the ES, SS, and ENS refer to the indicators in the three pillars of sustainability, namely economic, social and environmental, respectively. As an indicator to gauge the organizational improvement (Lim et al., 2015), key performance indicators (a) of sustainable supply chain management (SSCM) of the crude palm oil industry need to be identified. The present study reviews the literature to obtain sustainability KPIs for

assessing sustainable supply chain management (SSCM) of CPO mills and proposes the following indicators in **Table 3**.

Given the dynamic business environment, changing customer needs, and economic, environmental, and social concerns, having a sustainable supply chain (SSC) is vital to produce goods and services in the pandemic era (Bag et al., 2020). It is essential to integrate all the industry actors to implement the value of sustainability properly. A sustainable supply chain management (SSCM) can address socio-environmental issues and improve the performance of the community (Kusi-Sarpong et al., 2018) using appropriate KPI indicators, as suggested by past studies.

METHODOLOGY

The aims of the study are twofold. The first objective is to determine the sustainability indicators of SSCM in line with the

pandemic. The second objective is to examine if the sustainability indicators can help improve sustainability in supply chain management to augment the performance in the supply chain. An extensive review of extant literature broadly reached the first objective. A survey among the palm oil mill managers was conducted to reach the second objective of the study.

Screening of Literature

A literature screening has been carried out using basic phrases, such as: “drivers and indicators for sustainable supply chain adoption” OR “critical factors/motivators/key indicators” AND “sustainability drivers assessment pandemic” OR “investigate sustainable supply chain drivers” OR “impacts/effects of a pandemic on sustainability and sustainable developments of oil

TABLE 1 | Key locations of global oil palm cultivation in 2020 (Statista, 2020).

Ranking	Countries	Palm oil production (mt)	Palm oil production ()
1	Indonesia	42.5	58.8
2	Malaysia	18.5	25.6
3	Thailand	2.8	3.9
4	Colombia	1.5	2.1
5	Nigeria	1.0	1.4
	Others	5.9	8.2
	Total	72.3	

TABLE 2 | Sustainability Indicators to assess SSCM of Oil Palm.

Dimensions	Elements	Publications
Economy Sustainability (ECS)	<i>E₁: Environmental Expenses</i>	Zailani et al., 2012; Morali and Searcy, 2013; Esfahbodi et al., 2016; Rajeev et al., 2017; Kamble et al., 2020
	<i>E₂: Delivery Speed</i>	Ageron et al., 2012; Bag et al., 2020
	<i>E₃: Supply Chain Expense</i>	Ageron et al., 2012; Zimon et al., 2019; Choi, 2020
	<i>E₄: Market Competition</i>	Zailani et al., 2012; Morali and Searcy, 2013; Rajeev et al., 2017; Saeed and Kersten, 2017; Emamisaheh et al., 2018
	<i>E₅: Product Quality</i>	Ageron et al., 2012; Zailani et al., 2012; Craighead et al., 2020
	<i>E₆: Adaptability</i>	Ageron et al., 2012; de Sousa Jabbour et al., 2020; Majumdar et al., 2020
Social Sustainability (SS)	<i>S₁: Social Responsibility</i>	Azevedo et al., 2011; Zailani et al., 2012; Esfahbodi et al., 2016; Rajeev et al., 2017; Saeed and Kersten, 2017; Sroufe, 2017; Zimon et al., 2019
	<i>S₂: Health and Safety Measures</i>	Rajeev et al., 2017; Saeed and Kersten, 2017; Emamisaheh et al., 2018
	<i>S₃: Employee Development</i>	Saeed and Kersten, 2017; Emamisaheh et al., 2018
	<i>S₄: Human Rights issues</i>	Saeed and Kersten, 2017
	<i>S₅: Customer Rights</i>	Rajeev et al., 2017; Saeed and Kersten, 2017
Environmental Sustainability (ENS)	<i>N₁: Energy efficiency</i>	Zailani et al., 2012; Saeed and Kersten, 2017; Sroufe, 2017; Emamisaheh et al., 2018; Govindan, 2018; Zimon et al., 2019; Kamble et al., 2020
	<i>N₂: Material efficiency</i>	Tseng et al., 2015; Saeed and Kersten, 2017
	<i>N₃: Water usage</i>	Saeed and Kersten, 2017; Govindan, 2018; Kamble et al., 2020
	<i>N₄: Waste management</i>	Zailani et al., 2012; Tseng et al., 2015; Rajeev et al., 2017; Saeed and Kersten, 2017; Emamisaheh et al., 2018; Govindan, 2018; Kamble et al., 2020
	<i>N₅: Sustainable Supplier management</i>	Grimm et al., 2014; Rajeev et al., 2017; Saeed and Kersten, 2017

TABLE 3 | KPIs for palm oil industry obtained from literature review.

