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Sustainability and profitability of Malaysia crude palm oil supply chain management: system dynamics modelling approach

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Abstract

Purpose – The agriculture industry has a considerable impact on Malaysia's economy, as seen by its contribution of roughly 8.2% of gross domestic product in 2018 and its potential to absorb 11.09% of Malaysian labor in the same year. This study aims to simulate rising output in a system model of sustainable

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and profitable crude palm oil (CPO) supply chain management (SCM) and to formulate policy solutions to build sustainable and profitable SCM of Malaysian CPO.

Design/methodology/approach – This research included both primary and secondary data. This study used the dynamic system model to simulate palm oil land expansion, replanting policies and environmentally friendly growing techniques.

Findings – This study's findings suggest that the dynamic system model of Malaysia's CPO's sustainable and profitable SCM is valid when its structure and performance are tested. The fifth scenario provides the best results, with the most significant net benefit value compared to the other scenarios.

Originality/value – The ideal policy alternative is replanting sustainable agricultural practices without burning technologies during new land clearing to achieve the best net advantages.

Keywords Supply chain management, Crude palm oil, Profitability, Sustainability, Malaysia

Paper type Research paper

1. Introduction

The agriculture sector in Malaysia is vital to the country's economy. This sector's substantial contribution to the gross domestic product (GDP) was reflected in the size of the labor force it absorbed (GDP). In 2018, the agricultural business had the potential to absorb 11.09% of the total labor force (Statista, 2019). In the same year, it contributed 8.2% of GDP, or RM 99.5bn [2]. Agriculture is a comparatively robust sector in confrontation crunches of economy and reliable in recovering the Malaysian economy. The total oil palm planted area reached 5.9 million hectares by the end of 2019. This area produced 19.86 million tons of crude palm oil (CPO) in the same year. Now CPO is the biggest cultivated crop in Malaysia and the most significant edible oil traded in the world (MPOB, 2020). CPO contributed to the agricultural sector's GDP in 2018 at 37.9%, whereas plantations contributed approximately 6.9% (Department of Statistics Malaysia, 2019).

Palm oil is Malaysia's export commodity, critical to Malaysian national income and a significant contributor to GDP in the agricultural sector. Malaysia is a major producer and exporter of palm oil goods worldwide (Statista, 2019). It is the world's most traded vegetable oil. As consumer incomes rise and the population rises, demand for palm oil will likely climb. Previous research has revealed that the palm oil business has environmental consequences that impact social situations (Qaim *et al.*, 2020). As a result, this study uses a dynamic systems approach to examine supply chain management (SCM) in the Malaysian CPO industry regarding profitability and long-term viability. To put it another way, this research will look at the critical aspects of profitability and long-term SCM, which will help improve SCM performance while also giving theoretical support for future research.

In combination with the current social development situation in Malaysia, the social development in Malaysia is primarily restricted by the level of agricultural management. Given that CPO is the highest yield contribution to the agricultural economy in Malaysia, agricultural management will directly affect the profitability and sustainable development of the CPO SCM industry (Agriculture and Food Global and Practice, 2019). So improving the current SCM system to promote the healthy development of the agricultural economy as soon as possible is essential.

Using an SCM methodology appropriate for the Malaysian palm oil sector, to achieve profitable and sustainable development, this study provides important insight into key variables that enable managers or SC practitioners to understand better factors that affect SCM sustainability and profitability. This information is always helpful for the industry, especially for companies that plan to implement this approach. As research on the sustainability and profitability of SCM practices is scarce, extensive research on the profitability and sustainability of the CPO industry will help the Malaysian Government and policymakers to implement or propose new policies on this issue in the future. Therefore, this study hopes to make a valuable contribution to the CPO SC industry and provide policy and decision-making references for relevant governments and industry departments.

The rapid growth of this business raises numerous concerns regarding the palm oil industry's long-term sustainability. International nongovernmental groups have issued complaints and critical findings on the sustainability of the Southeast Asian palm oil industry (Department of Statistics Malaysia, 2019; MPOB, 2020; Statista, 2019). Malaysia, as one of the world's leading producers of palm oil, has been accused of using unsustainable methods to promote the sector (Department of Statistics Malaysia, 2019; MPOB, 2020; Statista, 2019). As a result, one of the current study's issues is the use of burning methods as the quickest and cheapest method of clearing the land of plantations. The other problem of this study represented the unsustainable practices through the energy consumption from fossil fuels used by the transportation sector in the Malaysian palm oil industry. Deforestation and transportation are the main contributors to greenhouse gas (GHG) emissions caused by increasing global and domestic CPO demand. Therefore, the questions that will be explored in this study are as follows. How can we learn about the current state of SCM in the Malaysian CPO sector? How can we model a situation where CPO's production capacity is steadily expanded while profit margins remain stable? How can Malaysian CPO SCM be improved by developing new policies? How can we increase profitability and promote sustainable growth in Malaysia's CPO industry?

This study offers significant insight into important vital variables to help SC managers or other practitioners better understand the variables that influence SCM. It is founded on an SCM model appropriate for the profitable and sustainable development of Malaysia's palm oil industry. The industry always benefits from profitability and long-term viability, especially for companies that intend to use this strategy in the future. Significant research on the profitability and viability of the CPO business will help the Malaysian Government and policymakers implement or challenge this in future new policies. There are few studies on SCM strategies' long-term viability and profitability. Therefore, our research adds value to the CPO SC sector by providing the resources required for policy and decision-making to government and industry departments.

2. Literature review

The biomass production sector is expanding in the developing nation because of its vision and industry for environmental, economic and social growth (FAO, 2018). According to Patwary (2022) data, Malaysia's planted palm oil area has risen by nearly 50,000 hectares in the last year. In 2008, the cultivated area was 4.49 million hectares and enlarged to 5.64 million hectares in 2015. In 2019, palm oil's planted area reached 5.9 million hectares (MPOB, 2015, 2016, 2017, 2020).

