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Measurement of key performance indicator Green Supply Chain Management (GSCM) in palm industry with green SCOR model

Masayu Rosyidah [a], Ninin Khoirunnisa [b], Umi Rofiatin [b], Asnah Asnah [c], Andiyan Andiyan [d,*], Dyana Sari [c]

[a] Industrial Engineering Study Program, Universitas Muhammadiyah, Palembang, South Sumatra 30263, Indonesia
[b] Agribusiness Study Program, Faculty of Agriculture, University of Tribhuwana Tunggadewi, Malang, East Java 65144, Indonesia
[c] Master of Agricultural Economics, Postgraduate School of University of Tribhuwana Tunggadewi, Malang, East Java 65144, Indonesia
[d] Architecture Study Program, Faculty of Science and Engineering, Universitas Faletehan, Bandung, West Java 40266, Indonesia

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ABSTRACT

SCOR (Supply Chain Operations Reference) model is a tool for diagnosing Supply Chain Management (SCM) that allows users to understand all processes in a business organization. This study aimed to analyze activities related to Green Supply Chain Management (GSCM), especially in the palm oil sector, and to determine the performance of Green Supply Chain Management (GSCM) at PT. Sutopo Lestari Jaya using the green score model. The results showed that the highest Green Objectives (GO) weight in environmentally friendly garden management was located on protected forest land used as plantation land by 38.82%, while waste minimization was found in Crude palm oil water content of 48%. Meanwhile, in minimizing and handling greenhouse gas emissions, the highest weight is found in the amount of fuel used in Fresh Fruit Bunch (FFB) shipments of 54.07%. For plantation management and palm oil management mills, the highest weight is in the percentage of water use per ton of FFB in PPKS 60.7%, while in waste management, the highest percentage lies in the standardized wastewater Biological Oxygen Demand (BOD) of 38.8%. In maximizing the use of new and renewable energy, the highest weight lies in renewable energy per tonne of FFB and the use of solid waste (empty shells and shells) as a substitute for fossil fuels of 45.5% each.

1. Introduction

From 2015 to 2019, oil palm plantation output increased. In 2018, Crude Palm Oil (CPO) output reached 42.88 million tons on 14.33 million hectares, rising to 48.42 million tons in 2019 on 14.60 million hectares [1]. Based on data from Statistics Indonesia, crude palm oil output reached 47.03 million tons in 2020, but it decreased to 46.88 million tons in 2021. The annual production quantity may have an environmental effect [2]. These adverse effects may come from plantation operations or industrial facilities since the procedures and trash may pollute the surrounding ecosystem [3]. The green concept's goal is to ensure the company's competitiveness while maintaining environmental sustainability [4]. The company's environmental concern may be achieved through reducing supply chain waste. According to Zero Waste, waste indicates inefficiency or hidden resources. A business may save money by reducing trash. The Zero Waste group uses a closed-loop strategy, so all raw materials utilized are products consumed by customers. Given the current environmental contamination issues, this study used a Green Supply Chain Management model to minimize waste and assess the environmental effects [5].

In a circular economy, Green Supply Chain Management (GSCM) is viewed as a solution to environmental issues and consumption habits across the supply chain. In an increasingly competitive market, GSCM performance is critical for environmental sustainability. The goal of GSCM is continuous improvement, and GSCM must achieve an optimum mix of environmental, economic, logistical, organizational, and marketing performance metrics. A new holistic performance assessment system combines the environment, the economy, logistics, operational performance, and marketing concepts [6]. The framework has three hierarchical

* Corresponding author.
E-mail address: andiyanarch@gmail.com (A. Andiyan).

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dimensions that contain primary criteria, sub-criteria, and stages for GSCM performance assessment. Green SCOR is a SCOR variant incorporating environmental concerns into the SCM process [7]. This research seeks to assess the performance of GSCM in the palm oil sector and analyze activities related to Green Supply Chain Management (GSCM), especially in the palm oil sector.

