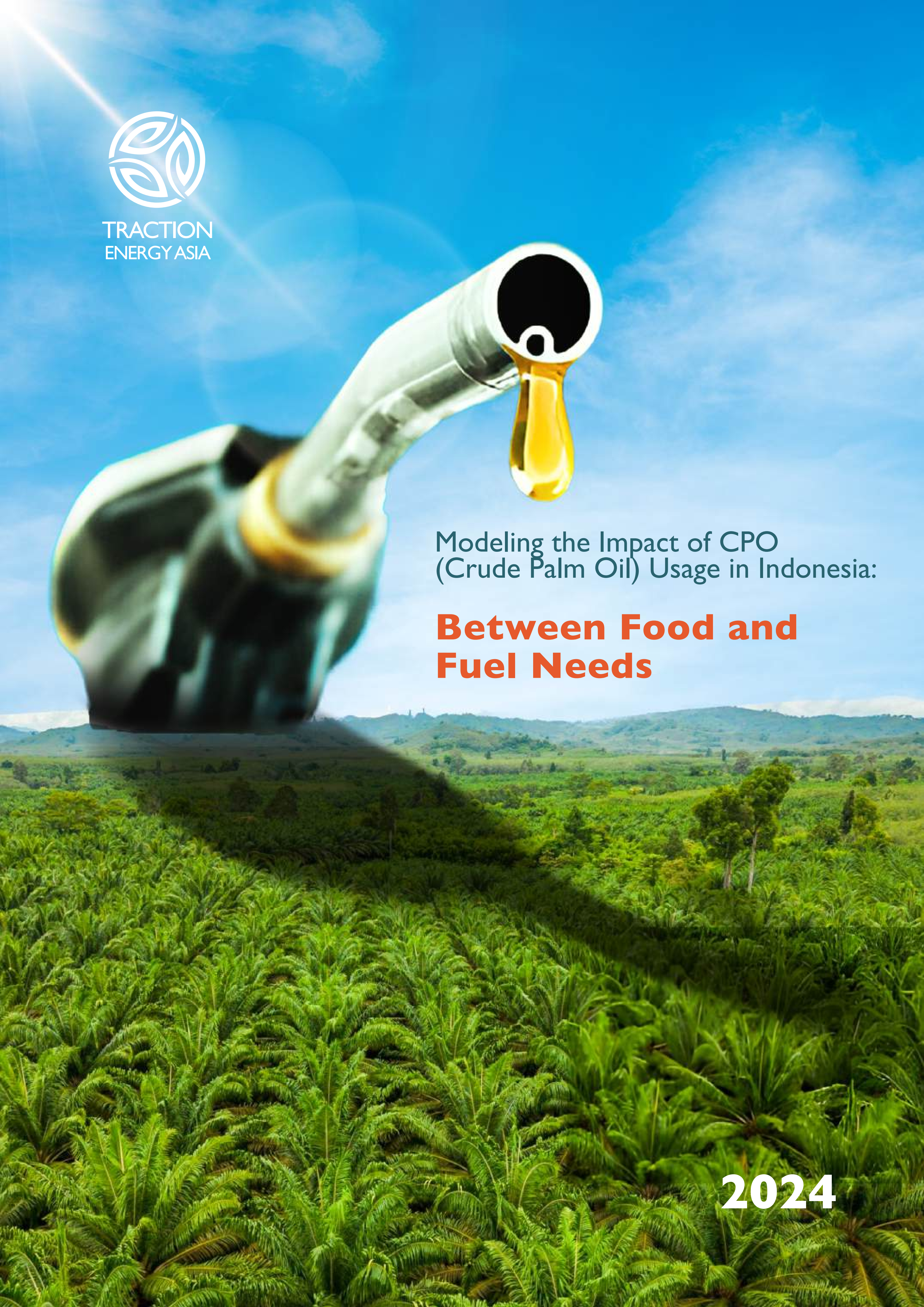

TRACTION ENERGY ASIA

Modeling the Impact of CPO (Crude Palm Oil) Usage in Indonesia:

Between Food and Fuel Needs

2024

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Contents

Executive Summary

This report discusses the conflict between food and fuel needs related to the use of crude palm oil (CPO) in Indonesia. As the world's largest CPO producer, the use of palm oil for biodiesel production has sparked debate about its impact on food security. Although bioenergy offers a renewable energy alternative, its effects on food supply must be carefully considered.

Main Points:

1. **CPO Production and Demand:**
   The production of CPO in Indonesia continues to increase annually, primarily due to its significant role in various industries. However, the rising demand for biodiesel, as part of government policies promoting renewable energy, has added pressure on the availability of CPO for food. The availability of CPO for food has become more limited, impacting the prices of cooking oil and other food products.

2. **Biodiesel Policy:**
   Mandatory, government-implemented biodiesel programs have boosted the utilization of CPO as biodiesel feedstock. These policies promote the use of blended biodiesel with fossil fuels, such as B30 and B35, which incorporate up to 35% of CPO in the blend. The aim is to reduce fossil fuel imports and enhance energy security. However, its impact on the supply of CPO for food appears significant, given the continuously increasing amount of palm oil used in biodiesel production.

3. **Implication for Food Security:**
   With the increasing demand for CPO for biodiesel, the supply for food becomes constrained, leading to rising prices of cooking oil and other food products. This triggers concerns about the availability and accessibility of palm oil for food needs, especially among low-income groups highly reliant on palm oil as their main source of fat and oil. The impact is also evident in food prices in both domestic and global markets.

4. **Food vs Fuel Conflict:**
   The tension between food production and fuel needs becomes apparent when CPO, utilized for bioenergy, reduces its availability for food purposes. This notably affects developing countries, especially Indonesia, where palm oil is a primary staple food. The increased use of CPO for fuel leads to deforestation, which escalates environmental pressures and affects food supply, posing serious challenges to national food security.

Recommendations:

1. Diversification of Biodiesel Feedstocks: Exploring alternative biodiesel feedstocks besides CPO to alleviate pressure on food supply.

2. Sustainability Standards: Adopting sustainable farming practices in palm oil production to mitigate adverse environmental impacts.

3. Technological Innovation: Investing in new bioenergy technologies to enhance biodiesel production efficiency without compromising food supply.

4. Holistic Approach: Promoting a holistic approach in bioenergy policies that considers their impacts on food and the environment.

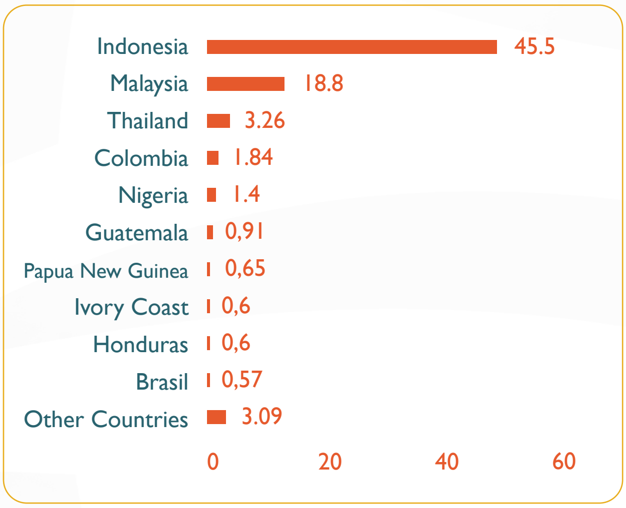
By implementing balanced policies and practices, Indonesia can ensure an adequate food supply while simultaneously meeting the demand for sustainable energy in the future.

Background

Biofuel is a type of bioenergy derived from organic materials or biomass, such as food crops, agricultural waste, or non-food crops, that can be used as an alternative or supplement to fossil fuels. The two main types of biofuel are bioethanol, produced through the fermentation of sugars or starch from crops such as corn or sugarcane, and biodiesel, made from vegetable oils such as palm oil or soybean oil. Biofuel has the potential to play a role in reducing dependence on fossil fuels.

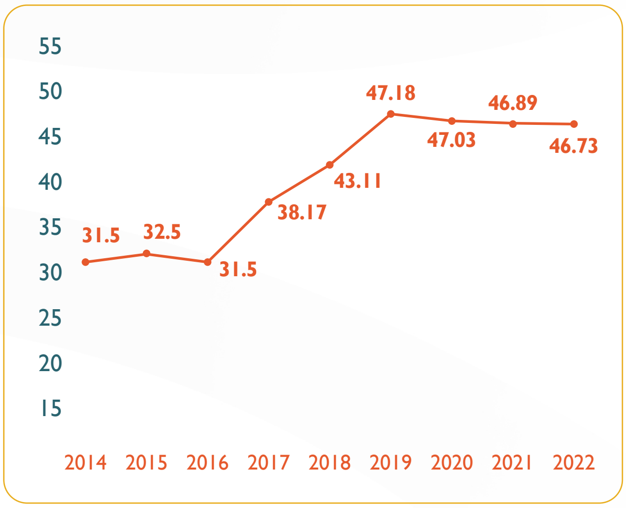
As the world's largest producer of crude palm oil (CPO), Indonesia has played a significant role in this industry. Based on data from the United States Department of Agriculture (USDA), Indonesia's CPO production is projected to reach 45.5 million tons in the 2022/2023 period, making it the largest in the world (Figure 1). Meanwhile, Figure 1 shows the trend of Indonesia's CPO production from 2014 to 2022. Despite experiencing declines from 2019 to 2022 due to various internal issues such as replanting targets and weather, CPO production has continued to show an overall increase, reaching 46.73 million tons in 2022 (down 0.34% from 2021).