The study results of Rahman *et al.* reported that Malaysia's CPO competitiveness is significantly high [9]. However, a suitable strategy is to boost CPO production, particularly considering their derivative products. The issue confronted by the industry of CPO is the profitable sustainability of the SC. Al-Odeh and Smallwood (2012), De Brito and Van der Laan (2010), Morais and Silvestre (2017), Rahman *et al.* (2014), Seuring and Müller, (2008) had performed studies related to SC. Al-Odeh and Smallwood; and Seuring and Muller made a literature review about sustainable SCM as numerous as 237 writings issued from 1995 to 2011 (MPOB, 2016; Patwary *et al.*, 2020; Rahman *et al.*, 2014). Al-Odeh and Smallwood checked out the studies on sustainable SCM in the latest decade by analyzing them from various perspectives (Al-Odeh and Smallwood, 2012). Assumpção urges company efforts to incorporate green practices into the slim-SCM to respond to environmental issues (Assumpção *et al.*, 2019). Even though there have been numerous research studies on palm oil, only a few have looked into SCM's viability and sustainability in Malaysia. Furthermore, only one study used dynamic systems models as a research tool, and most previous studies focused on Indonesia rather than Malaysia. Also, that study did not address the profitability and transportation cost issues.

The palm-oil SC frequently confronts the sustainability problem because of the assumption that planting palm causes land deterioration and soil erosion, GHG emissions, social conflicts and human rights violations (Awang Ali *et al.*, 2013; Colchester, 2011; Schrier-uijl *et al.*, 2013; Taheripour and Tyner, 2020; Valin *et al.*, 2015; Wicke *et al.*, 2011). To meet domestic and overseas demands, Malaysia is still expanding by clearing lands for new palm plantations, leading to deforestation. Palm plantation expansion is still considered the main factor for deforesting in Malaysia (Vijay *et al.*, 2016). Since 2010, many food industry corporations have said they will no longer work with palm-oil companies involved in deforestation in Malaysia (Alom *et al.*, 2019; Vijay *et al.*, 2016). Deforestation causes environmental deterioration and loss of many animals and plants because of losing their habitat, increasing GHG emissions and decreasing the water volume in the cloud that is supposed to be raindrops, which causes more dry soil and an inability to grow crops. Subsequently, deforestation effects encompass soil erosion and coastal flooding. In addition, deforestation also increases environmental pollution due to the high usage of fertilizer and pesticides; it also has a different adverse effect on the ecological function induced by the tropical forest environment when farms substitute forests and peat lands (Okia, 2012).

Another issue is the assumption that burning forests is the quickest and cheapest way to clear plantation land (Noor, 2003). Juárez-Orozco *et al.* (2017) mentioned that land clearing for plantations was the most likely cause of forest fires and other wildfires in Malaysia. They occur due to cleaning practices for creating a palm oil farm by burning the trees to make it quick and economical. It influences human life, health, subsistence, habitat and biodiversity and likely increases global warming (Varkkey, 2011). From 1990 to 2010, Malaysia lost nearly 96,000 hectares (0.43% annually). Generally, it lost approximately 8.6% (1,920,000 hectares) of total forests (Raihana *et al.*, 2018). Forest conversion into oil palm farms drives significant CO_2 emissions. One hectare of converted forest causes losing 174 tons of carbon, which will find its way into the air as CO_2 (Guillaume *et al.*, 2018). The World Bank (2017) estimated that the social cost of carbon was over $42 per ton (RM170) in 2010, and it is expected to reach $50 (RM 203) in 2030. It also cited a current figure of $40–$80 for every ton of CO_2 necessary to reduce emissions pollution effects to be regular with the temperature aims decided in the Paris Agreement.

However, increased productivity due to land conversion will promote labor assimilation, social affluence and economic development, especially in rural areas (Azman *et al.*, 2015; Otieno *et al.*, 2016). Poverty in the agriculture industry fell from 68.3% in 1970 to 11.8% in 1997. Oil palm smallholders had a slower rate of poverty reduction than other sub-sectors (Awang Ali *et al.*, 2013). Besides, this industry contribution is nearly 5%–7% of GDP, with export income averaging RM 64.24bn per year (Nambiappan *et al.*, 2018). To improve the reputation related to sustainability issues, Malaysia's Government has enacted several critical agricultural measures, including a 6.5-million-hectare acreage cap. According to Malaysian Primary Industries Minister Teresa Kok, the rules include prohibiting palm oil cultivation in new peat-land areas and tightening controls for actual oil palm growing on peat soil (Bernama, 2019).

Transportation is an essential factor in the SCM of palm oil (Arshad *et al.*, 2019). Deforestation is the dominant contributor to GHG in the atmosphere; however, transportation is also one of GHG's primary sources from fossil-fuel burning (Patwary *et al.*, 2022a; Perera, 2017). Transportation accounts for more than a quarter of global CO_2 emissions (Ritchie and Roser, 2020). CO_2 emissions have the potential to harm both humans and the environment. Flooding and drought are among the effects of climate change on the ecosystem, as are decreased food production, the extinction of marine life and a reduction in freshwater availability [33]. During transportation, a large share of energy is used. Ghadimzadeh *et al.*, in their review on CO_2 emission from transport in Malaysia, pointed out that the energy-consumption trend induced by the transport sector had been increasing [34]. In our model, highlighting the diesel consumption of the transport sector in the Malaysian CPO industry is beneficial for calculating CO_2 emissions from fuel consumption for transportation during the CPO SC. As a result, the findings of this study could be used to improve sustainable transportation regulations aimed at reducing the transportation sector's impact on the environment in Malaysia via the CPO industry.

Though financial gain is the key motivator for palm oil producers to use the SC, it is uncertain whether the new sustainable practices that go along with it are profitable. The current profitability of the palm oil SC is also critical, and future profitability is unknown unless sustainable SC policies are implemented (Borrello *et al.*, 2019; Choong and McKay, 2013; Muzayanah *et al.*, 2018). As a result, the palm oil industry's difficulty reflects SCM's profitability and viability. From the plantation and transportation perspectives, this study examined if SCM is economical and sustainable for the Malaysian palm oil sector. As previously said, this industry is confronted with a significant environmental concern that has societal ramifications. According to Muzayanah *et al.* (2018), managing natural resources, which includes the sustainability of CPO's SC, is challenging due to its dynamic and uncertain nature and its contradicted objectives (environmental, social and economy).

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The Malaysian palm oil industry has not been studied the same way as other industries such as automotive, electrical and electronics, food retail, SMEs and packaging (Amann *et al.*, 2014; Ellram and Cooper, 1993; Khang *et al.*, 2010; Kot, 2018; Laurin and Fantazy, 2017; Li *et al.*, 2022; Lopes de Sousa Jabbour *et al.*, 2011; Mustaffa and Potter, 2009; Olugu *et al.*, 2017; Rabiul *et al.*, 2022; Sohal *et al.*, 2002; Spina *et al.*, 2015; Sundram *et al.*, 2011; Teuscher *et al.*, 2006; Turker and Altuntas, 2014; Vorst, 2000). The findings of this study will contribute to closing the knowledge gap in Malaysia about SCs and present in-depth data on the sustainability and profitability of Malaysian industrial SCM techniques using quantitative methodologies such as dynamic system models.