KPI	Literature
1. Work in process	Faulkner et al., 2012; Kusriani and Primadasa, 2018
2. EHS (env, health and safety) expenses	Veleva and Ellenbecker, 2001; Bai and Sarkis, 2014; Kusriani and Primadasa, 2018
3. Rate of Customer Complaint and Return	Veleva and Ellenbecker, 2001; Kusriani and Primadasa, 2018
4. Materials usage	Hall et al., 2012; Sparks, 2014; Kusriani and Primadasa, 2018
5. Acidification Potential	Veleva and Ellenbecker, 2001; Kusriani and Primadasa, 2018
6. Physical Load Index	Faulkner et al., 2012; Kusriani and Primadasa, 2018

palm sector” OR “scale-up/improving supply chain sustainability in the palm oil industry”. For a literature search, databases like Scopus, EBSCO, and Google Scholar have been utilized. Based on the review of extant literature, some sixteen drivers of SSC have been designated.

Also, followed by an extensive literature review, the indicators and sub-elements of SSCM performance were determined. Based on **Table 2**, for economic dimensions, a total of 6 sub-elements have been chosen for the study, such as environmental expenses, delivery speed, supply chain expense, market competition, product quality, and adaptability. For social dimensions, 5 sub-elements of social responsibility, health and safety measures, employee development, human rights issues, and customer rights have been determined. Another set consisting of 5 sub-elements have been decided for the study, including energy efficiency, material efficiency, water usage, waste management, and sustainable supplier management. Based on **Table 3**, for KPI, the sub-elements have been derived as work-in-process, EHS (environment, health & safety) expenses, rate of customer complaint and return, materials usage, acidification potential, and physical load index.

Survey

Study Area and Sample

The study was to collect opinions of the Indonesian palm oil stakeholders on the additional indicators to measure the supply chain’s performance in adapting to the pandemic. The research data were collected to get an overview of the pandemic-ridden management of the mills. The key respondents were the Managers, Assistant Managers, Executives, Engineers, and the other representative of sustainability decision-makers of the oil mills. This study used primary data collected from two Indonesian regions named Sumatera and Kalimantan. The data collected through a questionnaire survey with 108 out of 120 were completed and accepted for further analysis. The sample size was 108, which follows the rules of thumb for determining sample size as proposed by Roscoe (Sekaran, 2003). Roscoe (1975) proposes that sample sizes larger than 30 and less than 500 are appropriate for most research. Appropriate sample size is required for validity, and in regression analysis, many researchers acknowledge that there should be at least 10 observations per variable. This study uses three independent variables and one dependent variable; a clear rule would be to have a minimum sample size of 40.

Questionnaire Development

A survey through questionnaire is the best method to cover a large population. Therefore, the present study developed the questionnaire as the vital device for data assemblage. The questionnaire has been carefully formulated after extensive reviewing of the extant literature (Zhang et al., 2018; Kusriani and Maswadi, 2021). It was first created in English and then was translated into Bahasa Indonesia to anticipate the non-English speaking respondents. The entire questionnaire was divided into three sections A, B, and C. Section A considered the sociodemographic variables of the respondents such as position, gender, education, employee size, and production capacity.

Section B contained the responses toward the sustainability indicators by palm oil millers in Indonesia. Section C had open-ended questions relating to stakeholder benefits. These variables were used in the questionnaire to ensure consistency with the previous studies of Zhang et al. (2018) and Kusriani and Maswadi (2021).

Sampling Technique and Data Collection

The responses came from the samples, out of which 108 were found complete with helpful information and were accepted for further analysis. The remaining 12 distributed questionnaires had incomplete answers and were excluded from the analysis. A “cluster sampling technique” was adopted to collect samples, as it confirms that each subgroup within the population obtains proper representation within the sample of 120. This particular technique was consistent with (Begum et al., 2019). The response data was designed to analyze using a five-point Likert scale that ranged from the “Lowest Extent (1)” to the “Highest Extent (5).” The survey was conducted through a google form questionnaire distributed and collected over April, May, and June of 2021.

Statistical Analysis

Analysis of sustainability indicators’ role in improving SSCM was derived from data analysis undertaken through IBM SPSS statistical software 21.0 to calculate data reliability, frequency distribution, Confirmatory Factor Analysis (CFA) to understand the relationships between the various elements of social, economic, and environmental factors. As suggested by (Urban and Naidoo, 2012), the Kaiser–Meyer–Olkin (KMO) test by SPSS was also used to assess the sampling adequacy and evaluate the correlations among variables. A Kaiser-Meyer-Olkin (KMO) test is used in research to determine the sampling adequacy of data that are to be used for Factor Analysis. It has been introduced Henry Kaiser in 1970 and modified by Kaiser and Rice in 1974 (Kaiser and Rice, 1974). The reliability construct was calculated separately, and data reliability for the diagnosed CFA was assessed. The variables (from section Screening of Literature) determined will be assessed for a diagnosis of CFA to identify the association sustainability indicators and SSCM performance.