***Figure 1.** Projection of CPO Production in 2022/2023 Period (Million Tons)*



Source: USDA

***Figure 2.** Indonesia's CPO Production (Million Tons)*



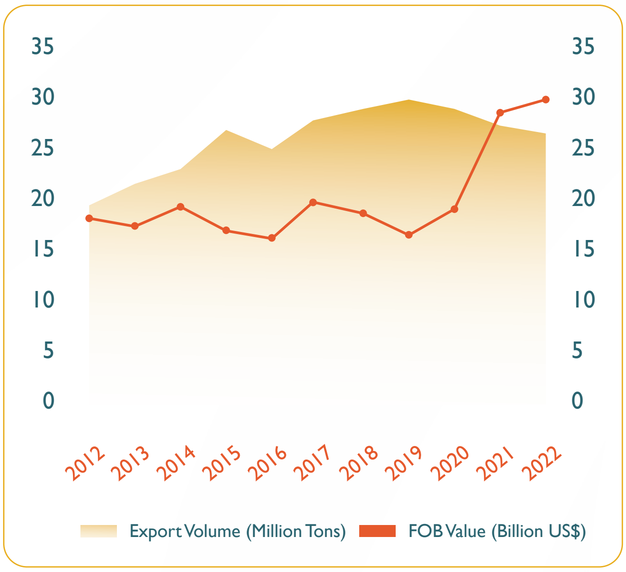
Source: *Indonesian Palm Oil Association (IPOA/GAPKI)*

The majority of Indonesia's CPO production is exported to various countries worldwide, amounting to 56.11% in 2022 (Statistics Indonesia, 2023). This makes the sales value and price of CPO highly vulnerable to changes in global economic conditions or international policy changes, especially in countries that are the main export destinations. In 2019, the European Union halted the use of palm oil for biodiesel as stated in the Delegated Regulation Supplementing the EU Renewable Energy Directive II (RED II) as part of the EU countries' efforts to address the climate and energy crisis. This policy led to a decrease in global CPO demand and caused a decline in global CPO prices. This impacted Indonesia's CPO export value in 2019, which dropped from US$17.9 billion to US$15.54 billion (a fall of 13.18%) (Figure 3).

The Indonesian government responded to these challenges by promoting the industrialization of CPO into domestic processed products (Alen et al., 2021). The three main pathways in the downstreaming of CPO, which became the focus, are the Oleofood Complex Industry, Oleochemical Complex Industry, and Biofuel Industry. The mandatory biodiesel program has been in force since 2008, but in 2019, acceleration was made by implementing B30, which was supposed to be realized in 2020 in response to the European Union's policy (Febriatama, 2020).

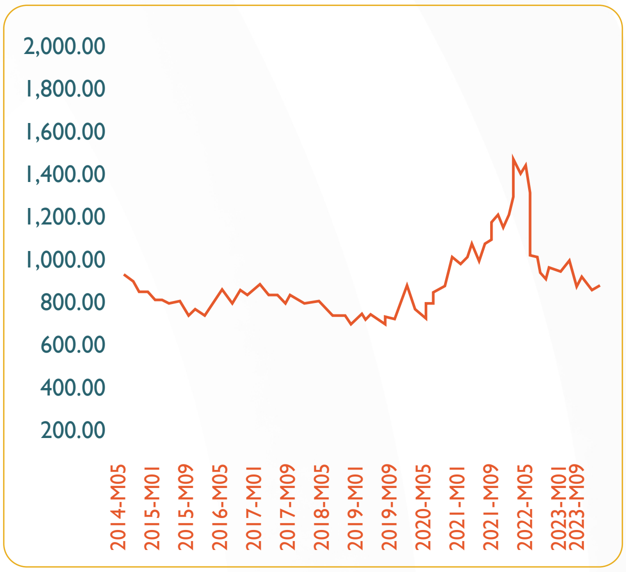
Between 2012 and 2022, Indonesia's CPO export value showed an upward trend. Although it saw a decrease in export volume from 2019 to 2022, there was an increase in prices during the 2021-2022 period. This indicates a spike in global prices mainly triggered by CPO downstreaming efforts in Indonesia (Emeria, 2022). In 2022, Indonesia's CPO export volume reached 26.22 million tons with an FOB value of US$15.97 billion.

***Figure 3.** Indonesia's CPO Exports*



Source: Statistics Indonesia (BPS)

***Figure 4.** Global CPO Prices*



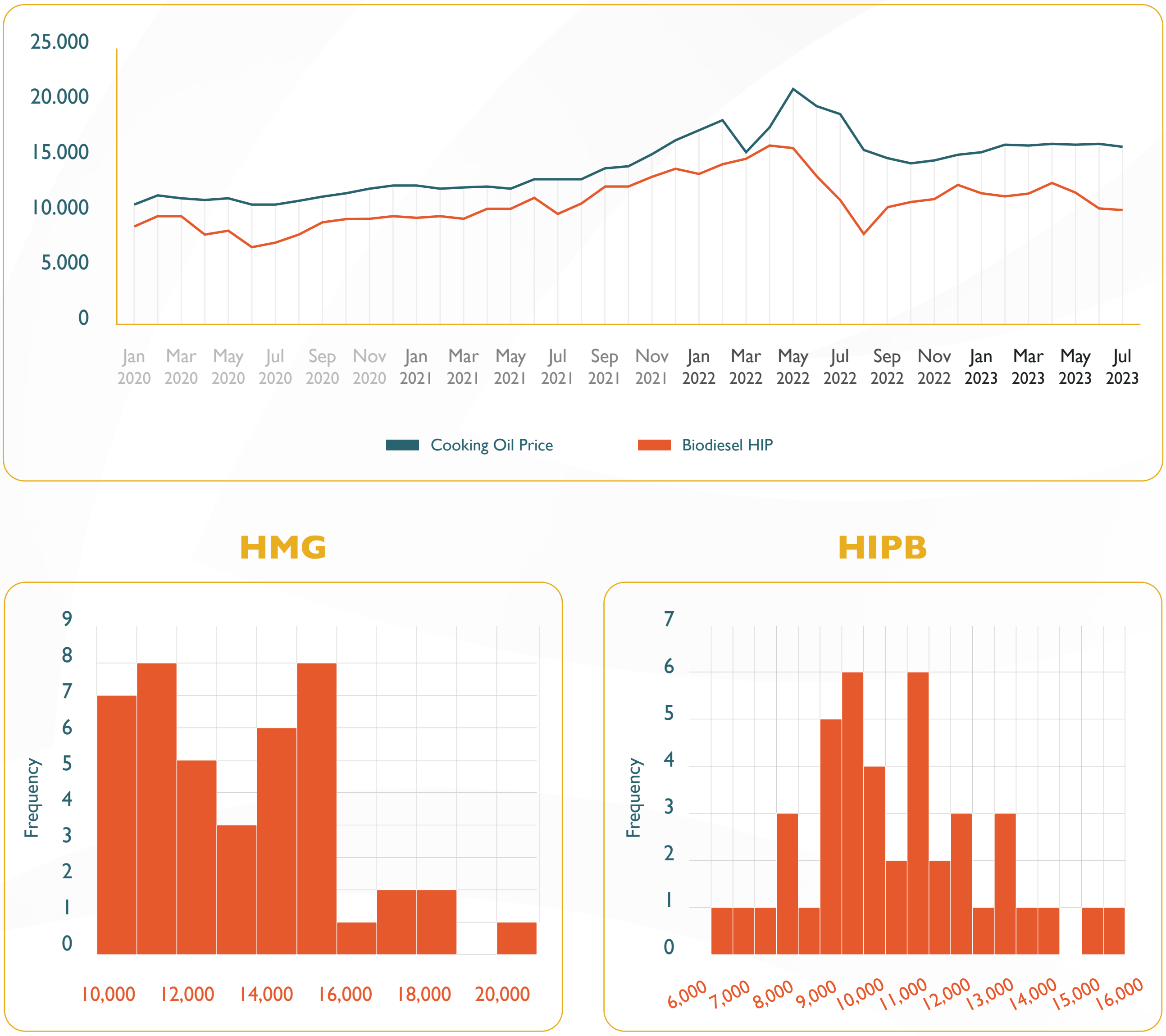
Source: Commodity Futures Trading Regulatory Agency (Bappebti)

The mandatory biodiesel program aims not only to protect Indonesia's CPO commodity and boost its added value but also to reduce dependence on imported fuel, enhance energy resilience, and fulfill commitments to reduce greenhouse gas emissions (KESDM, 2019). Since 2023, the government has implemented B35 in this program in the hope that the proportion of vegetable oil in fuel will continue to increase. However, this shift in CPO usage raises several concerns, particularly regarding food security.