As a result, the natural resources debate could be a viable alternative to the dynamic system approach. The dynamic system model then discusses sustainable and profitable SCM for Malaysia's CPO production. Simulating sustainable production increase scenarios on the CPO's sustainable and profitable SCM and formulating alternate strategies to boost CPO's sustainable SCM in Malaysia are the study's objectives.

3. Materials and methods

Primary and secondary data were used in this investigation. The Malaysian Palm Oil Board supplied the original data (MPOB, 2020). After that, the model was emailed to specialists to confirm the forming models' systematic thinking. The data collection mechanism was designed with the knowledge and experience of the respondents in mind. Secondary data was gathered by reading and seeing various publications and previous studies linked to this study, such as books, reviews, articles and the internet.

A system dynamics model shows a system as a collection of stocks and flows. State changes occur continuously throughout time in the stock-and-flow paradigm. In the model, you may specify the relationships between the variables and examine the dynamic characteristics between them. These connections are used to create mathematical equations that can be used to perform simulations. Using system dynamic in this study allowed for an in-depth examination of the palm oil industry's sustainable and profitable production from the replanting and transportation perspectives. Several interconnected factors contribute to the issue, including land, labor, demand, diesel use and CO_2 emissions. System dynamics enables us to simulate and test a CPO production system that includes managerial, ecological, social and economic elements, as well as simulation models that can help us understand the dynamics of oil palm production composite systems and test different strategies for ensuring their long-term viability (Ibragimov *et al.*, 2019).

Vensim is an interactive platform for creating, investigating, analyzing and perfecting simulation models. Model quality and comprehension are enhanced by its features, developed with expert modelers in mind. Even though its creators never intended Vensim to be used in a classroom setting, the program has proven to be entertaining and instructive for students just starting. Currently, work is being done to facilitate deployment as a learning environment, emphasizing imparting knowledge (Zahraee *et al.*, 2019, 2022; Zlatanovic, 2012). Because VENSIM is a premier simulation modeling software for SCM, we used it to simulate the system. VENSIM is a simple modeling tool for creating, analyzing and simulating dynamic system models. It allowed us to create oil palm industry causal loop and stock-and-flow graphs. The arrows reflect causal links and capture correlations between system variables. Equation Editor 1 has that interface to assist in the creation of an empirical model. As a result, we built our oil palm model by considering the cause and effect of variables and their feedback loops. To investigate the system's behaviors, a verified model on the VENSIM interface can be used. Eberlein and Peterson provide more information about VENSIM (1992). This software has been used in several studies that model and simulate SC stages, including some that look at environmental issues [26–29]. This program simulates one or more variables that vary over time. It also has a graphical interface for modeling complicated environments and the ability to test and explore scenarios and watch system behavior over time at any degree of detail. In addition, collecting the intricacies of known processes allows for a more precise forecast. VENSIM is used in our research to give decision-makers a flexible way to understand how complicated linkages in the CPO SCM work in a variety of "what-if" scenarios with system uncertainties.

This study used the dynamic system model to process and analyze data. The model was used to simulate an increase in production by regenerating and lowering the environmental cost of palm oil plantation and transportation. Furthermore, it was simulated by implementing a no-burn strategy on palm oil plantation openings and lowering diesel energy consumption to reduce CO_2 emissions caused by these practices. The dynamic model is a simplified and abstracted representation of a complex system, but it aims to describe the system accurately. Furthermore, the scenario simulation of policy is carried out based on the logically created supposition by taking a stand on the acquired dynamic model [38]. The model for this study will be built using working time sequence data, principles, information and government policy on palm oil, as well as references to several models that have enhanced CPO and other commodities. Figure 1 depicts the study's framework diagrammatically.

3.1 Problem formulation

The system should be thoroughly understood before specifying and expressing the problem. In the case of palm oil, SCM's concern is that increased palm oil production due to plantation expansion will also boost CPO sector income and labor absorption. However, increased output means more CPO transportation, which means more CO_2 emissions into the atmosphere. As a result, increasing CPO production by expanding palm oil plantations increases CPO industry profitability and palm oil plantation labor absorption, which is a problem with palm oil SCM. Expanding palm oil plantations, on the other hand, will exacerbate environmental degradation and increase environmental costs.

3.2 Model conceptualization

This procedure entails identifying the members involved in this system, forming a causal loop and analyzing the system's limitations by using the relationships between the members. The restriction is used to make monitoring the analyzed system easier. The next step is to draw a causal-loop diagram, as shown in Figure 2. The causal loop diagram was created based on Muzayanah *et al.* (2018) research. Model formulization signifies transforming the relationships between elements or members into the programming language (computer language). In the current study, system subdividing was made to give range limitations for the steps carried out. In such research, the sub-models involve the production policies, social, environmental and economic sub-models (Figure 3).