As with other statistical methods, the CFA model relies upon assumptions. Procedures such as evaluating distributional characteristics of indicators and examining data for outlying cases should be conducted before CFA techniques are employed. For estimation and model identification purposes, a minimum of three observed variables for each latent variable is recommended as latent factor measured by one variable (e.g., one subscale) is not optimal and may lead to problems with an estimation as well as with construct interpretation (Bollen, 1989). The study did not conduct sensitivity analysis, as it may increase the false sense of security among managers if all pessimistic estimates of the model are optimistic and do not consider the interaction among variables. Hence, no in-depth analysis to check the model’s reliability might be considered one limitation of the study.

TABLE 4 | KMO and Bartlett's Test statistic.

	ECS	SS	ENS	KPI	
KMO and Bartlett's Test					
Kaiser-Meyer-Olkin measure of sampling adequacy.	0.786	0.786	0.809	0.744	
Bartlett's test of sphericity	Approx. Chi-Square	163.156	163.156	271.667	317.825
	Df	15	15	15	15
	Sig.	0.000	0.000	0.000	0.000

TABLE 5 | Reliability statistics.

	Cronbach's Alpha	No of items	Reliable for study
Economic sustainability	0.776	6	Yes
Social sustainability	0.767	6	Yes
Environmental sustainability	0.839	6	Yes
Key performance index (KPI)	0.830	6	Yes

RESULTS

Reliability Test

To verify the suitability of the collected data for factor analysis, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's Test of Sphericity value have been investigated. Referring to **Table 4**, KMO value for Economy Sustainability (ECS), Social Sustainability (SS), Environmental Sustainability (ENS), and Key Performance Index (KPI) are 0.786, 0.786, 0.809, and 0.744, respectively, while Bartlett's Test value is significant ($p = 0.000$). Therefore, factor analysis in this regard is required.

The internal consistency and reliability of the pilot survey were tested using the Cronbach's α , which is consistent with (Ogunbiyi et al., 2014). An α -value of the range of 0.7 is considered acceptable, and any value above 0.8 is found to be good. In the present study, data reliability with 108 sample sizes can be seen in **Table 5**. For ECS, the Cronbach's α is 0.776, SS Cronbach's α is 0.767, while ENS Cronbach's α is 0.839, and KPI Cronbach's α is 0.830. Thus, these figures are considered good and acceptable for further study.

Demographic Profile of Respondents

Seven hundred ninety-one palm oil mills existed in Indonesia (Ministry of Energy and Mineral Resources, 2019). Most of the Palm oil mills are situated in the Sumatra area. The demographic background of the respondents shows the percentages of the respondents (Millers) in terms of gender, education, and economic position. The majority of the executive positions are held by males (89.8%), while 10.2% are females. Moreover, most respondents (77.8%) completed their degree levels and have 2 to 3 years (50.9%). An employee with a minimum of 2 years of experience should be considered reliable to provide information about a firm or mill, according to Dustmann and Meghir (2005). Some 501 employees and above (60.2%) were found to be

TABLE 6 | Demographic statistics.

Item	Measures	Frequency	Percentage
Location	Sumatera	56	51.9
	Kalimantan	35	32.4
	Riau	6	5.6
	Lampung	5	4.6
	Papua	3	2.8
Years of operation	5 to 10	6	5.6
	10 to 15	66	61.1
	15 and above	36	33.3
Designation	Manager	16	14.8
	Assistant Manager	26	24.1
	Executive	12	11.1
	Engineer	44	40.7
	Other	10	9.3
Gender	Male	97	89.8
	Female	11	10.2
Highest Education	Masters	24	22.2
	Bachelor Degree	84	77.8
Service Length	0 to 2 years	5	4.6
	2 to 3 years	55	50.9
	3 to 5 years	30	27.8
	5 years and above	18	16.7
No of Employees	201 to 500	43	39.8
	500 and above	65	60.2

recruited by the surveyed mills to perform their operations (See **Table 6**).

Frequency Distribution of Factors

The mean and standard deviation of the palm oil miller's level of responsiveness to economic sustainability is described in **Table 7**. The respondents indicated that they have a "neutral" level of economic sustainability practices in these observed variables; "purchase eco-friendly materials (Ec_1)" wherein 49.1%, "minimize waste disposal expenses (Ec_2)" (46.3%), and "minimum time spent on completing an order (Ec_5)" which represent the majority of the respondents (55.6%). About 45.4, 42.6, and 43.5% of the respondents indicated that they have a "high extent" level of economic sustainability practices which include "minimize operating costs (Ec_3)", "on-time delivery (Ec_4)", and "able to respond to changes in delivery schedule (Ec_6)".