CPO plays a crucial role in the food industry as the primary raw material for cooking oil and many other food products. Cooking oil from CPO/palm oil serves as a vital source for meeting food demand, especially in various Southeast Asian countries, reflecting its diverse roles and implications across several industries, including the food and energy sectors.

The downstreaming policy strategy to maintain CPO prices can exert pressure on downstream products. For instance, the mandatory biodiesel program may reduce the availability of CPO for food needs and affect other downstream products, such as oleochemicals. Additionally, this downstreaming policy can impact CPO exports. A decline in CPO availability for food consumption, such as cooking oil, can have serious consequences, particularly regarding price hikes and limited access for people.

***Figure 5.** National Cooking Oil Price and Biodiesel Market Index Price (HIP)*



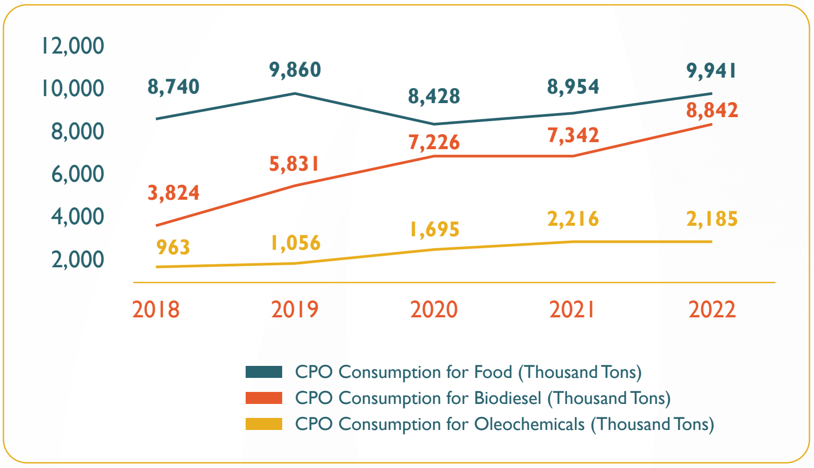
Note: HMG refers to the price of cooking oil, and HIPB refers to the biodiesel market index price. / **Source:** The National Strategic Food Price Information Center (PIHPS) and Directorate General of New Renewable Energy and Energy Conservation (Ditjen EBTKE), processed

The trend in cooking oil prices indicates that biodiesel is considered a threat to food security through demand pressures that affect prices in line with the national biodiesel market index price (Figure 5). The use of CPO as the primary raw material for biodiesel production raises concerns about its impact on the food sector. As one of the world's most widely produced and consumed vegetable oils, CPO plays a crucial role in the food industry as it is used in various products, from margarine to other processed foods.

From 2018 to 2022, CPO production for biodiesel consumption experienced positive growth (Figures 6 and 7). However, biodiesel consumption has continued to rise without reducing the use of CPO for food consumption due to high demand in the food sector. This shows that the demand for CPO will continue to increase to meet food and national energy needs. Nevertheless, the growing demand for CPO may pose new problems related to CPO production factors, particularly land. Increasing demand for CPO can lead to rising demand for CPO production factors, such as oil palm plantation land. The assumed growth of oil palm plantation land is around 1% - 1.74% annually, which can occur through deforestation or land conversion from forests to plantations. It can occur considering that conversion of lands, for example, from rubber plantations to oil palm plantations, usually occurs in smallholder-owned plantations and on a small scale. The expansion of oil palm plantation land by 1% - 1.74% per year or 153,800 - 267,000 hectares per year generally occurs on plantation concession land. Deforestation processes commonly involve capital and heavy equipment, making it impossible for smallholder oil palm farmers to carry out large-scale land conversion or deforestation.

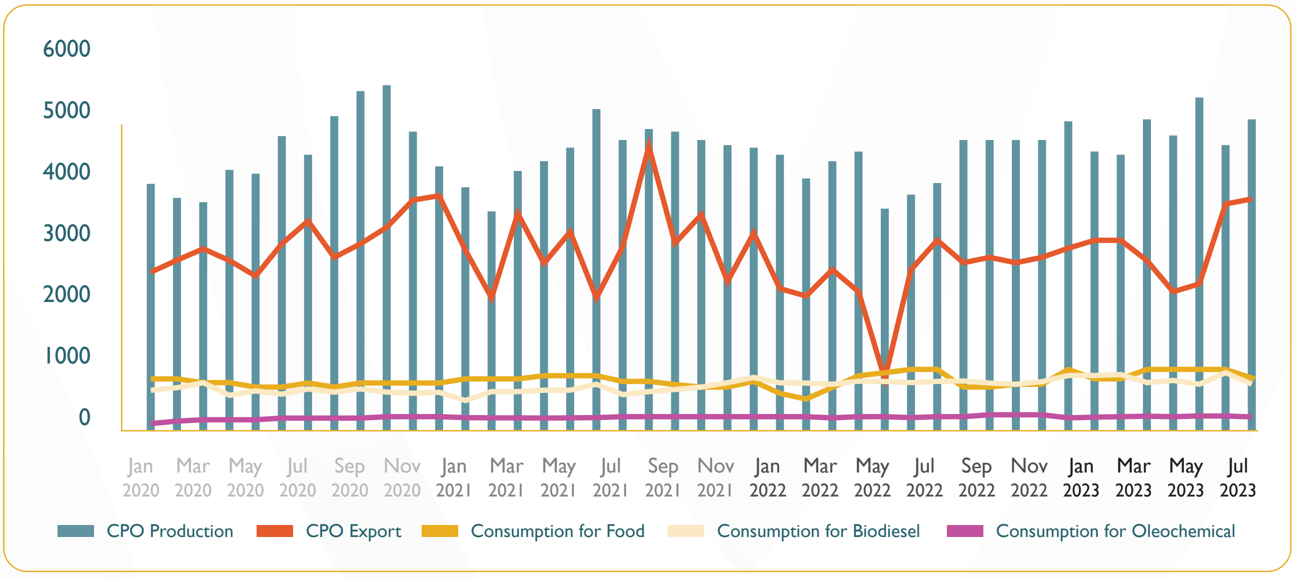
The resulting impact is increased deforestation, which may negatively affect the environment, biodiversity, and efforts to reduce greenhouse gas emissions. Deforestation that occurs during land clearing for oil palm plantations contributes to habitat loss for endangered species and significant carbon emissions release. Additionally, unsustainable farming practices can cause soil degradation, water pollution, and socio-economic issues for local communities. Therefore, despite CPO's potential as a more environmentally friendly fuel source, there are significant concerns regarding its impact on food sources and the environment. This calls for a more sustainable and responsible approach to the development of the palm oil industry, including the implementation of sustainability standards and innovation in agricultural techniques and land management.

Figure 6. *CPO Consumption for Food, CPO Consumption for Biodiesel, and CPO Consumption for Oleochemicals in Indonesia*



Source: Databook (2023)

Figure 7. *Development of Production and Consumption of Crude Palm Oil (CPO) in Indonesia*



Source: Indonesian Palm Oil Association (IPOA/GAPKI)

Increased biodiesel production using CPO may reduce CPO supply for the food market and lead to a global CPO price hike. It can impact the prices of food products that use CPO as the main component, ultimately increasing overall food prices. Rising food prices, especially in developing countries, can worsen food accessibility for low-income groups, which in turn can exacerbate issues of malnutrition and food security.

This situation underscores the need for a balance between developing renewable energy to address climate change and protecting global food security. A proposed solution is to explore alternative raw materials for biodiesel production that do not directly compete with the food sector, such as agricultural waste or non-food crops.

This research aims to analyze the pressure on CPO demand for food by considering various scenarios, including CPO production and Indonesian CPO demand for biodiesel, oleochemicals, and exports. Although the research focuses on economic aspects and does not directly consider environmental aspects, its findings can still provide insights into environmental impacts, such as oil palm plantation expansion that may lead to deforestation. Additionally, this research does not specifically address the environmental aspects of domestic and international demand for Indonesian CPO.

Research Objectives

The objectives of this research are divided into two categories: general and specific. Overall, this research aims to analyze the impact of biodiesel production using CPO on food production, which also uses CPO.

The specific objectives of this research are to analyze CPO production or supply; analyze CPO demand for food, biodiesel, and exports; simulate CPO demand and supply; and estimate the pressure of biodiesel production on food.

To achieve these objectives, models for projecting CPO production or supply and CPO demand for domestic use and export were developed. The models were then simulated using several scenarios related to the size of oil palm plantation land (land area growth) and the policies on biodiesel blend in the diesel fuel sold in the domestic market. The results of the projections of CPO production or supply and demand for various domestic and export needs were utilized to estimate biodiesel blending policies' impact on CPO availability for food purposes.