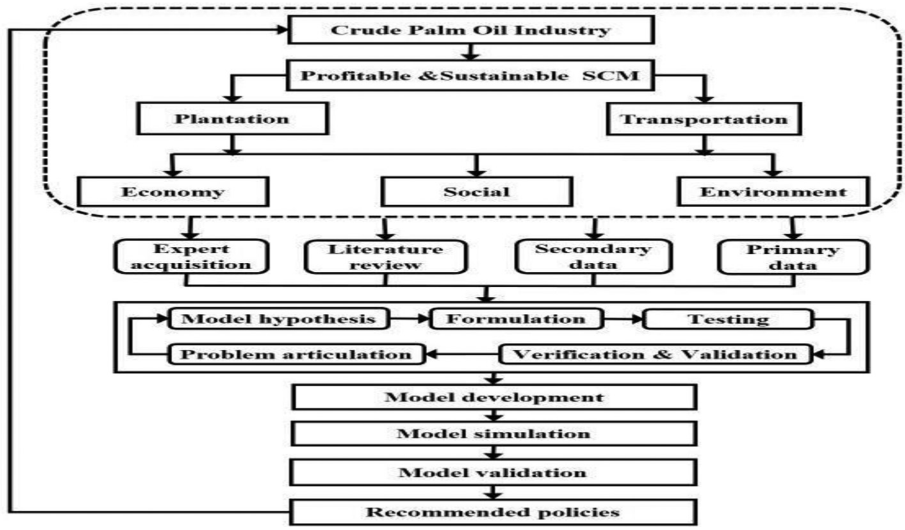

Figure 1.
Research conceptual framework

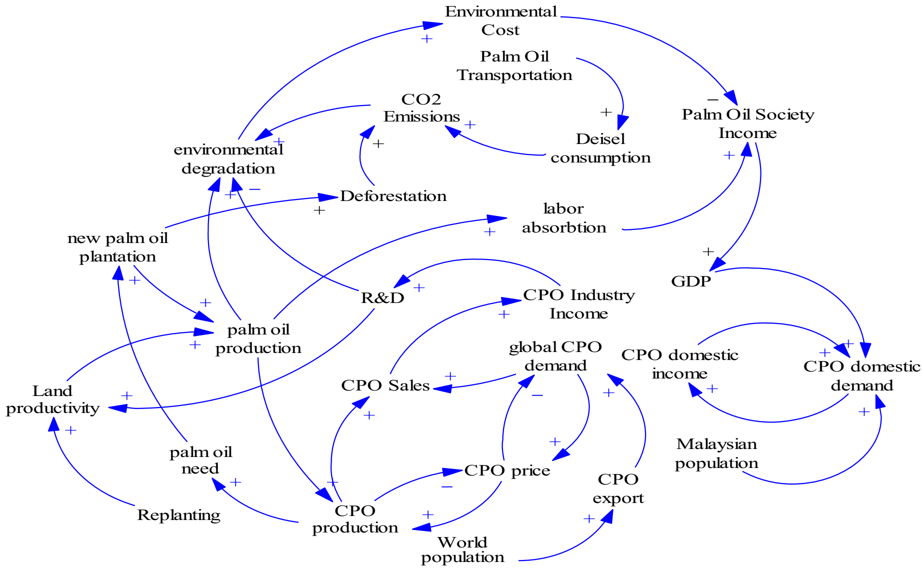

Figure 2.
Causal-loop diagram of CPO SCM

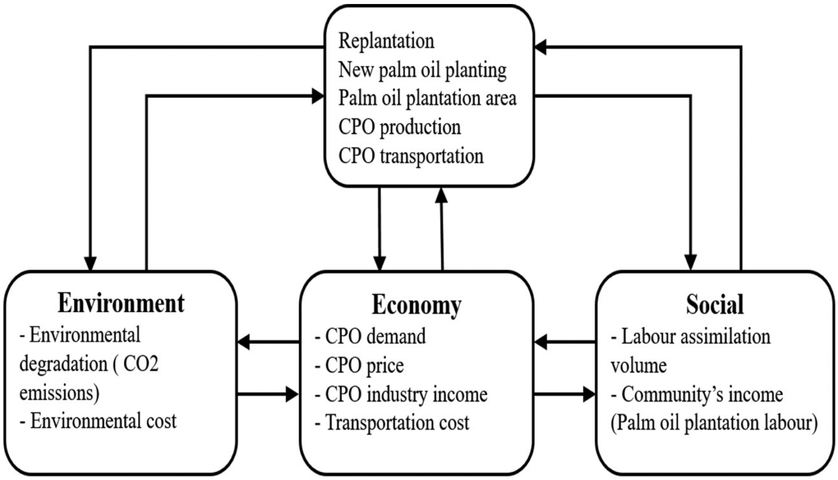

Figure 3.
Experimental research model

4. Results

4.1 System dynamic model of Malaysia's crude palm oil sustainable and profitable supply chain management

The model in this study has been divided into five sub-models as follows:

(1) Production policy sub-model.

In this sub-model, the land area used for palm plantation is divided by biomass production system based on the plant's conditions. At the beginning of the model's formation, it was presumed that there was no suspension yet. Through this sub-model, CPO production annually will be measurable with control variables from production policies, land expansion of palm plantation, replanting and land clearing for planting new palm.

(2) Social policy sub-model.

Palm plantation leads to many beneficial and unbeneficial social effects. The beneficial effects contain absorbing domestic labor, boosting the domestic economy and increasing farmers' income [16], [44]–[46].

(3) Economic policy sub-model.

This sub-model has been evolved by variables such as demand and income of the CPO industry. Overseas and local markets were differentiated. CPO demand outside Malaysia is assumed to be grown along with the world's increasing population. According to Li *et al.* (2022), palm oil demand is predicted to rise in line with global population growth, affluence, and the current state of the biofuel sector. As Malaysia's population grows, domestic consumption is expected to rise in tandem with the demand for biodiesel and cooking oil [47]. With the alteration of previous historical data, it is assumed that CPO and diesel prices will reduce or increase arbitrarily.

(4) Environment policy sub-model.

This sub-model concentrates on CO_2 emissions from forest fires and diesel consumption in CPO transportation. The CO_2 emission cost data for each ton were derived from Stanton and Fisher's forecasting data (2015). Carbon allowances, carbon taxes or the marginal abasement cost of carbon might all be used to cover this expense. CO_2 emission cost, according to Patwary *et al.* (2022), is the overall cost of emitting one ton of CO_2 into the atmosphere. Because of land conversion and CPO shipping, the environmental sub-model in this study shows how the establishment of new palm farms could boost carbon dioxide emissions.

4.2 Stock-flow of supply chain management in the system dynamics model

Closed-loop and stock-flow diagrams are illustrated based on the causal logic thinking and the dynamic system approach, which is elucidated as a whole in Figure 4.

The changes in CPO production values, labor absorption, environmental cost, CPO transportation cost, and net benefit were evident in the study's five-scenario simulation results. The net benefit value of this study was based only on the cash created by the CPO industry from CPO sales, society's income from labor wages, the cost of CO_2 emissions and the cost of replanting and land clearing:

- CPO production.

The simulation results revealed that the fifth scenario simulation yielded the best value of CPO output, implying that the highest-value production was derived through the policy of replanting based on needs. The lowest CPO output value was obtained in the second scenario, which reduced the average annual expansion of the palm planted area by 10% while maintaining the current yearly replantation percentage. Productivity would rise due to the expansion policy for new palm plantations, and CPO production would also rise. It is assumed that the value of CPO production will decrease by limiting land expansion. The changes in CPO production between the five scenarios are depicted in Figure 5.

- Labor absorption.