The mean and standard deviation of the palm oil miller's level of responsiveness to social sustainability is described in **Table 8**. The respondents indicated that they have a "neutral" level of social sustainability practices in these observed variables; "demonstrate concern for any social entity (S_1)" wherein 49.1%, "enhance community relationship (i.e., with Government or NGOs) (S_2)" (46.3%), and "enhance employee's job satisfaction (S_5)" which represent the majority of the respondents (55.6%). About 45.4, 42.6, and 43.5% of the respondents indicated that they have a "high extent" level of economic sustainability

TABLE 7 | Responsiveness to the economic sustainability of palm oil millers.

Independent variables	Observed variables	1	2	3	4	5	Mean	SD
Economic Sustainability	Purchase eco-friendly materials (Ec_1)	2(1.9)	8(7.4)	53(49.1)	42(38.9)	3(2.8)	3.33	0.736
	Minimize waste disposal expenses (Ec_2)	1(0.9)	9(8.3)	50(46.3)	45(41.7)	3(2.8)	3.37	0.718
	Minimize operating costs (Ec_3)	1(0.9)	11(10.2)	44(40.7)	49(45.4)	3(3.8)	3.39	0.747
	On-time delivery (Ec_4)	5(4.6)	11(10.2)	38(35.2)	46(42.6)	8(7.4)	3.38	0.934
	Minimum time spent on completing order (Ec_5)	0(0)	5(4.6)	60(55.6)	38(35.2)	5(4.6)	3.40	0.655
	Able to respond to changes in delivery schedule (Ec_6)	1(0.9)	5(4.6)	39(36.1)	47(43.5)	16(14.8)	3.67	0.820

Numbers in bracket represent percentage.

TABLE 8 | Responsiveness to the social sustainability of palm oil millers.

Independent variables	Observed variables	1	2	3	4	5	Mean	SD
Social sustainability	Demonstrate concern for any social entity (S_1)	2(1.9)	8(7.4)	53(49.1)	42(38.9)	3(2.8)	3.33	0.736
	Enhance community relationship (i.e., with Government, NGOs etc.) (S_2)	1(0.9)	9(8.3)	50(46.3)	45(41.7)	3(2.8)	3.37	0.718
	Minimize in employee' work-related injury/ death (S_3)	1(0.9)	11(10.2)	44(40.7)	49(45.4)	3(3.8)	3.39	0.747
	Ensure employees' education and training program (S_4)	5(4.6)	11(10.2)	38(35.2)	46(42.6)	8(7.4)	3.38	0.934
	Enhance employees' job satisfaction (S_5)	0(0)	5(4.6)	60(55.6)	38(35.2)	5(4.6)	3.40	0.655
	Enhance customer awareness of safe and healthy products (S_6)	1(0.9)	5(4.6)	39(36.1)	47(43.5)	16(14.8)	3.67	0.820

Numbers in bracket represent percentage.

TABLE 9 | Responsiveness to the environmental sustainability of palm oil millers.

Independent variables	Observed variables	1	2	3	4	5	Mean	SD
Environmental sustainability	Efficient use of renewable energy (rain, air, sunlight etc.) (En_1)	6(5.6)	17(15.7)	36(33.3)	43(39.8)	6(5.6)	3.24	0.96
	Efficient consumption of energy (electricity etc.) (En_2)	13(12.0)	20(18.5)	27(25.0)	35(32.4)	13(12.0)	3.14	1.21
	Minimize using of hazardous and toxic materials (En_3)	10(9.3)	34(31.5)	32(29.6)	25(23.1)	7(6.5)	2.861	1.08
	Reduce producing of solid waste (En_4)	6(5.6)	27(25.0)	37(34.3)	33(30.6)	5(4.6)	3.04	0.985
	Reduce pollution due to smoke and waste (En_5)	2(1.9)	7(6.5)	44(40.7)	40(37.0)	15(13.9)	3.55	0.880
	Evaluate suppliers in terms of quality, price, availability and speed (En_6)	6(5.6)	35(32.4)	54(50.0)	13(12.0)	16(14.8)	3.69	0.757

Numbers in bracket represent percentage.

practices which include “Minimize in employee' work-related injury/ death (S_3)”, “ensure employees' education and training program (S_4)”, and “enhance customer awareness of safe and healthy products (S_6)”.