2. Literature review

2.1. Green Supply Chain Management (GSCM)

An economic paradigm that presently dominates industrial production systems in Asia, the circular economy is an essential alternative. This ancient approach has fueled extraordinary economic development. Material inputs and waste production must be reduced via eco-friendly design, product recycling and reuse, new business models, and new technologies. Circular products and manufacturing methods are required for efficient material processing, sorting, and recycling. Connecting people and products requires interactive platforms [8]. In recent decades, the circular economy (CE) has been a popular topic in both natural science and business literature. CE is a dual-loop regenerative technology that optimizes both environmental and economic performance. Dual CE efforts improve resource eco-efficiency and efficacy. CE impacts economic and operational benefits. This emphasizes the need to rethink the definition to evaluate better and develop the field's breadth and variety, as shown in Fig. 1 states about the circular economy cycle. This research showed that the significant highlighted components—organizational planning procedures, consumers and society, ecological use, and economic resource flow—provide a solid circular economy concept. It is also recommended that future CE research should focus on three areas: (1) circular design as value generation and capture, (2) antecedents of essential activities, and (3) outcomes of critical processes. There is a little empirical study on CE, and much of what is done is theoretical, conceptual, or normative. Few empirical studies are cross-sectional and concentrate on developing and emerging economies. The research concludes that developing CE projects is critical to the increasing digital transformation of the value chains. There is a lack of study on the circular economy and Industry 4.0. Future studies may examine the impact of digital transformation on CE deployment and digital performance management [9]. A closed-loop of materials and energy reduces waste, pollution, and energy consumption in a circular economy [10].

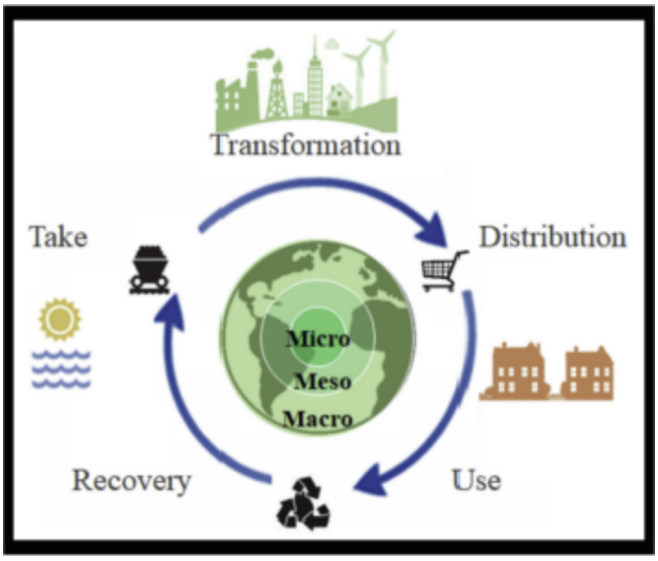

Fig. 1. Circular economy cycle.

Much study has been done to investigate the antecedents of green practices and their effects on businesses' economic and environmental performance. Environmental management concepts are applied to all supply chain operations, including design, sourcing, production, assembly, packaging, transportation, and distribution [11]. Environmental, economic, and social advantages are improved by reducing waste, pollution, and resource use [12]. Fig. 2 depicts a circular economy-based green supply chain [7].

Green Supply Chain Management is a recent idea. Green Supply Chain Management is a new creative SCM strategy essential for any business to achieve financial and environmental advantages concurrently to minimize adverse effects and hazards in the environment.