The labor absorption was shown in simulation results in scenarios 2, 3 and 4, which were likewise the lowest. Due to a decrease in the yearly average of new palm plantations, which reduces labor absorption, the first and fifth scenarios were similar but more significant than the

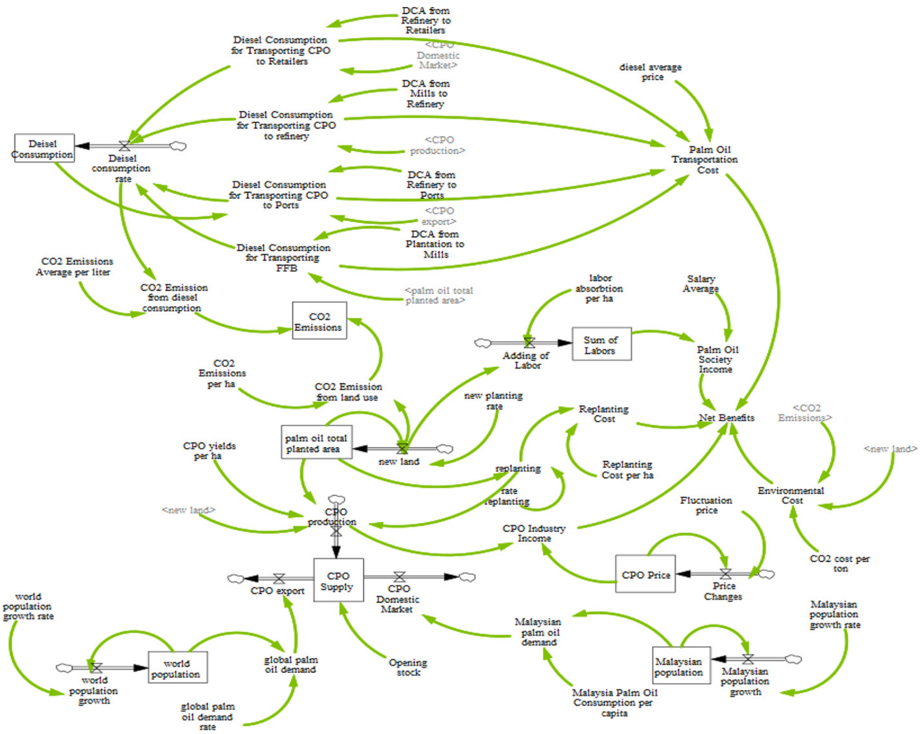

Figure 4.
The system dynamic model of Malaysia's CPO sustainable and profitable SCM

other three scenarios. The lower the rate of new palm expansion, the lower the rate of labor absorption. The changes in labor absorption value among the five scenarios are depicted in Figure 6.

- Environmental cost.

The modeling findings revealed that Scenarios 4 and 5, which implemented environmentally friendly land removal (without fire), had the lowest environmental cost. It demonstrated that an environmentally friendly new land clearance might lower environmental costs by reducing wildfire risks, resulting in lower CO_2 emissions. Despite this, there was a trade-off regarding the additional expense of land clearing. Compared to the environmentally benign new land clearing, the new land expansion lowered the environmental cost even further. Figure 7 depicts the environmental cost comparisons between the scenarios.

- CPO transportation cost.

The lowest CPO transportation cost was obtained from scenario five because reducing new land expansion was applied. It is concluded that the CPO transportation cost would also be lower with the policy of lowering new land palm plantations. Figure 8 shows the scenarios' comparisons of CPO transportation costs.

- Net benefit value.

Due to the reduction in new land planted in Scenario 2, the net benefit was at its lowest value. On the other hand, the new plantation, replanting strategies and using land clearing

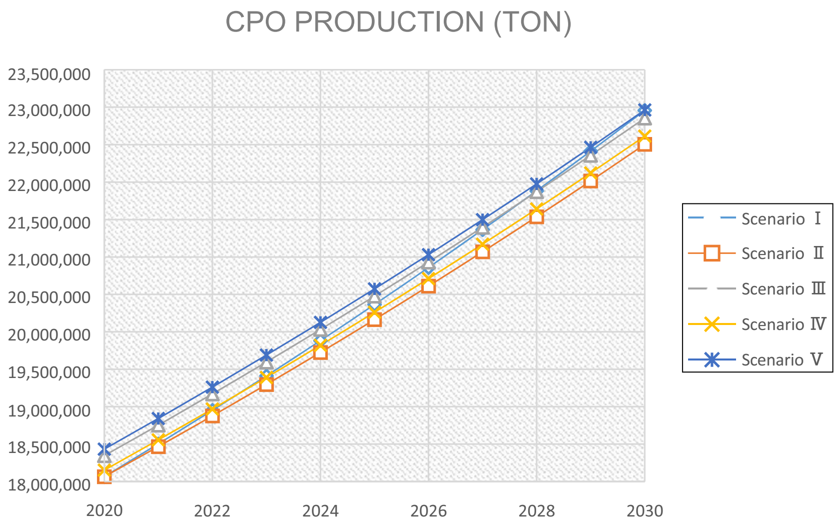

Figure 5. The differences between scenarios in CPO production

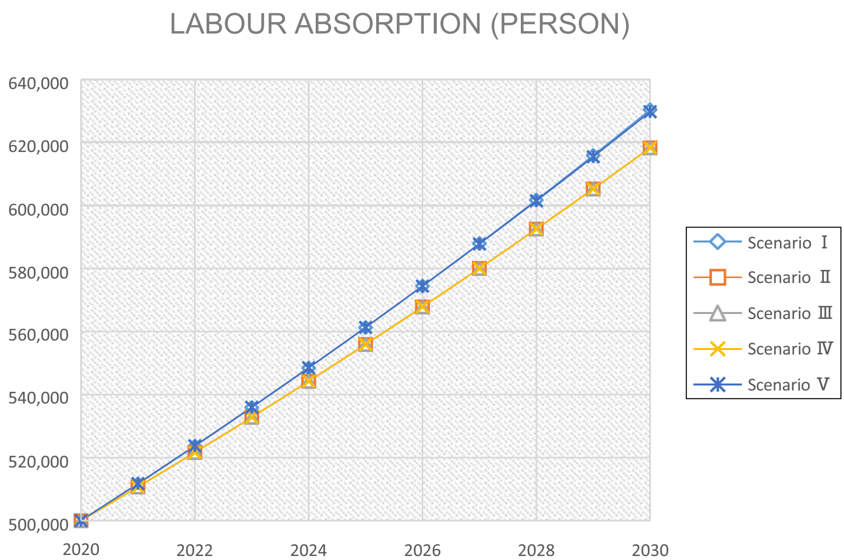

Figure 6. The differences between scenarios in labor absorption

sustainability provide the maximum value in Scenario 5. It demonstrates that the net benefit value increases as the regenerated plantation area grows in importance while using environmentally friendly procedures. The value of CPO industry income from CPO sales and society's income from palm plantation employers' pay were used to calculate the net benefit in this study. Deduct the cost of replanting, shipping, and environmental damage caused by the fire, as well as an extra fee for no land clearing. The net benefit/cost ratio for each of the five situations is depicted in Figure 9.