The mean and standard deviation of the palm oil miller's level of responsiveness to environmental sustainability can be referred to in **Table 9**. Approximately 39.8 and 32.4% of the respondents agree that they have a “high extent” in “efficient use of renewable energy (rain, air, sunlight, etc.) (En_1)” and “efficient consumption of energy (electricity, etc.) (En_2)”. On the other hand, the majority of the respondents (50%) agreed that they are “neutral” in “evaluating suppliers in terms of quality, price, availability, and speed (En_6)”. About 40.7 and 34.3% of the respondents also agree that they have “neutral” in “reduce pollution due to smoke and waste (En_5)” and “reduce producing of solid waste (En_4)”. 31.5% of the respondents indicate that they

have a “low extent” in “minimize using of hazardous and toxic materials (En_3)”.

The mean and standard deviation of the palm oil miller's Key Performance Indicators (KPI) of palm oil mill's sustainable supply chain management can be referred to in **Table 10**. The majority of the respondents (59.3%) agree that they have a “high extent” of KPI in “materials usage (KPI_5)”. About 44.4, 52.8, 42.6, and 37.0% also agree that they have a “high extent” in “Work in process (KPI_1)”, “Rate of Customer Complaint and Return (KPI_3)”, Acidification Potential (KPI_5), and Physical Load Index (KPI_6). While 43.5% of the respondents agree they are “neutral” in “EHS (environment, health, and safety).”

The mean and standard deviation distribution of the palm oil miller's level of SSCM against the sustainability indicators are summarized in **Table 11**. The highest mean of sustainability element is the Environmental Sustainability (4.04, sd: 0.1470),

TABLE 10 | Key Performance Indicators (KPI) of palm oil mill's SSCM.

Independent variables	Observed variables	1	2	3	4	5	Mean	SD
Key	Work in process (<i>KPI₁</i>)	4(3.7)	10(9.3)	33(30.6)	48(44.4)	13(12.0)	3.52	0.952
Performance	EHS (env, health and safety) expenses (<i>KPI₂</i>)	1(0.9)	8(7.4)	47(43.5)	46(42.6)	6(5.6)	3.44	0.753
Index	Rate of Customer Complaint and Return (<i>KPI₃</i>)	0(0)	2(1.9)	28(25.9)	57(52.8)	21(19.4)	3.90	0.723
	Materials usage (<i>KPI₄</i>)	1(0.9)	4(3.7)	19(17.6)	64(59.3)	20(18.5)	3.91	0.768
	Acidification Potential (<i>KPI₅</i>)	0(0)	2(1.9)	28(25.9)	46(42.6)	32(29.6)	4.00	0.797
	Physical Load Index (<i>KPI₆</i>)	2(1.9)	5(4.6)	35(32.4)	40(37.0)	26(24.1)	3.77	0.933

TABLE 11 | Descriptive statistics.

	N	Mean	SD
Economic Sustainability	108	3.42	0.5258
Social Sustainability	108	3.25	0.7385
Environmental Sustainability	108	4.04	0.1470
Key Performance Index (KPI)	108	3.76	0.6073

indicating that the respondents mostly tend to have slightly more than “great extent” answers for this particular item. While the rest of the items only indicate that they are “neutral” in demonstrating a considerable concern toward their stakeholders while emphasizing their sustainable improvement in supply chain management of their palm oil companies in the country. The second highest mean is the Key Performance Index (3.76, sd: 0.6073), followed by Economic Sustainability (3.42, sd: 0.5258) and Social Sustainability (3.25, sd: 0.7385).

Confirmatory Factor Analysis

A Confirmatory Factor Analysis (CFA) model is used to examine the hypothesized relationships between and among the constructs (factors) in the model (Figure 1). A relatively significant result was found concerning criteria implementations. The findings of the present study indicate that:

- (i) A positive relationship exists between the SSCM and economic sustainability indicators.
- (ii) A positive relationship exists between the SSCM and social sustainability indicators.
- (iii) A positive relationship exists between the SSCM and environmental sustainability indicators.

The Pearson Correlation test is carried out to measure the association between variables. Referring to Figure 1, it can be concluded that EN (Environment) contributes the most in explaining the relationship with dependent variable or KPI (77.3%), followed by SS (Social) (73.2%), and EC (Economic) (70.3%). The convergent validity test results include the coefficients and variance estimates between factors and variable loadings on the factors for each variable (refer to Table 12). Among the EC latent variables, this study found that the path coefficient of the “minimizes waste disposal expenses” obtained the highest value (0.78), followed by “minimum time spent on completing order” (0.76), “minimize operating costs”

(0.69), “able to respond to changes in delivery schedule” (0.69), “purchase eco-friendly materials” (0.68), and “on-time delivery” (0.68). Among the SS latent variables, the path coefficient of the “demonstrate concern for any social entity” and “enhance customer awareness of safe and healthy products” scored the highest value (0.70 respectively), followed by “enhance employees’ job satisfaction” (0.66), “minimize in employee’ work-related injury/ death” (0.65), “ensure employees’ education and training program” (0.64), and “enhance community relationship (i.e., with Government, or NGOs)” (0.61).