Literature Review: Food vs Biofuel

Food security is a crucial topic amidst the climate crisis. Bioenergy production from food-based raw materials can significantly affect food availability, prices, and production. The choice of raw materials, whether edible or non-edible, plays a crucial role in determining the impact on food security parameters. The utilization of edible raw materials, such as edible oils, for bioenergy production may lead to high production costs and negatively impact food security (Nikhom et al., 2019). Conversely, using non-edible raw materials, such as inedible oilseed crops, algae, and agricultural waste, for biofuel production is seen as a viable option to alleviate concerns regarding food security (Kichonge & Kivevele, 2023).

The expansion of the bioenergy sector plays an essential role in global energy transition efforts and can significantly contribute to achieving sustainable development goals (Alsaffat et al., 2020). However, research conducted by Yadeta et al. (2021) highlights that the impact of developing this sector on food security is a complex issue involving various considerations. On the positive side, bioenergy development can drive technological innovations, create job opportunities, and boost farmers' income through diversification of income sources, especially in rural areas. The utilization of agricultural waste as bioenergy feedstock can also add economic value to previously underutilized agricultural products while reducing greenhouse gas emissions. Nevertheless, bioenergy development raises concerns about the potential competition between land use for food production and bioenergy feedstocks. This can lead to increased land and agricultural input prices, ultimately putting pressure on local food prices and limiting food accessibility for poor communities. Furthermore, the conversion of agricultural land to bioenergy production land may reduce the available land area for food production, potentially threatening food security at both local and global levels.

Since biofuel production became a shared aspiration to achieve green energy, economists and environmental experts have been divided into two factions. The first group believes that biofuel production is the ideal solution to climate change issues and marks the beginning of a gradual transition towards environmentally friendly energy sources. This is achieved by reducing carbon emissions from the combustion of fossil fuels and by absorbing carbon units through photosynthesis, where power plants absorb carbon dioxide. Energy provision from renewable sources can also contribute to reducing dependence on traditional energy imports while serving as a source of foreign exchange earnings for the country.

Biofuel production can ultimately be used to develop the agricultural sector and provide more job opportunities (Alsaffat et al., 2020). The second group believes biofuel production can potentially neglect food security. These scientists compare food security on one side and energy security on the other. The implication is that the intensity of biofuel production using food crop sources will negatively impact the surplus of food crops allocated to the poorest and most vulnerable people in need (Robert & Florentine, 2021). Another perspective suggests that profitability may incentivize agricultural producers to cultivate biofuel crops at the expense of food crops, resulting in the increasing number of poor populations on one side and the proportion of world hunger on the other. Nevertheless, it is undeniable that biofuel production continues to grow, with its production expected to increase exponentially, driving the adoption of new-generation biofuel production that can align food security and energy security requirements (Parthiban, et al., 2021). Policies to encourage the production and use of biofuels (biodiesel and bioethanol) have been implemented since the early 2000s in developed and developing countries. The application of biofuels as a renewable energy source offers opportunities for climate change mitigation and greater energy security for many countries (Gunatilake, et al., 2011).

This dualism of opinion is supported by several studies conducted by researchers in various countries. Diaz Chavez et al. (2010) stated that bioenergy production in Africa could contribute to an increase in agricultural production, which would also increase the domestic supply of staple food crops depending on the crops' portion used for feeds, fibers, fuels, and exports.

Minot (2010) and Robles (2011) believed that bioenergy production can reduce the domestic supply of staple food crops due to the decreased availability of these plants and/or an increase in these crops' portion used for feeds, fibers, and fuels unless imports can fill the gap between domestic supply and demand. In addition, the production of bioenergy feedstocks can change the demand for inputs, such as land, water, and fertilizers used in staple crop production, potentially affecting the prices of these inputs.

Khan et al. (2021) stated that biofuel is a potential renewable energy source in the transportation industry that can reduce greenhouse gas emissions. Gunatilake et al. (2011b) showed that the policy on biodiesel use in India could enhance energy security, create significant employment opportunities, and achieve inclusive growth without causing adverse impacts on other economic sectors.

Altenburg et al. (2009) and Gasparatos et al. (2013) discussed biodiesel's potential to create an additional source of income for rural residents while highlighting its impact on food prices and the environment. Salleh et al. (2020) pointed out that the establishment of a comprehensive and inclusive national bioenergy policy would lead to sustainable renewable energy development in Malaysia.

Yadeta et al. (2021) underscored the importance of a holistic approach to developing the bioenergy sector, which includes ensuring that bioenergy development is sustainably conducted, minimizing land use conflicts, and supporting food security goals. Hasegawa et al. (2020) discussed the growing interest in bioenergy crops as alternative energy sources and their impacts on global food production and security.

Wang et al. (2019) highlighted the importance of second-generation biofuels in addressing environmental and food security problems and creating new economic opportunities in rural areas. Moyib & Omotola (2018) discussed the use of non-food raw materials in bioenergy production as a step towards greener and more sustainable energy.

Sahara (2022) researched the economic impact of the biodiesel sector in Indonesia, highlighting the policy implications for national macroeconomic situations, other sectors, and household income.

The conclusion is that the choice of raw materials for bioenergy production has a crucial role in determining its impact on food security. Non-edible raw materials and second-generation biofuels can be sustainable alternatives that do not compete with food production, thereby contributing to energy and food security goals.

Biofuels become a primary sustainable solution to environmental problems and dependence on fossil fuels. Despite the promise of reducing greenhouse gas emissions, biofuel development faces serious challenges, especially in the context of the "food versus fuel" dilemma. This dilemma arises because most first-generation biofuels are made from food crops, such as corn, sugar cane, and soybeans, which have the potential to compete with food production (Debnath et al., 2019).

An attractive option in biodiesel production is crude palm oil (CPO), which is high in supply and can potentially reduce greenhouse gas emissions. However, the expansion of oil palm plantations has raised concerns regarding pressure on food sources and the environment. Such expansion often sacrifices land previously used for food agriculture, affecting food security locally and globally (Kichonge & Kivevele, 2023).

Increased demand for these crops for fuel causes a spike in food prices and reduces their availability for human consumption, especially in countries with limited food supplies. This criticism prompted the development of second-generation biofuels that use non-food biomass, such as straw, corn husks, sawdust, and specialty crops not intended for human consumption, such as switchgrass and miscanthus (Rock et al., 2021; Wang et al., 2021).

Second-generation biofuels promise to reduce pressure on food sources, but their development requires more complex processing technology. The potential to further lower carbon footprint and avoid direct competition with food production makes second-generation biofuels an attractive option to reduce dependence on fossil fuels and minimize negative impacts on global food security.

Conventional biofuel production, which relies on fresh water and food crops, has sparked deep concerns regarding the "food versus fuel" dilemma. Using food crops as a source of biofuel creates a conflict of interest between meeting global food demand and sustainable energy demand (Zaky, 2021). The situation is compounded by the consequences of using biofuels from food crops, such as potentially intense market competition and the risk of losing valuable biodiversity (Guerrero, 2019).

The "food versus fuel" debate has been in the spotlight over the past few years, indicating the need to reevaluate sustainable biofuel production methods. The use of first-generation biofuels derived from food crops has raised additional dilemmas related to direct competition with food production (Diniz et al., 2023).

Solutions developed to overcome these challenges include continued research and development in second- and third-generation biofuels. These generations of biofuels use non-food raw materials, such as agricultural waste and microalgae, to address sustainability issues (Rock et al., 2021; Wang et al., 2021). This technology reduces pressure on food sources and creates opportunities to use land unsuitable for food agriculture.

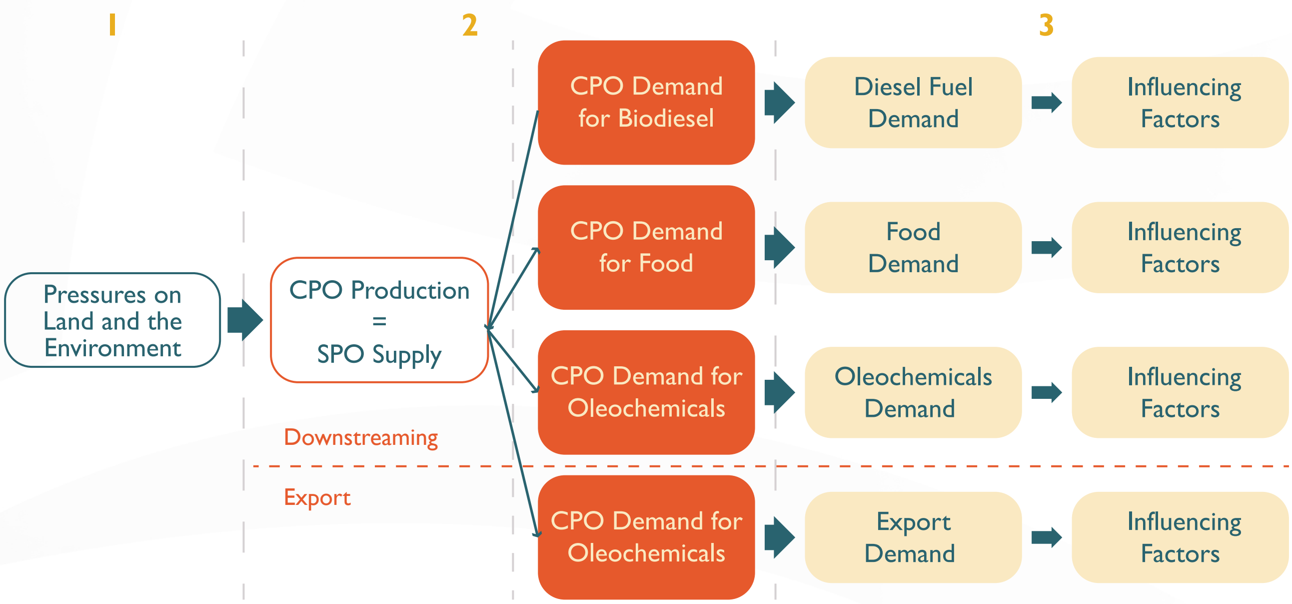
The world can achieve a more sustainable energy system through innovative and sustainable solutions, such as developing next-generation biofuels. Although biofuels offer a renewable energy alternative, challenges related to food production and environmental sustainability must be handled with holistic and integrated solutions.