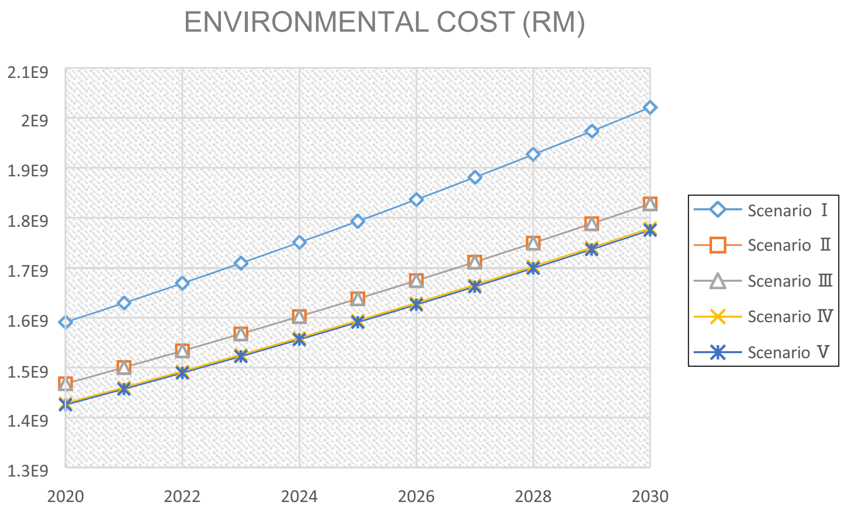

Figure 7.
The differences between scenarios in environmental cost

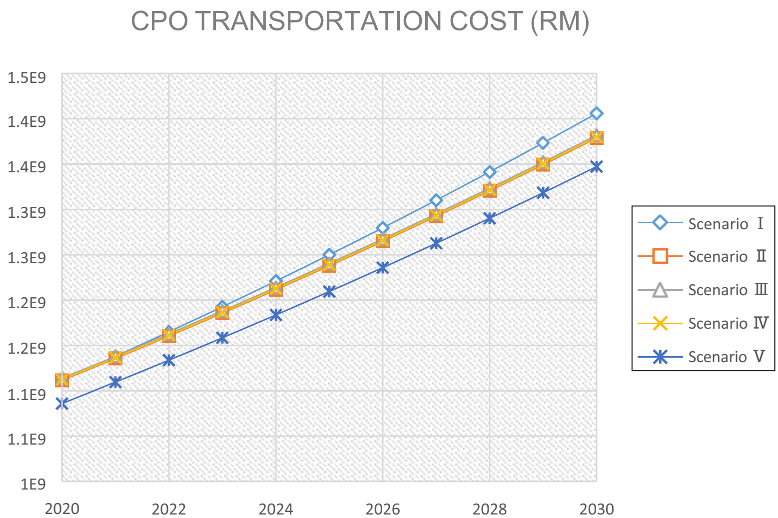

Figure 8.
The differences between scenarios in CPO transportation cost

Figure 9 shows that Scenario 5 is the greatest compared to the other scenarios, as it has the most significant net benefit value. It demonstrates how replanting and sustainability techniques can positively impact the environment, society and economy. The productivity of CPO can rise even when the replanting area expands. In other words, even if replanting would increase the cost, and it will take 3–5 years for the palm trees to give fruit, implementing sustainable policies can lower the cost of adverse environmental consequences despite the additional cost of implementation.

From the five scenarios, replanting in an environmentally favorable area yields the most significant financial gain. The financial benefit value was established by the CPO industry's profits and society's income, with replanting costs, environmental costs and the cost of using environmentally friendly growing procedures having a negative impact. A policy to expand Malaysia's CPO market share for both abroad and domestic markets is also required to raise CPO demand in addition to improved production policies. Even though there will be a higher expense in the application, wildfire costs are decreased by environmentally friendly practices. In addition, it can boost international society's acceptance of Malaysia's environmentally friendly CPO products. In this analysis, the optimum policy option was replanting applications based on land needs and land clearing with sustainability in mind (zero burning). However, because of the increased production, the impact of diesel use on emissions is considerable in all five scenarios. It should be highlighted that increasing the volume of CPO delivered leads to an increase in the number of visits between SC stages while also lowering emissions significantly. The environmental cost decreases as distances and the amount of CPO transported change. These findings suggest that if SC stations were closer to one other, GHG emissions would be reduced.

4.3 Oil palm industry and diesel consumption policy impacts on Malaysian replantation and transportation

From the five scenarios, eco-friendly replanting delivers the most financial gain. Financial benefit value was decided by CPO industry income and society's income, whereas replanting cost, environmental cost and eco-friendly cultivation cost affected it negatively. In addition to improving its production policies, Malaysia needs to enhance its CPO market share in domestic and international markets to boost CPO demand. Through eco-friendly techniques, wildfire costs are lowered, despite an additional application cost. Besides that, it increases international acceptance of Malaysia's eco-friendly CPO products. Replanting based on land needs and sustainable land clearing was the best policy solution in this study (zero burning).