Green Supply Chain Management (GSCM) is a concept that aims to reduce waste, emissions, energy, and solid waste. As the concept of supply chain management covers all parties involved, such as suppliers, manufacturers, distributors, wholesalers, retailers, and so on, adding "green" to SCM includes several green activities in all their SCM operations [13]. Greener Supply Chain Management can incorporate environmental management principles throughout

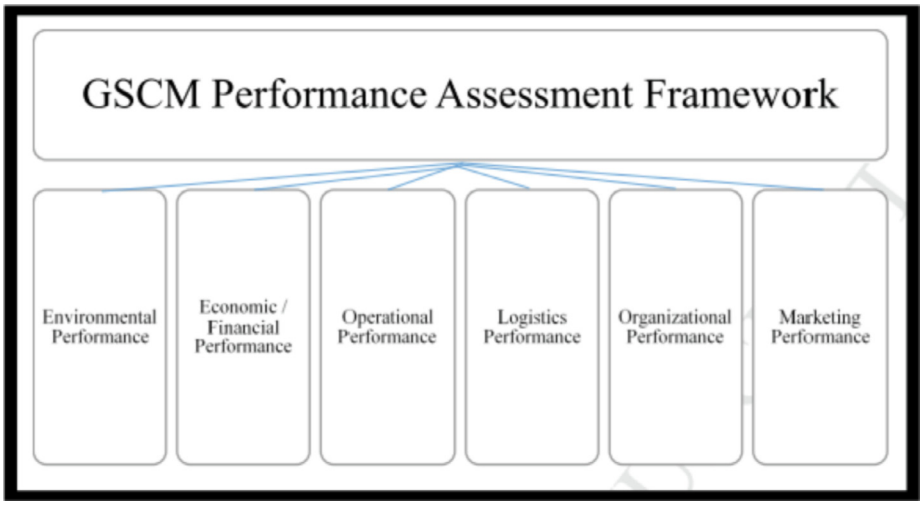

Fig. 2. Green supply chain management framework.

supply chain management to improve company profitability and market share goals [14,15].

Zhu and Sarkis describe Green Supply Chain Management as management that "closes the loop" from suppliers to manufacturers to consumers. However, according to another definition, Green Supply Chain Management incorporates environmental considerations into all aspects of the supply chain, from product creation to end-of-life management [16].

Green Supply Chain Management improves work operations by using environmentally friendly solutions:

a. Increase agility

GSCM helps to reduce risk and accelerate innovation.

b. Improve adaptation

GSCM analysis often results in innovative processes and continuous improvement.

c. Promotes harmony

GSCM includes discussing rules with suppliers and customers to improve business process alignment.

Table 1
SCOR process categories.

Category	Description
Plan	Processes associated with planning, scheduling, and coordinating supply chain activities
Source	Processes associated with procuring material, physically receiving material, and storing raw materials
Make	Processes associated with transforming raw material into a finished product. In defense maintenance, repair, and overhaul operations, the Make category is used to model maintenance activities
Deliver	Processes associated with storing, packaging, and delivering finished products to the customer
Return	Processes associated with delivering and receiving material from a customer to a supplier are commonly called reverse logistics
Enable	Processes that facilitate the movement of materials (e.g., business rules, data management, performance management, contract management, asset management, and compliance management)

2.2. Green SCOR

The Supply-Chain Council created the Supply Chain Operations Reference Model to provide a common framework for assessing, monitoring, and improving supply chain performance. The Supply Chain Council created the Supply Chain Operation Reference (SCOR) model (SCC) [17]. SCOR is a framework for defining supply chain operations from suppliers to consumers. This approach incorporates three key management elements: business process reengineering, benchmarking, and process measurement [18].

The green supply chain is critical to the industrial environment and industrial ecology. All supply chain operations have risks and adverse environmental effects. To preserve the environment, responsible supply chain management must address the ultimate and present environmental effects of all goods and activities, including:

1. Environmentally friendly design (green design).
2. Environmentally friendly manufacturing process (green manufacture).
3. Reverse logistics.
4. Waste management.

Measuring the Green Supply Chain's performance helps build an eco-friendly supply chain. SCOR categorizes the supply chain into the six groups indicated in Table 1.