Research Method

There are three main parts of analyzing how CPO demand for biofuel puts pressure on CPO demand for food (see Figure 8). The first part is the initial input, which includes CPO production factors, such as land availability. This section describes how land availability may be affected by the expansion of CPO production.

The second part is the interaction between CPO production and demand, which is divided into four parts, namely CPO demand for biodiesel, CPO demand for food, CPO demand for oleochemicals, and CPO demand for export. In this section, it is assumed that the factors influencing CPO production and demand are external.

Figure 8. Model Analysis Framework of CPO Production and Demand



The third section discusses general market conditions for CPO products. For instance, if the second part discusses factors that influence CPO demand for biodiesel, the third part will discuss factors that influence demand for diesel fuel as a whole, not just that derived from biodiesel. This research will focus on the second part.

This research projects production levels, CPO demand for biodiesel, CPO demand for food, and CPO demand for export until 2045. The CPO referred to in this research includes CPO and PKO (Palm Kernel Oil) production. CPO is produced from the pulp of oil palm fruit, while PKO is produced from the kernel of the fruit (Larasati et al., 2016). The models for projecting each variable are as follows:

Model of CPO Production

CPO production is the amount of CPO and PKO produced by Indonesia. In this analysis, CPO production is a function of the area of oil palm plantation land. CPO production was estimated and projected using an error correction model with long-run and short-run equations. The data on PCPO (CPO Production) and oil palm plantation land area used were obtained from Statistics Indonesia from 2001 to 2022. The projected CPO production until 2045 was calculated using several land scenarios, as seen in the simulation scenarios section.

Model of CPO Demand for Biodiesel

CPO demand for biodiesel is the amount of CPO used to produce biodiesel. The CPO demand for biodiesel was projected with a mathematical model with the following projection steps:

1. Projecting biodiesel needs in 2023-2030. Data on and projections for biodiesel demand in this research were obtained from the Agricultural Outlook 2021-2030 (OECD, 2021). For information, OECD projections used the B30 policy assumption. The data and projections from the OECD were then utilized to re-project the demand for biodiesel in 2031-2045 with the Holt-Winter/Triple Exponential Smoothing/Error, Trend, Seasonality method.

2. Calculating the demand for biodiesel based on the biodiesel blend program, meaning $n*$ is a natural number from 1 to 100 according to the mandatory government policy. The applied biodiesel blend scenario can be found in the simulation scenarios section. The biodiesel blend program is a government program that requires blending biodiesel with diesel fuel. For example, the B20 program is a mandatory government program that requires blending 20% of biodiesel with 80% of diesel fuel.

3. Calculating CPO demand for biodiesel production in each biodiesel blend scenario.

Model of CPO Demand for Food

CPO demand for food is the amount of CPO used to produce food. The model of CPO demand projection for food utilized a mathematical model with the following projection steps:

1. Projecting CPO demand for food (palm cooking oil) in 2023-2030. The demand for palm cooking oil was obtained by multiplying the population by the amount of palm cooking oil consumption per capita, which is assumed to be 19.95 kg/capita/year, obtained from the average per capita consumption of cooking oil in 2018-2022. This value is supported by research conducted by PASPI (2021), in which the amount of consumption in 2020 was 19.6 kg/capita/year (PASPI, 2021). The population projections until 2045 used in this research are based on the projections of Statistics Indonesia.

2. Calculating CPO demand for food with the assumption that the volume of cooking oil produced per 1 ton of CPO is 683 kg and 1 liter of cooking oil equals 0.8 kg (Trihusodo, 2022).

Model of CPO Demand for Oleochemicals

The model of CPO demand projection for oleochemicals was only based on the historical composition of CPO for oleochemicals to CPO as a whole. The composition of CPO demand for oleochemicals until 2045 is assumed to be 3.91% of total CPO production, obtained from the average proportion of CPO demand for oleochemicals in 2020-2022.

Model of CPO Demand for Export

CPO demand for biodiesel is the amount of CPO exported. CPO demand for export is a function of global CPO prices. The estimates and projections of CPO demand for export until 2045 were calculated using an error correction model, in which CPOE is CPO Demand for Export (thousand tons) and HCPO is Global CPO Price (USD/mt).

The model of CPO demand for export used export data from the Indonesian Palm Oil Association (GAPKI) from January 2020 to October 2023 and data on monthly global CPO prices from the World Bank's Pink Sheet. The global CPO prices used as a shock to project CPO demand for export were obtained using the Holt-Winters/Triple Exponential Smoothing/Error, Trend, Seasonality method as in Equation 4. Meanwhile, to project the monthly CPO prices for November 2023 to December 2045, the authors utilized monthly price data from January 1960 to October 2023 taken from the World Bank's Pink Sheet.

Simulation Scenarios

Scenarios of Oil Palm Plantation Land Area

1. Scenario 1, the area of oil palm plantation land is assumed to grow at a constant rate of 1.74% per year. The growth value of 1.74% was the average growth in 2018-2022.
2. Scenario 2, the area of oil palm plantation land is assumed to grow constantly at 1% per year.
3. Scenario 3, the area of oil palm plantation land is assumed to continue growing at 1.74% in 2023, and the land area in 2024-2045 is assumed to remain the same as the area of oil palm plantation land in 2023.

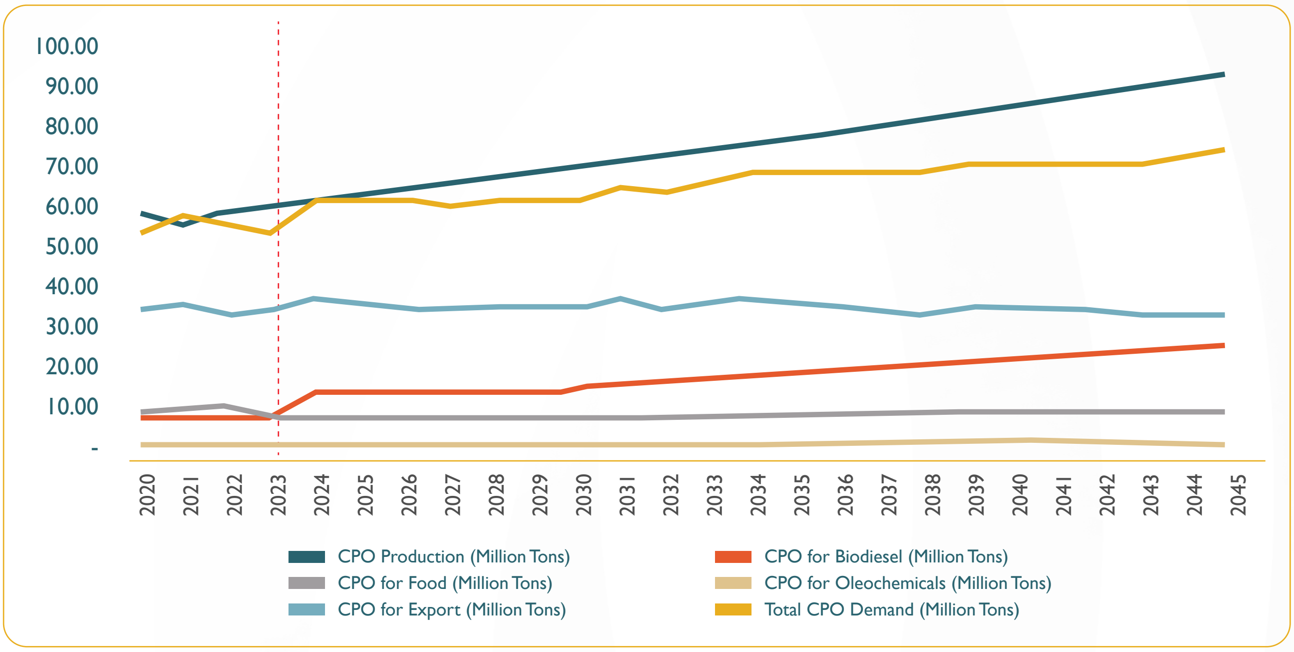
Scenarios of Biodiesel Blends

1. Scenario (a), in 2023, the biodiesel blend is set at 30% (B30), and in 2024-2045, the biodiesel blend is set at 35% (B35). B35 is applied in models starting from 2024 although B35 has been implemented nationally since August 2023 (Nano, 2023).
2. Scenario (b), the biodiesel blend is set at 30% (B30) in 2023, the biodiesel blend is set at 35% (B35) in 2024, and the biodiesel blend is set at 40% (B40) in 2025-2045. The B40 policy will begin to be implemented in 2025 with the consideration that B50 will be achieved in 2029 (Wahyudi, 2023).
3. Scenario (c), the biodiesel blend is set at 30% (B30) in 2023, the biodiesel blend is set at 35% (B35) in 2024, the biodiesel blend is set at 40% (B40) in 2025-2028, and the biodiesel blend is set at 50% (B50) in 2029-2045 (Wahyudi, 2023).