According to the findings, replanting 60% of existing palm oil trees and clearing 70% of new land for palm oil plantations without burning can boost production by 2.45%; however, replanting without zero burning can only raise production by 2% from baseline. Plantation productivity can be increased through replanting, increasing CPO production without the need for significant plantation expansion. On the other hand, supporting oil palm production and fuel consumption policies for the transportation sector is suitable for smallholder and

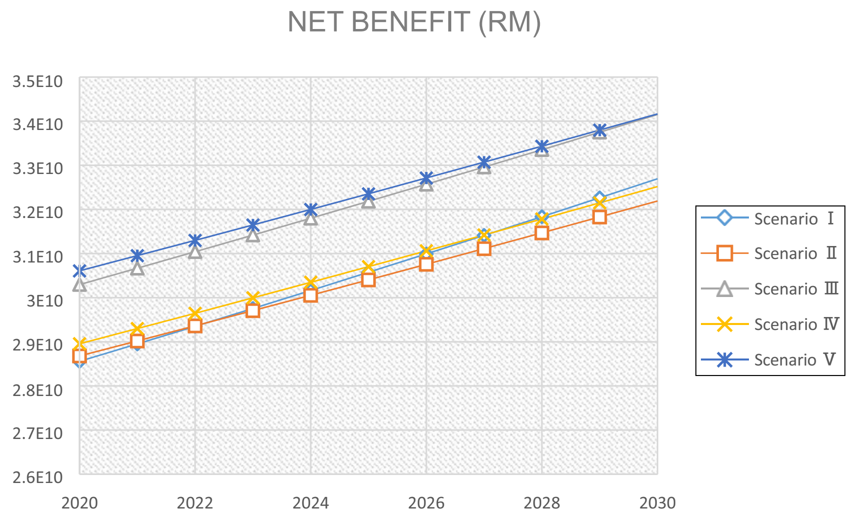

Figure 9.
The differences between scenarios in net benefit value

small-scale oil palm growers, who constitute around 40% of worldwide palm oil production. As of April 2017, Malaysia had 440,262 palm oil workers (exclusive of 280,977 independent smallholders). The oil palm cultivation and diesel consumption blending mandate, directly and indirectly, provide socio-economic benefits to oil palm growers, providing a primary income source from steady demand, allowing thousands of oil palm growers to invest in improving their cropland, enhancing environmental conditions and providing a good education for their children [57].

5. Discussion

By Zlatanovic (2012), the steps to solve any problem by using the dynamic system approach are as follows:

5.1 Validation

According to Costhelper Home and Garden (2020), validation in the system dynamic model can be conducted using various methods. It is performed before simulation (direct structure test), after simulation (oriented structure test), or by comparing the quantitative behavior. This study's validation is conducted by comparing the quantitative behavior using mean absolute percentage error (MAPE) to test the average significance difference between the actual and simulated data. If MAPE $< 5\%$, the simulation data is considered very accurate, $5\% <$ MAPE $< 10\%$ is considered accurate, and MAPE $> 10\%$ is not considered accurate (Morley *et al.*, 2018).

This paper used all aspects that have a causal relationship with replantation and transportation as primary contributions to the environmental cost to more clearly and intuitively convey the factors that influence the environmental cost of CPO production. The environmental cost of CPO production in Malaysia is primarily determined by the cost of replanting and the cost of CO_2 emissions, which are used to assess the profitability and long-term sustainability of CPO productivity(Nurfatriani *et al.*, 2019; Pacheco *et al.*, 2020; Varkkey *et al.*, 2018). Significant challenges in productivity parameters such as labor inputs can explain the poor development in CPO productivity per unit of the planted area. Environmental factors also influence changes in productivity. Various factors influence sustainable land use and fuel consumption over time, exacerbated by the vicious circles of low productivity, resulting in the need to expand cultivated areas and transportation rates.

In this model, validation that was conducted includes testing the structure validity and testing the model performance validity test. Regarding the test of structure validity, it has not found any conflict in using this dimension. In this study, the validation was conducted using the MAPE test, which is used to test the average significance difference between actual and simulated data. Data for the total number of the plantation, Fresh Fruit Branches (FFB) yield and CPO production from 2009 to 2019 were used in this validation. Based on the statistical test, MAPE for total palm plantation, FFB yield, and CPO production accounted for 9.77%, 5.2%, and 9.46%, respectively, less than 10%. Consequently, it was concluded that this model has no significant difference between actual and simulated data.

5.2 Simulation

The dynamic models are frequently used to investigate a system's behavior under changing situations. In this context, investigations of scenarios that reflect many conceivable situations or interventions are extremely valuable. We looked at five policy scenarios and how they would affect oil palm productivity, land usage and diesel use, all related to Malaysia's desire to balance or reduce carbon emissions. The differences between the five simulation situations are shown in Table 1.

A simulation was conducted to observe the model's behavior, which resembles the actual system. The following five-scenarios implemented the simulation in this model:

5.2.1 Scenario I. The simulation with the primary line shows the current state, with the presumption of the increasing new-planting average by 5.9% of the gross plantation based on the historical data over the last ten years (MPOB, 2009, 2020), and the annual replantation is 3.5% of the gross planting (USDA, 2012). According to Azman *et al.* (2015), from 8 to 10 hectares of planted land, an estate needs one worker (in this scenario, it is assumed that 10:1 hectare/worker). Regarding CPO transportation cost simulation assumed that the diesel consumption price for each liter is RM1.95 as an average price over the past five years (Index Mundi, 2020).

5.2.2 Scenario II. The simulation assumes that the annual expansion average of palm oil planted area reduces by 10% as the land increase is the primary trigger of deforestation (Awang Ali *et al.*, 2013; Vijay *et al.*, 2016; Wicke *et al.*, 2011).

5.2.3 Scenario III. Assuming that the land-expansion average declines by 10% and replanting 60% of the tree's age is older than 25 years or nonproductive trees. This presumption measurement (60%) has been used to the reason for the high cost and fund lack to conduct replanting. The present impediment farmers face is that replanting is an innovation that worries them about losing their livelihoods, mainly because of the lack of capital (USDA, 2011). Replanting cost is within MR 12,000 per hectare, according to AA RESOURCES (2011) and ERE Consulting Group Sdn Bhd (2012). New palm oil land clearing depends on the actual data status.

5.2.4 Scenario IV. Replanting simulation based on the primary line shows the current state with the assumption of decreasing 10% of average palm oil planted area expansion and assuming that 70% of new palm oil land clearing will be implemented sustainably without burning.

According to Purnomo *et al.* (2018), the average cost of land clearing with fire is about $3,000 per hectare, but with no fire, it is about $500–$2,500 higher than using fire (Costhelper Home and Garden, 2020).