Among the EN latent variables, the path coefficient of the “efficient consumption of energy (electricity, etc.)” scored the highest value (0.86). This value is followed by “minimize using of hazardous and toxic materials” (0.84), “reduce producing of solid waste” (0.70), “evaluate suppliers in terms of quality, price, availability and speed” (0.69), “efficient use of renewable energy (rain, air, sunlight, etc.)” (0.66), and “reduce pollution due to smoke and waste” (0.56). Among the KPI latent variables, the path coefficient of the “materials usage” scored the highest (0.84), followed by “Acidification Potential” (0.83), “Physical Load Index” (0.78), “Rate of Customer Complaint and Return” (0.71), “EHS (environment, health, and safety)” (0.69), and “Work in process” (0.59).

Diagnostic Test of CFA

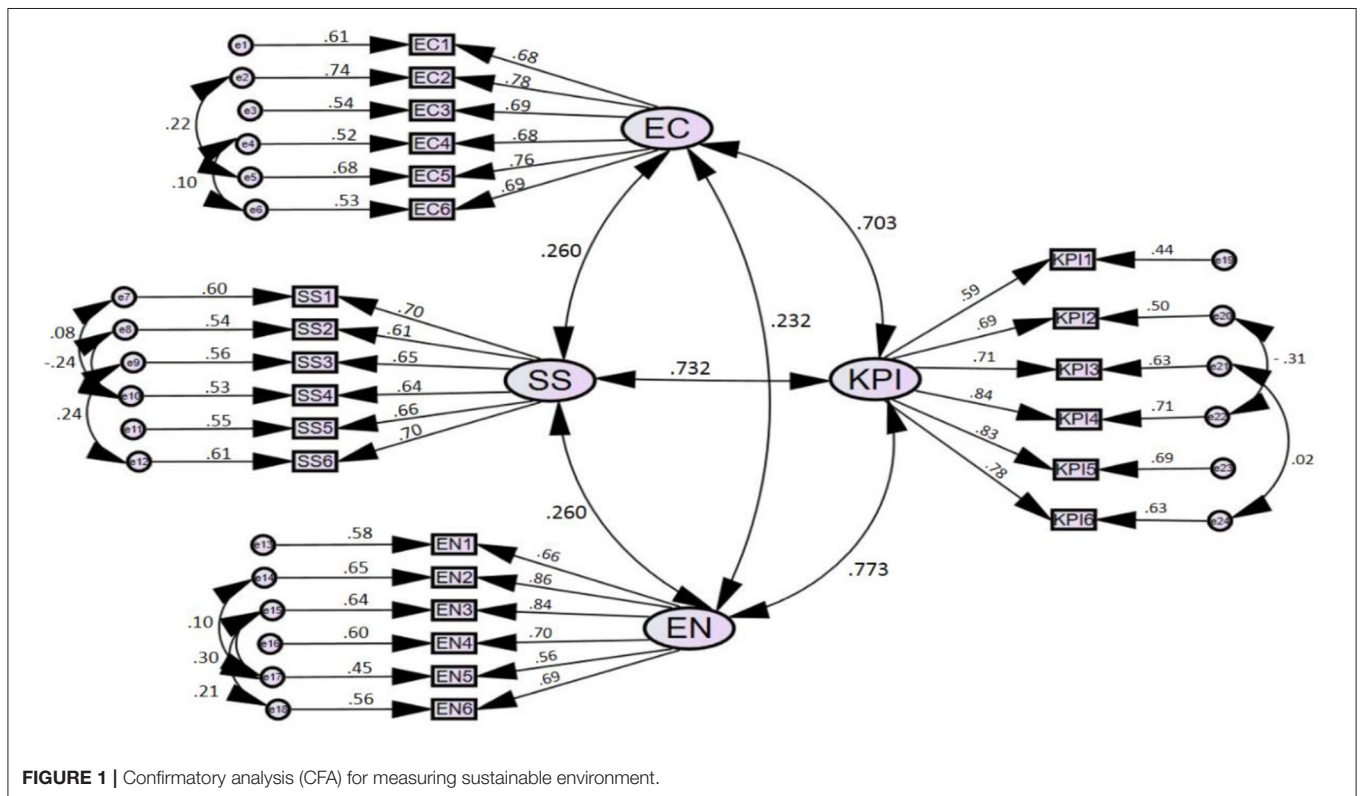
To govern the best fit of the model, some specific indicators were verified. Cronbach’s alpha is used to determine the reliability of the factors of three dimensions. The latent variable of the model contains Cronbach’s alpha values for the dimension at 0.897. Therefore, as directed by (Nunnally and Bernstein, 1994), the reliability level for the attitude toward the dimension fulfills the critical value of 0.7.