These procedures are further subdivided into three tiers. Level 1 specifies the supply chain's scope and measures its competitiveness. It divides the chain into three main types:

- Make to stock
- Make to order
- Engineer to order

Level 3 specifies a supply chain's operations. These levels describe a company's performance using best practices and performance indicators. Fig. 3 depicts levels 1 and 2. Further process decomposition can be done if needed, although it is beyond the scope of the SCOR model.

SCOR procedures may be used to simulate supplier and customer interactions. As illustrated in Fig. 4, a user may use the same six high-level procedures to represent a complete supply chain.

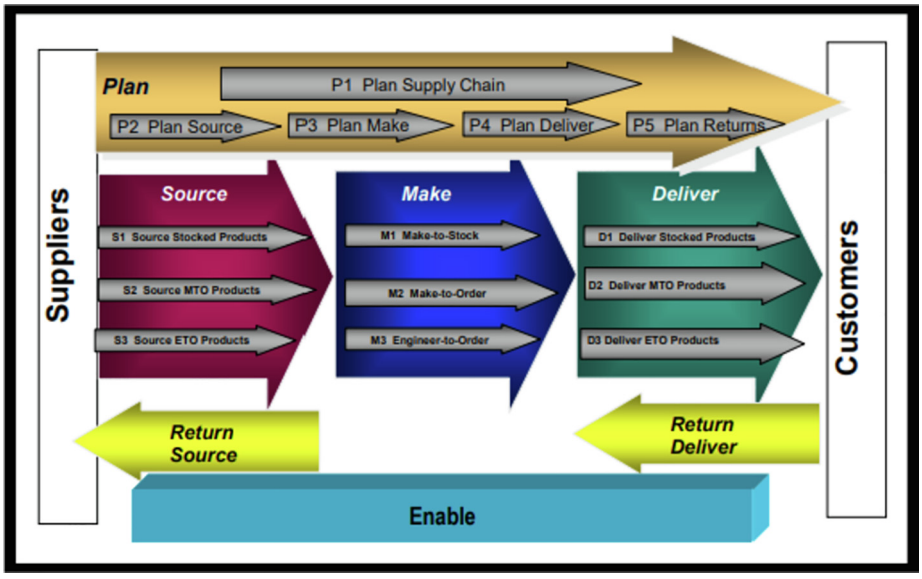

Fig. 3. SCOR process.

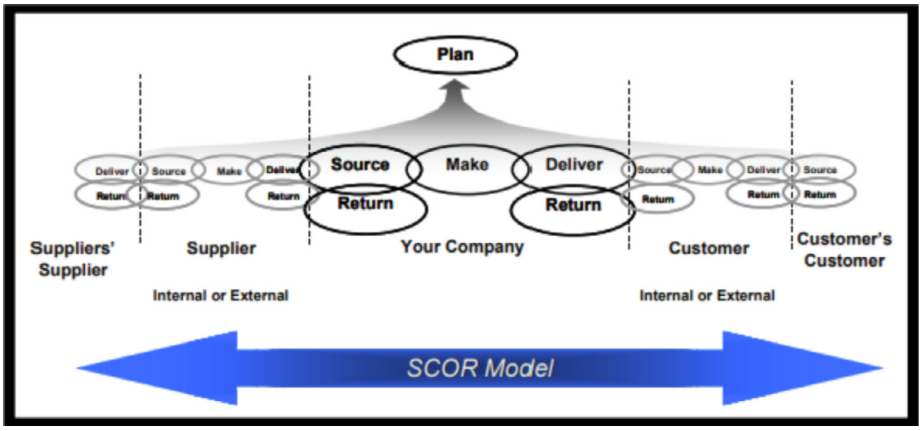

Fig. 4. SCOR depiction of end-to-end supply chain.

2.3. Key performance indicator (KPI)

According to Ulfa (2018), there are 6 main components in the Green SCOR model used in this study, including:

1. Plan is the initial stage carried out in the entire supply chain.
2. Source focuses on the process of procuring raw materials.
3. Make the process of making a product by considering its effect on the environment.
4. Deliver is a process to fulfill customer demand, including managing orders, transportation, and distribution.
5. Return is an activity to return products for various reasons.
6. Enable, enabling processes to support realization and governance planning and execution of supply chain processes.