4. Scenario (d), the biodiesel blend is set at 30% (B30) in 2023, the biodiesel blend is set at 35% (B35) in 2024, the biodiesel blend is set at 40% (B40) in 2025-2028, the biodiesel blend is set at 50% (B50) in 2029-2034 (Wahyudi, 2023), and the biodiesel blend is set at 100% (B100) in 2035-2045. The B100 scenario is based on the energy sector targets that the government seeks to achieve (Arvirianty, 2019), while the year of the policy implementation was determined by the researchers.

Results and Discussion

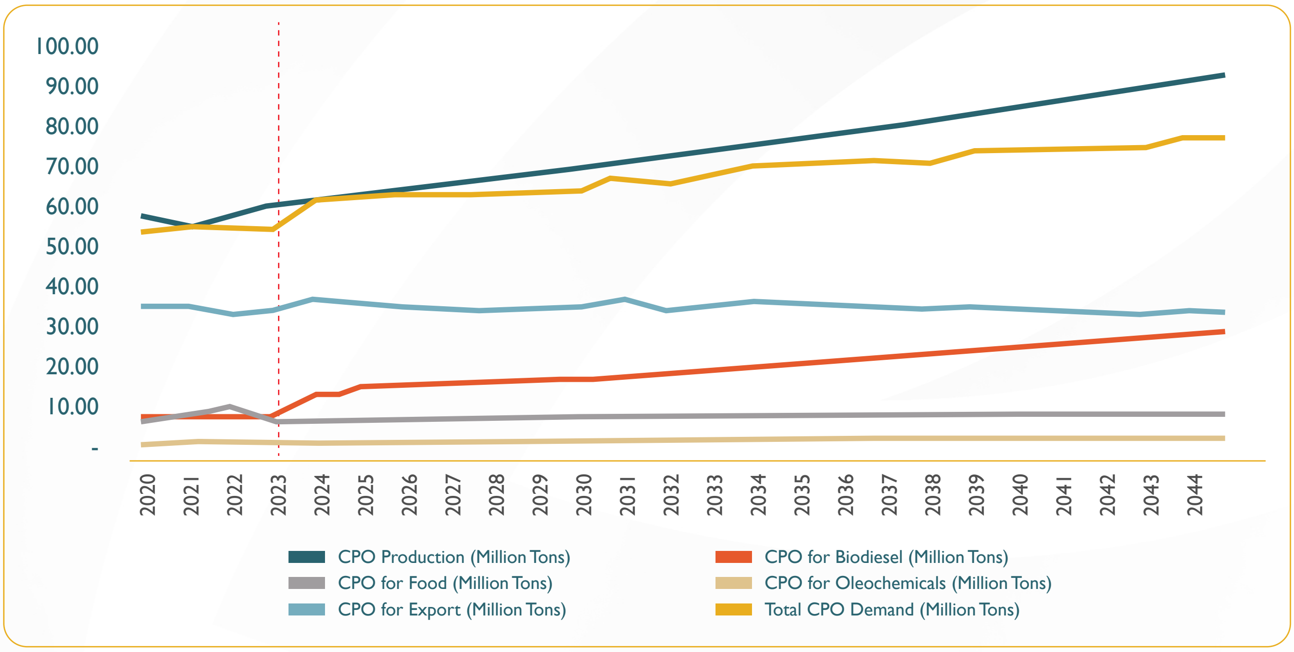
***Figure 9.** Results of Scenario 1a*



Based on Figure 9, **the simulation results of Scenario 1a** reflect an attractive prospect. In this context, the annual oil palm plantation land growth of 1.74% and the implementation of the B30 biodiesel blend in 2023, followed by an increase to B35 from 2024 to 2045, are the focus of the analysis. This simulation shows that the CPO production is more than sufficient to meet the demand, resulting in a significant surplus. The CPO demand for all purposes, including biodiesel, food, oleochemicals, and export, will remain controlled below the CPO production level.

A temporary decline in CPO demand in 2023, followed by a significant increase in 2024 after the B35 blend implementation, marks an impactful change in the market. However, there will be no supply shortage or excessive pressure on CPO demand for domestic purposes. Thus, the conclusion that can be drawn is that the B30 and B35 biodiesel blend policies and oil palm plantation land growth effectively maintain the balance between CPO production and demand.

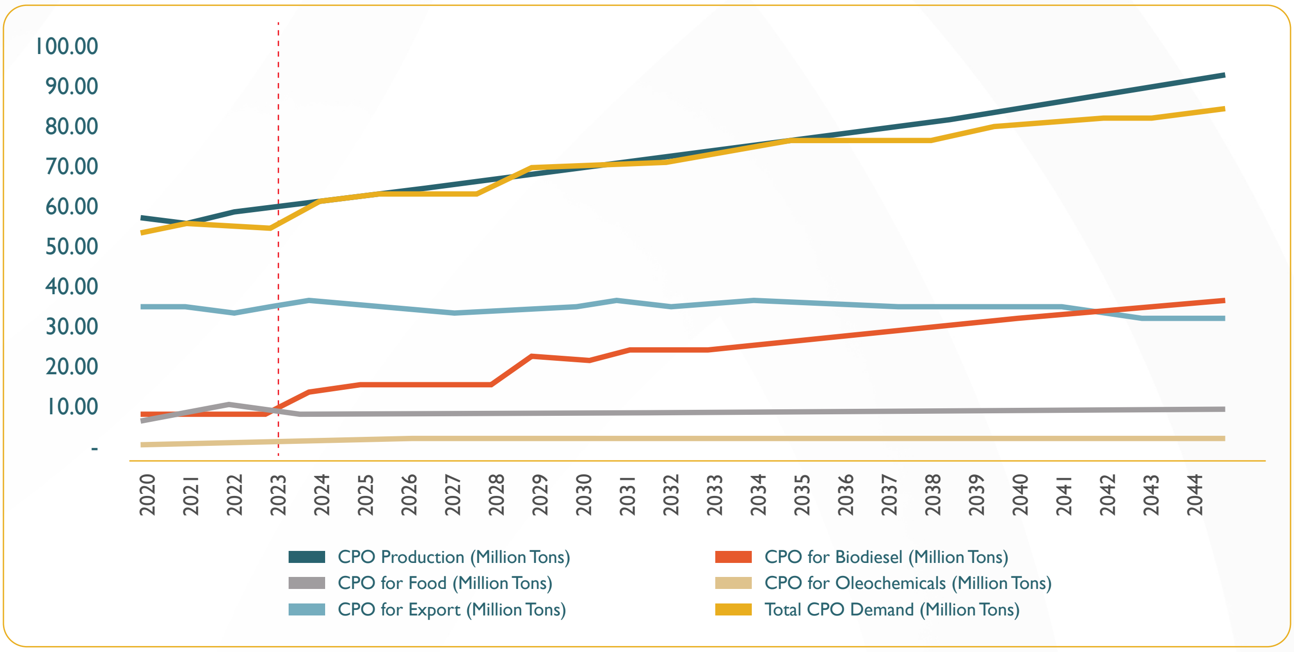
***Figure 10.** Results of Scenario 1b*



The simulation results of Scenario 1b, depicted in Figure 10, are fascinating to discuss. In this scenario, oil palm plantation land grows by 1.74% per year, and the implemented biodiesel blend policies are B30 in 2023, B35 in 2024, and B40 from 2025 to 2045. The CPO balance shows an overall surplus, similar to the findings in Scenario 1a Simulation, with production of 89.44 million tons and demand of 74.33 million tons in 2045. It should be noted that with the initial implementation of the B40 policy in 2025, there will likely be a CPO production deficit or excess CPO demand for various purposes, such as biodiesel, food, oleochemicals, and export. However, the total CPO demand is forecast to remain below production levels in 2026 and onwards.

Although there will be pressure on the CPO demand to meet the B30, B35, and B40 biodiesel blend policies and land growth of 1.74% per year, overall, there will be no increase in pressure on CPO demand for food. This is in line with the simulation results of Scenario 1a. At the initial implementation of the B40 policy in 2025, the CPO supply for food may experience pressure; this will be temporary and only occur in a very short period.