FINDINGS

This study has prioritized examining Indonesian palm oil mills’ sustainable supply chain management practices parameters. Environmental costs, rapidity, and adaptability are more suitable as the primary indicator to express the performance of SSCM of the palm oil industry, especially during and post-pandemic periods. These findings are aligned with those of Kamble et al. (2020). The first level is related to environmental costs, specifically minimizing waste disposal expenses. Secondly, it is also highlighted that rapidity, which refers to minimizing time spent on completing orders by the surveyed palm oil

TABLE 12 | Output summary of the confirmatory factor analysis (CFA).

Latent variable	Observed variable	Correlation (coefficient)	Effect (variance)
Economic Sustainability	EC ₁ = Purchase eco-friendly materials	0.68	0.61
Sustainability	EC ₂ = Minimize waste disposal expenses	0.78	0.74
	EC ₃ = Minimize operating costs	0.69	0.54
	EC ₄ = On-time delivery	0.68	0.52
	EC ₅ = Minimum time spent on completing order	0.76	0.68
	EC ₆ = Able to respond to changes in the delivery schedule	0.69	0.53
	Social Sustainability	S ₁ = Demonstrate concern for any social entity	0.70
Sustainability	S ₂ = Enhance community relationship (i.e., with Government, NGOs, etc.)	0.61	0.54
	S ₃ = Minimize in employee' work-related injury/ death	0.65	0.56
	S ₄ = Ensure employees' education and training program	0.64	0.53
	S ₅ = Enhance employees' job satisfaction	0.66	0.55
	S ₆ = Enhance customer awareness of safe and healthy products	0.70	0.61
	Environmental sustainability	En ₁ = Efficient use of renewable energy (rain, air, sunlight, etc.)	0.66
Sustainability	En ₂ = Efficient consumption of energy (electricity etc.)	0.86	0.65
	En ₃ = Minimize use of hazardous and toxic materials	0.84	0.64
	En ₄ = Reduce producing of solid waste	0.70	0.60
	En ₅ = Reduce pollution due to smoke and waste	0.56	0.45
	En ₆ = Evaluate suppliers in terms of quality, price, availability, and speed	0.69	0.56
	Key performance index	KPI ₁ = Work in process	0.59
Sustainability	KPI ₂ = EHS (env, health and safety) expenses	0.69	0.50
	KPI ₃ = Rate of Customer Complaint and Return	0.71	0.63
	KPI ₄ = Materials usage (KPI ₄)	0.84	0.71
	KPI ₅ = Acidification Potential (KPI ₅)	0.83	0.69
	KPI ₆ = Physical Load Index (KPI ₆)	0.78	0.63



mills, also generated positive economic sustainability, leading to SSCM in Indonesia. The third-ranking level of economic sustainability is environmental costs that involve minimizing operating costs and responding to changes in delivery schedule (adaptability). The fourth level includes purchasing eco-friendly material (environmental costs) and on-time delivery (rapidity).

From a social aspect, social development, workforce development, health, and safety workforce development, as well as consumer issues are the crucial indicators for assessing the performance of SSCM, which has been reflected in the study of Zimon et al. (2019) as well to ensure sustainable operational management. Implementation of all mechanisms and protocols of COVID-19 prevention must be continued to ensure employee health and human development. The first level is related to the social development indicator of demonstrating concern for any social entity and consumer issues, including enhancing customer awareness of safe and healthy products. The notion is consistent with the findings of the study by Esfahbodi et al. (2016), Rajeev et al. (2017), and Sroufe (2017). The second level includes enhancing employees' job satisfaction (workforce development), which is consistent with the study findings by Emamisaleh et al. (2018). The third level is health and safety, explicitly minimizing employee work-related injury or death. The fourth level is workforce development or ensuring an employee's education and training program. Lastly is social development, explicitly enhancing community relationships with government, NGOs, and the like.

From an environmental aspect, energy efficiency, material efficiency, waste and emissions management, and sustainable supplier management are the most preferred indicators for assessing the performance of SSCM. The first level is energy efficiency that refers explicitly to efficient consumption of energy. The second level is the material efficiency or minimizes use of hazardous and toxic materials. The notion is consistent with the findings of the study by Saeed and Kersten (2017). The third level involves reducing the production of solid waste (waste and emissions management). The fourth level is sustainable supplier management or specifically evaluates suppliers in terms of availability, commitment, timeliness, price, and quality. The fifth level is energy efficiency (efficient use of renewable energy like rain, air, sunlight, etc.). Therefore, companies must emphasize cultivating their suppliers' sustainability performance by refining flexibility, speed, quality, and dependability (Vural, 2015).