A Green Supply Chain performance assessment system, includes Key Performance Indicators (KPI). KPIs are performance indicators for supply chains established by predetermined strategic goals(4).

3. Methods

For lean and green SCM performance assessment, this research phase focuses on observing and studying key indicators. This study was done in South Sumatra at a palm oil business. This study's data collection includes goods, raw materials, suppliers, manufacturing methods, and business marketing. Then the information for the parties involved (stakeholders) is required, as well as the requirements and contributions of each stakeholder in the company's supply chain. Observation, interviews, and expert verification were used to gather data. Interviews were performed to gather information about the company's current state, supply chain business procedures, raw material suppliers, manufacturing methods, transportation, and marketing of injection plastics. Expert verification is used to gather data and assess the importance of each indication. After experts verify the data, it will be processed with AHP (Analytic Hierarchy Process) method to determine the priority indicator.

4. Results

4.1. Palm oil industry supply chain system

This research was conducted in PT. Sutopo Lestari Jaya. Before identifying KPI, the researcher needed to analyze the whole supply chain system. So, Fig. 5 shows the supply chain system in this palm oil industry.

4.2. Green Objectives

Identifying key performance indicators (KPI) of lean and green supply chains are required to assess the palm oil industry's supply chain performance. The method used to select KPIs was based on assessing lean and green supply chain performance, documentation, and corporate conversations. Green aims are the environmental goals of all supply chain stakeholders, and Table 2 shows the palm oil industry's green goals.

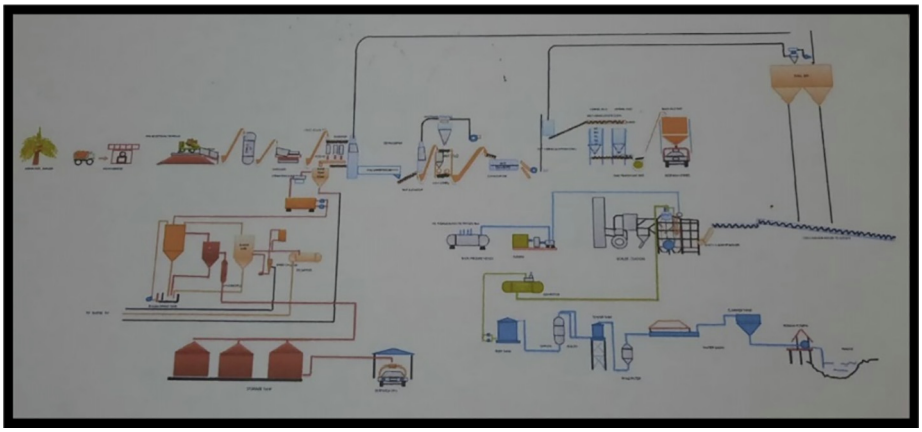

Fig. 5. Palm oil industry supply chain system.

Table 2
Green objectives of the palm oil industry supply chain.

Green objectives	Stakeholder
Environmentally friendly garden management	Garden, FFB supplier
Waste minimization	Processing section FFB (PPKS)
Crude Palm Oil (CPO) storage capable of maintaining low acidity levels (Low FFA)	Sales, Storage tank processing sub-section Crude Palm Oil (CPO)
Minimization and management of greenhouse gas emissions	Garden, transportation section, Crude Palm Oil (CPO) treatment section, sales
Management of plantations and mills certified by ISPO or RSPO	Garden, PPKS (FFB treatment)
Minimize the use of water and do not interfere with the community's water needs	Garden, PPKS
Waste treatment	Garden, Transportation Section, FFB treatment section (PPKS), salesman
Maximize the use of new renewable energy	Transportation, PPKS, sales
Consumer satisfaction related to Crude Palm Oil (CPO) products from the environmental aspect	Sales

FFB: Fresh Fruit Bunch; FFA: Free Fatty Acid; PPKS: Pusat Penelitian Kelapa Sawit; ISPO: Indonesia Sustainable Palm Oil; RSPO: Roundtable on Sustainable Palm Oil.