5.2.5 Scenario V. This simulation involves replanting 60% of the total plantation area and the presumption that 70% of new land clearing for palm oil plantations is implemented sustainably without burning. Moreover, in this scenario, each liter's diesel consumption

Policy variables and units	Scenario	Before policy change	After policy change	Unit
The annual expansion average of palm oil planted area	S1	18%	5.9%	Hectare
Replanting the trees whose age is older than 25 years or non-productive trees		1%	3.5%	Hectare
Diesel price (per letter)		2.1	1.9	RM
the annual expansion average of palm oil planted area	S2	18%	−10%	Hectare
The annual expansion average of palm oil planted area	S3	18%	−10%	Hectare
Replanting the trees whose age is older than 25 years or non-productive trees		1%	60%	Hectare
The annual expansion average of palm oil planted area	S4	18%	−10%	Hectare
Clearing the new land without burning		0%	70%	Hectare
Replanting the trees whose age is older than 25 years or non-productive trees	S5	1%	60%	Hectare
clearing the new land without burning		0%	70%	Hectare
Diesel price (per letter)		2.1	1.95	RM

Table 1. The differences between the five simulation scenarios

price is RM1.9, as an average price will be based on the past ten years (Index Mundi, 2020), and the labor absorption will be 9 hectares for every worker (Azman *et al.*, 2015).

5.3 Policies/decisions analyzing and improving

The model's reliability was examined, and the results helped observe or test the analyzed condition. By using this model, it is possible to follow the system status, behaviors, responses and policies. Consequently, adjusting policies and system model structure can be conducted instantly if necessary.

5.4 Policies/decisions application

Analyzing the system dynamic model's simulation results to discover and apply the most appropriate and suitable policies in the field.

Replanting is carried out in conjunction with the environment in the five scenarios; the sustainable policy provides the most financial advantage. The net benefit was calculated by adding the determinants, such as CPO industry income and societal income, and subtracting the determinants, such as replanting costs, CPO transportation costs, environmental costs and the cost of using environmentally friendly production practices. Aside from production growth policies, policies to increase Malaysia's CPO share in international and domestic markets are also required, increasing CPO demand. Wildfire expenses fall due to environmentally friendly methods, notwithstanding the higher cost of applying no-fire land removal. It may also persuade international society to accept Malaysia's environmentally beneficial CPO product. As a result, the optimum policy option in this study was replanting by land demands and land clearing while keeping sustainability in mind (no fire).

According to the findings, replanting 100% of the total number of old trees from baseline conditions can boost production by 2.425%, whereas replanting 60% of the total old trees can only raise production by 2.221%. Plantation productivity can be boosted through replanting, resulting in increased CPO production without the need for a large-scale expansion of the plantation. Numerous factors have been taken into account as parts of the costs and advantages of sustainable implementation, according to a review and analysis of earlier studies for palm oil from the perspective of replanting and transportation. Implementation is challenging because farmer awareness is low. Reduced diesel consumption and zero-burn replanting are two advantages of sustainable transportation and replanting. Environmentally friendly vehicles, fireless tree cutting and new tree planting are some of the costs involved. Such compartmentalization represents a more thorough compendium than the more simplistic analysis used by researchers to determine whether the costs of sustainability outweigh those of unsustainability replanting and transportation (Ibragimov *et al.*, 2019; Zahraee *et al.*, 2019, 2022).

Researchers are urged to conduct additional cost-benefit analyses. Still, their research methodologies have limitations in providing a more comprehensive strategic understanding, which is required for effective communication with all practitioners. It's crucial to consider profitability while broadening our understanding of that concept from a strategic angle[53–55]. This is a crucial point to consider because adhering to the system dynamics standard also affects sustainable practices. For instance, (Lim and Biswas, 2019) proposed that requirements for sustainable plantations provide a way or framework for implementing diesel consumption reduction and zero-burning efficiency. Diesel prices and zero-burning costs undoubtedly impact all practitioners' financial performance. Still, thanks to sustainability's increased effectiveness, the stakeholder's financial decline in a downturn are less likely than that of their competitors. Stakeholders reap the most significant long-term benefits. As a result of their relatively early entry into the global palm oil market, sustainable plantation companies have been identified by Lim and Biswas (2019) as enjoying an early-mover advantage. While smallholders are less likely to benefit from this, buyers do not favor their unsustainable produce.

Additionally, this study summarized that the price of the environment, the price of transporting CPO, the price of replanting and the price of employing are environmentally responsible farming methods. Using sustainable practices, such as no-fire land removal during replanting, is the best policy for increasing net benefit value. Greater regenerated plantation area always results in greater CPO output.

6. Conclusion

Malaysia's economy relies heavily on agriculture. This sector's large workforce reflects its contribution to the GDP. Agriculture could absorb 11.09% of the workforce in 2018. In 2014, it contributed 8.2% of GDP, or RM 99.5bn. Agriculture is a reliable sector for recovering Malaysia's economy during economic crunches. At end-2019, oil palm planting reached 5.9 million hectares. In the same year, this region produced 19.86 million tons of CPO. CPO is Malaysia's largest crop and the world's most significant edible oil. CPO contributed 37.9% to agricultural GDP in 2018, whereas plantations contributed 6.9%. Palm oil is Malaysia's export commodity and contributes to agricultural GDP. Malaysia exports palm oil goods worldwide. It is the most-traded vegetable oil. Palm oil consumption will rise as incomes and populations rise. The previous study has shown that palm oil has environmental and societal effects. This study used a dynamic systems method to evaluate SCM in the Malaysian CPO industry. This research examined the essential components of profitability and long-term SCM to improve future SCM performance and provide theoretical support for future research.

In this study, the average significance difference between the actual and simulated data was tested using the MAPE test, which is used for this purpose. According to the statistical test, MAPE for the entire palm plantation, FFB yield, and CPO production accounted for 9.77%, 5.2% and 9.46%, respectively, below 10%. As a result, it was determined that in this model, there is no discernible difference between actual and simulated data. Based on the model's structure and performance test, the dynamic system model of sustainable and profitable SCM of Malaysia's CPO was valid and suitable. The simulation results in each of the five situations were different. The fifth scenario produced a value of 4.49% more significant than the baseline and the highest of the four situations. The net benefit value was positively influenced by the CPO industry's and society's earnings.

Replanting 100% of old trees from baseline conditions can boost production by 2.425% while replanting 60% can only raise production by 2.221%. Therefore, replanting can increase plantation productivity and CPO production without a large-scale expansion. Meanwhile, there is the cost of replanting, the cost of CPO transportation, the cost of the environment and the expense of using environmentally acceptable growing practices. The best policy option to increase net benefit value is to implement sustainable practices such as no-fire land removal during replanting. The CPO production will be higher in any instance when the regenerated plantation area is more extensive.

7. Recommendation

According to this study, the influence of negative variables on the environment and society should be reduced by increasing the management of environmentally friendly palm plantations. More research is needed to increase CPO productivity and reduce deforestation in Malaysia. Further research is needed to improve the study model by including some variables that affect CPO industry income, such as production and research costs.

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