Figure 11. Results of Scenario 1c



The simulation results of Scenario 1c, illustrated in Figure 11, show an interesting situation. In this scenario, the growth of oil palm plantation land is 1.74% per year, while the implementation of the B30 biodiesel blend policy begins in 2023, followed by B35 in 2024, B40 from 2025 to 2028, and B50 from 2029 to 2045. Figure 11 suggests that there will be a surplus of CPO production in 2045 compared to the total CPO demand, with production reaching 89.44 million tons and demand of 81.44 million tons.

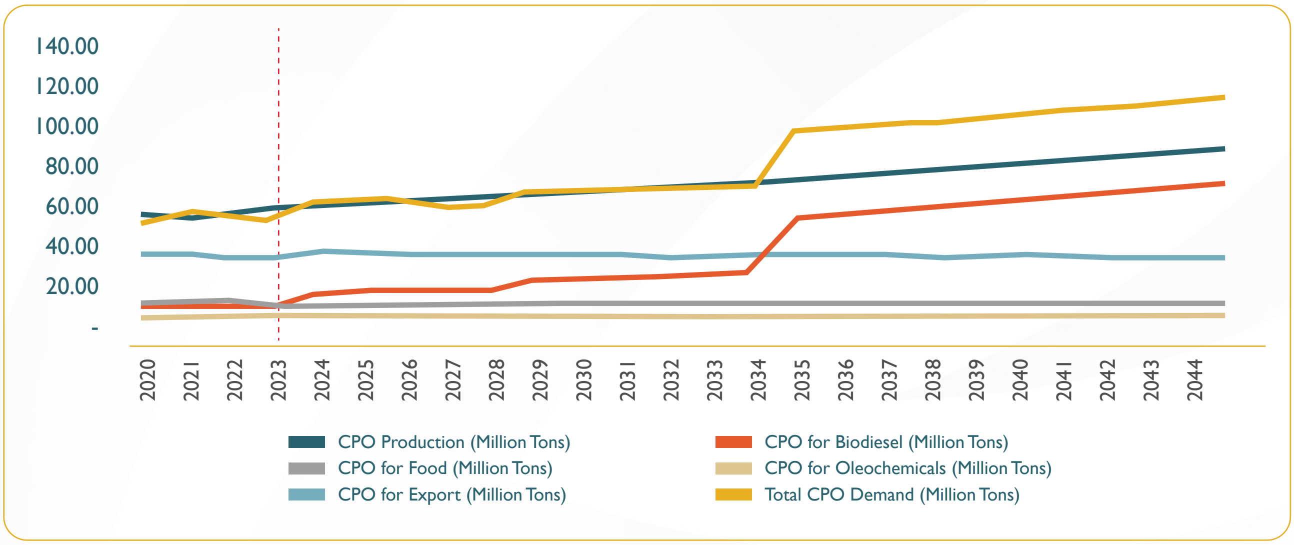
In the analysis, there will be periods where demand for CPO exceeds production, such as in 2025, 2029, and 2031. However, CPO production is projected to exceed demand in the following years until 2045.

Based on Scenario 1c, there will be pressure in implementing the B30, B35, B40, and B50 biodiesel blend policies and achieving land growth of 1.74% per year, but the pressure on CPO availability for food will not occur throughout the whole projection period. This is due to the total CPO demand, which is expected to remain lower than the overall CPO production from 2023 to 2045. Nevertheless, at the beginning of the implementation of the biodiesel blend policies, CPO availability for food may experience pressure. However, this is likely to be temporary and only occur in a short term.

Projection results based on a scenario with oil palm plantation land growth of 1.74% per year, as well as the implementation of B30 in 2023, B35 in 2024, B40 from 2025 to 2028, B50 from 2029 to 2034, and B100 from 2035 to 2045, depict a challenging situation. Starting in 2025, a deficit in CPO production is likely to occur, with total demand exceeding CPO production.

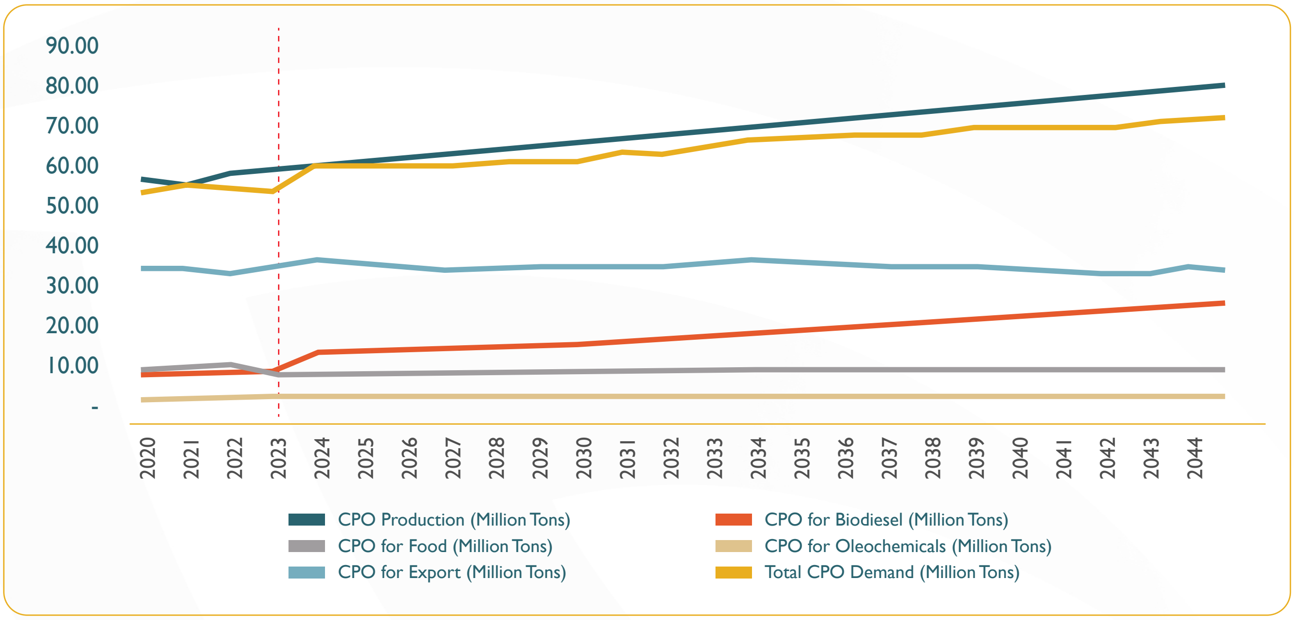
Although there will be periods with a CPO surplus between 2024 and 2034, a deficit is expected to occur again in 2045 where domestic CPO demand is projected to reach 116.99 million tons, whereas the production is forecast to reach only 89.44 million tons, leaving a deficit of 27.55 million tons. In that year, CPO use is projected at 71.1 million tons for biodiesel, 32.93 million tons for export, 9.47 million tons for food, and 3.49 million tons for oleochemical needs.

Figure 12. Results of Scenario 1d



Based on Scenario 1d, throughout 2024-2045 period, there may be a shortage of CPO to meet all demands. The scarcity of CPO for food is a real possibility, especially due to the mandatory policy of using a B100 biodiesel blend. If the CPO export policy remains unchanged by the government, there could be an increase in prices for food products that use CPO and its derivatives. Certainly, increasing pressure on demand for CPO will result in rising CPO prices in global and domestic markets.

Figure 13. Results of Scenario 2a



The simulation results of scenario 2a, which involves oil palm plantation land growth of 1% per year and the implementation of the blend of B30 in 2023 and B35 from 2024 to 2045, show that the CPO balance tends to experience a surplus (with production reaching 78.29 million tons and demand of 70.77 million tons in 2045) (see Figure 13). Despite a decrease in CPO demand in 2023, a significant increase is expected to occur in 2024 with the implementation of the B35 policy. The potential impact is a spike in the CPO demand for biodiesel in 2045 up to 24.89 million tons, an increase of 196.48% from 2022.

Using this scenario, there will be a CPO production deficit or excess demand in the domestic market in 2024, but the situation will gradually improve as time goes by. However, the B30 biodiesel blend policy implemented simultaneously with B35 until 2045 is likely to put pressure on CPO demand for food, oleochemicals, and export in the initial phase of the simulation. CPO production is projected to still be able to meet demand, especially because of land growth of 1% per year, indicating a positive aspect that CPO demand for all sectors, both domestic and export, can be met from 2025 onwards.