To summarize, environmental costs, rapidity, and adaptability are the primary economic indicators. The social aspect, social development, workforce development, health, and safety workforce development, and consumer issues are the crucial social indicators. Energy efficiency, material efficiency, waste and emissions management, and sustainable supplier management are the most preferred indicators for environmental aspects. Also, these are the key findings that are suitable as the primary indicator to express the performance of SSCM of the palm oil industry, especially during and post-pandemic periods. Studies addressing supply chain issues comprehensively on determinants to enhance SSCM performance from an economic, social, and environmental perspective specifically suited for pandemic-era

has not been carried out before. Thus, the baseline of SSCM assessment to compare against is peripheral.

DISCUSSION

Studies like the present one offer substantial opportunities for future sustainable palm oil supply chain management research, as it creates better managerial insights encompassing SSCM at the micro (individual mill), meso (group of mills), and macro (mill and supply chain) levels. It reveals that many millers have adequate knowledge of sustainability concerns of palm oil milling practices, especially in its supply chain. The study's findings will be helpful for the suppliers, partners, and customers of the palm oil sector to enhance the sectoral contribution to the Indonesian economy. The Indonesian government will better formulate policies to encourage the palm oil sector to perform better with the study's insights. The paper also offers functional academic implications as it uses the methodology and variables to operate and sustain in the pandemic and post-pandemic environments.

The contingency planning tools determined and discussed in this study will help the companies to survive by adjusting to the emergencies amid this pandemic. The findings infer that it is imperative to conduct customized demand drafting to assess suppliers for collaboration. Managers will benefit from the guideline to conduct continuous outreach on skills and health protocols of employees, on rapid, adaptable, and cost-effective customer service and efficient use of energy, material, waste, and emissions, and manage sustainable suppliers. The critical findings can be channeled to study the demand level and plan accordingly. At the same time, the findings can help evaluate the suppliers on the dimension of potential collaboration. The policymakers should also assist the palm oil supply chain stakeholders in resolving supply chain challenges during the pandemic and post-pandemic era.

The key strength of the present study is twofold. First is the replicability offered by the study. This paper showcases adequate background and transparency of information to the audience that the research can be repeated or 'replicated' in other contexts concerning supply chain management sustainability. Future researchers can test the findings of the research and either confirm or oppose the findings. Secondly, the relevance, clarity, and exciting questions included in the questionnaire made most of the respondents agree to participate in the survey and share their opinions. The questionnaire, being customized in their preferred language, which is Bahasa Indonesia, enhanced their understandability.

This study faces a couple of limitations too. First, the expert opinions of the survey mainly covered the palm oil companies, not from their value chain. Therefore, the opinions from the customers or suppliers remained unheard. It may include other stakeholders such as suppliers and clients to ensure that the determinants are more meaningfully catering to the interests of all supply chain actors and reveal a 360-degree portrait of sustainable supply chain management. Second, the study used Cronbach's alpha test from SPSS to test the model's reliability and did not conduct an in-depth analysis such as sensitivity analysis.

Hence, the study proposes a few cogent future research directions too. For instance, in the future, multiple-criteria decision-making (MCDM) methods or Fuzzy analytical hierarchy processes may be used to assess sustainable supply chain management practices. A sensitivity analysis can be conducted in the base model to make an in-depth analysis for future improvement. The researchers may also use a multi-criteria decision-making model or other mathematical models to analyze sustainable supply chain management practices targeting reducing environmental cost, enhancing rapidity and adaptability in scheduling and using eco-friendly materials, and increasing customer and supplier satisfaction. Also, an evaluation model may be used to study companies' performance considering the criteria of supply-chain and environmental collaboration and sustainable or green supply chain management practices.

CONCLUSION

This study provides a platform on the implications of the pandemic to assess the management of a sustainable palm oil supply chain in Indonesia. It has illustrated the significant challenges concerning the crude palm oil sector regarding the social, environmental, and economic issues following the COVID-19 pandemic. It also provides insight into Indonesian palm oil mills' sustainable supply chain management practices parameters suitable for application during and post-pandemic periods. To revive and improve supply chain performance, the companies must increase adaptability to the new schedule, use more eco-friendly materials, have rapid response time, emphasize workforce development, health and safety, resolve consumer issues, and sustainable supplier management. These indicators positively ensure resilience, efficiency, and agility.

The sustainability drivers to accommodate the pandemic-ridden environment were evaluated from the collective opinions of extant literature. The second study objective of investigating the role of sustainability indicators to improve the SSCM of the CPO sector was reached using statistical analysis tools

and subsequent analysis of the findings. It was revealed that moving toward sustainable practices would offer more significant managerial insights and incredible benefits to CPO businesses. Such consciousness parameters can impact the rejuvenation and sustainable images of the related companies.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

NH has composed the LR and methodology. KA has calculated and analyzed the responses. AL has suggested the idea. DN has helped collect the data. SW has reviewed the draft and improved. All authors contributed to the article and approved the submitted version.

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