Table 3
Control hierarchy of the palm oil industry supply chain.

Green objectives	Stakeholder	Control hierarchy
Environmentally friendly garden management	Garden, FFB Supplier	Pay attention to protected forest land, the content, and disposal of toxic pesticides
Waste Minimization	FFB Treatment Section (PPKS)	Pay attention to the regimen and levels of Crude Palm Oil (CPO)
Crude Palm Oil (CPO) storage capable of maintaining low acidity (low FFA)	Salesman, Crude Palm Oil (CPO) Storage tank management sub-section Crude Palm Oil (CPO)	Pay attention to Crude Palm Oil (CPO) FFA levels
Minimization and management of greenhouse gas emissions	Gardens, transportation department, Crude Palm Oil (CPO) processing department, sales	Analyze greenhouse gas emissions, reduce fuel and emissions from Crude Palm Oil (CPO) shipments to consumers
Management of plantations and palm oil mills that are ISPO or RSPO certified	Garden, PPKS (FFB treatment)	Have certification from ISPO or RSPO
Minimize the use of water and do not interfere with the community's water needs	Garden, PPKS	Please pay attention to the percentage of water use and ensure that it does not interfere with community needs
Wastewater treatment	Garden, Transportation section, FFB treatment section (PPKS), sales	Pay attention to waste and waste disposal standards
Maximize the use of new renewable energy	Transportation, PPKS, sales	Must use renewable energy and utilize sound waste
Consumer satisfaction related to Crude Palm Oil (CPO) products from the environmental aspect	Sales	Must have a certified Crude Palm Oil (CPO) percentage

FFB: Fresh Fruit Bunch; FFA: Free Fatty Acid; PPKS: Pusat Penelitian Kelapa Sawit; ISPO: Indonesia Sustainable Palm Oil; RSPO: Roundtable on Sustainable Palm Oil.

Table 4
Palm Industry GSCM KPI Design.

Green objectives (GO)	KPI
Environmentally friendly garden management	Protected forest land used as plantation land
	The percentage level of toxic pesticide content
	Safe disposal of pesticide containers
	Forest fire prevention
	Irrigation practices that can minimize erosion
Waste Minimization	Crude Palm Oil (CPO) yield
	Water content in Crude Palm Oil (CPO)
Crude Palm Oil (CPO) storage capable of maintaining low acidity levels (Low FFA)	FFA Crude Palm Oil (CPO) content
Minimization and management of greenhouse gas emissions	Greenhouse gas emission
	Amount of fuel used in FFB delivery
	Percent emission from POME (Palm Oil Mill Effluent)
	Emissions from Crude Palm Oil (CPO) shipments to consumers
Management of plantations and palm oil mills that are ISPO or RSPO certified	Percentage of FFB from plantations that are ISPO or RSPO certified
Minimize the use of water and do not interfere with the community's water needs	percent of water use per ton FFB in PPKS
	The use of water in the garden does not interfere with the needs of the community
Waste management	BOD of wastewater according to standard
	COD of wastewater according to standard
	Safe storage of B3 waste
	Utilization of liquid waste for land applications
	Good waste disposal
Maximizing the use of new and renewable energy	Use of renewable energy per ton of FFB
	Utilization of solid waste (empty shells and shells) instead of fossil fuels
Consumer satisfaction related to Crude Palm Oil (CPO) products from the environmental aspect	% ISPO or RSPO certified Crude Palm Oil (CPO)

FFB: Fresh Fruit Bunch; FFA: Free Fatty Acid; PPKS: Pusat Penelitian Kelapa Sawit; ISPO: Indonesia Sustainable Palm Oil; RSPO: Roundtable on Sustainable Palm Oil.

Table 5
The results of the questionnaire to the expert resulted.

Environmentally friendly garden management	Protected forest land used as plantation land	The percentage level of toxic pesticide content	Safe disposal of pesticide containers	Forest fire prevention	Irrigation practices that can minimize erosion
Protected forest land used as plantation land	0,366	0,474	0,649	0,352	0,1
Percentage level of toxic pesticide content	0,122	0,158	0,13	0,211	0,1
Safe disposal of pesticide containers	0,073	0,158	0,13	0,352	0,2
Forest fire prevention	0,073	0,053	0,026	0,07	0,5
Irrigation practices that can minimize erosion	0,365854	0,157895	0,064935	0,014085	0,1
Total	0,999854	1,000895	0,999935	0,999085	1

Table 6
Vector normalization of weights key performance indicators human resources for environmentally friendly garden management.

Environmentally friendly garden management	Protected forest land	Percentage level	Disposal of containers	Forest fire prevention	Irrigation practice	Total	Quality
Protected forest land used as plantation land	0,366	0,474	0,649	0,352	0,1	1,941	0,3882
Percentage level of toxic pesticide content	0,122	0,158	0,13	0,211	0,1	0,721	0,144197
Safe disposal of pesticide containers	0,073	0,158	0,13	0,352	0,2	0,913	0,18261
Forest fire prevention	0,073	0,053	0,026	0,07	0,5	0,722	0,14444
Irrigation practices that can minimize erosion	0,366	0,158	0,065	0,014	0,1	0,703	0,140554

Businesses and specialists then verify the indications. Verification is carried out to verify the indicators' appropriateness to the current supply chain system and may be used in all palm oil processing businesses. The solutions in Table 3 also control possible risks.

Palm Industry KPI SCM Design Table 4 shows the KPIs for the manufacturing sector by reducing the green goals that have been established.

After forming the hierarchy, the significance level's weight is calculated. Three palm oil industry specialists gave a pairwise comparison questionnaire comparing indicators. The experts took their time filling out the questionnaire based on their palm oil expertise. Comparing KPIs is done on a 1–9 scale (1 = equal, 3 = moderate, 5 = strong, 7 = very strong, and 9 = extreme). The consistency ratio (CR) is used to verify the comparison. If the CR is less than 1, the comparison is valid. The pairwise comparison is consistent since the CR value is 0.01674 and 0.09568. This demonstrates that experts consistently weigh the palm oil industry's green supply chain management KPI.

The table below shows how to calculate ecologically friendly garden management for green goals (GO) (see Table 5).

The normalized eigenvectors are calculated by adding each row and dividing by the criteria. Table 6 shows the normalizing vector findings.

5. Conclusion

1. Plantation and factory management, waste management, maximizing the use of new and renewable energy, and consumer satisfaction related to Crude Palm Oil (CPO) products are all examples of Green Supply Chain Management (GSCM) in palm oil industry.
2. Protected forest area is utilized as plantation land by 38.82 percent, whereas waste reduction has a water content of 48 percent in Crude Palm Oil (CPO). The fuel used in FFB shipments is responsible for 54.07 percent of total greenhouse gas emissions. The most significant percentage of water consumption per tonne of FFB in PPKS is 60.7 percent, whereas the highest percentage of wastewater BOD is 38.8 percent. The most significant weight is given to the use of renewable energy per ton of FFB and solid waste (empty shells and leaves) as a fossil fuel replacement (45.5%).

CRediT authorship contribution statement

Masayu Rosyidah: Conceptualization. **Ninin Khoirunnisa:** Data curation. **Umi Rofiatin:** Formal analysis, Funding acquisition, Investigation, Methodology, Project administration. **Asnah Asnah:** Resources, Software, Supervision. **Dyana Sari:** Validation, Visualization. **Andiyan Andiyan:** Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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

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