Figure 14. Results of Scenario 2b

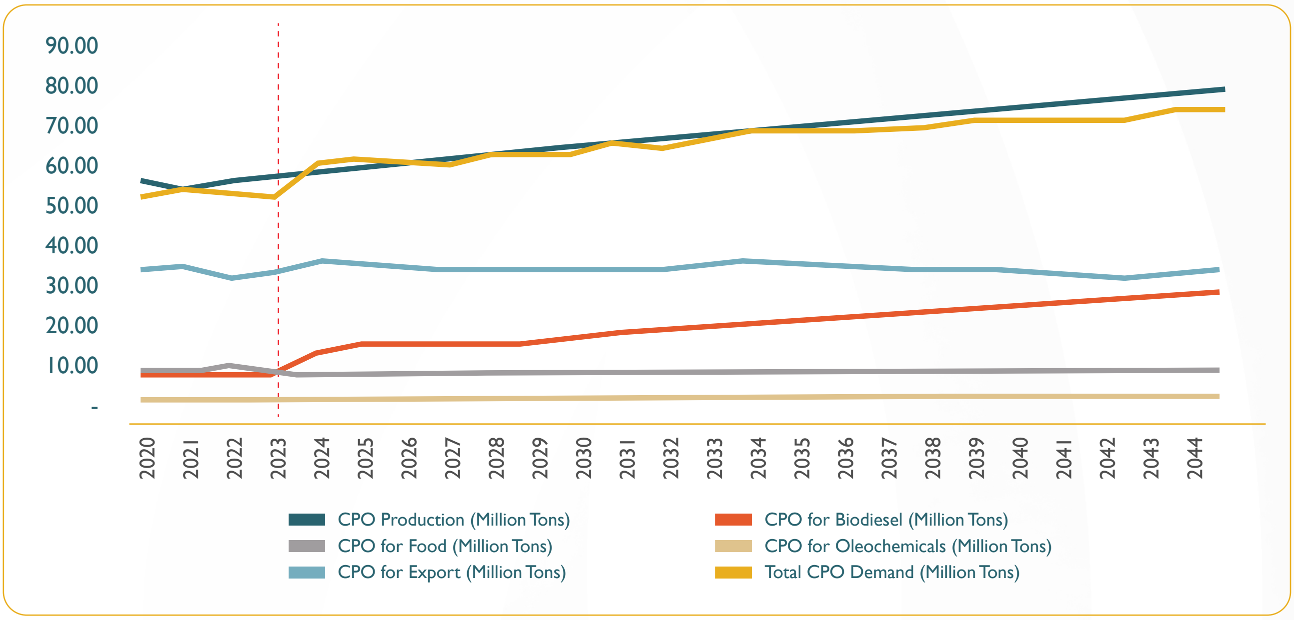


Figure 14 shows the simulation results of scenario 2b. In this scenario, there is land growth of 1% per year, and the B30 biodiesel blend is implemented in 2023, followed by B35 in 2024 and B40 from 2025 to 2045. In general, the CPO balance shows excess production or surplus, similar to the simulation results of scenario 2a (with production reaching 78.29 million tons and demand of 73.89 million tons in 2045). However, during the initial implementation of the B40 policy, a CPO production deficit or CPO excess demand for biodiesel, food, oleochemicals, and export is likely to occur in 2025, although total CPO demand will fall in 2026.

Using scenario 2b, with CPO demand for implementing the B30, B35, and B40 biodiesel blend policies and an increase in land area of 1% per year, pressure on CPO demand for food will generally not occur, similar to the simulation results of scenario 2a. This is because the total CPO demand for all consumption sectors, including export, is projected to remain lower than the overall CPO production from 2023 to 2045. Nevertheless, during the early stage of the B40 policy implementation in 2025, the policy may put pressure on the availability of CPO for food, but this will be temporary and only occur in a very short period.

Figure 15. Results of Scenario 2c

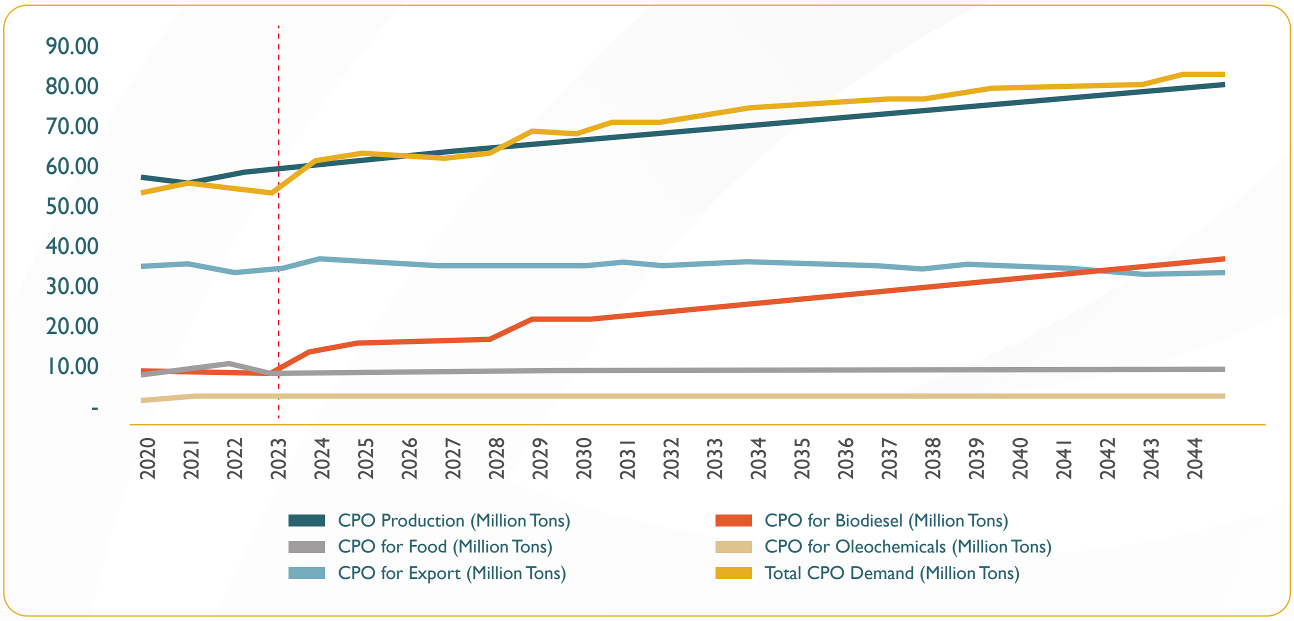
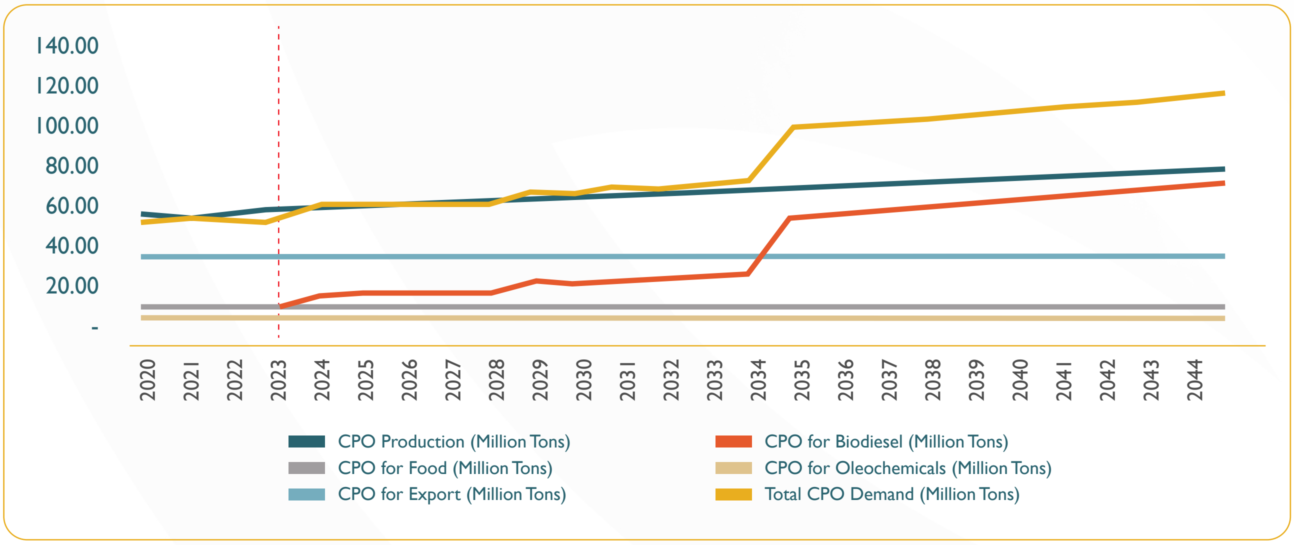


Figure 15 shows the simulation results of Scenario 2c where there is an increase in land of 1% per year and the implementation of B30 biodiesel blend begins in 2023, B35 in 2024, B40 from 2025 to 2028, and B50 from 2029 to 2045. Finally, a surplus of CPO production is forecast to occur in 2045 (with production reaching 78.29 million tons and demand of 81 million tons). During the analysis period, CPO production will be greater than the demand in 2023, 2026, 2027, and 2028, yet starting in 2029, or from the implementation of B50, CPO production will no longer meet the demand.

Using Scenario 2c, with the demand for CPO to meet the B30, B35, B40, and B50 biodiesel blend policies, and an increase in land area of 1% per year, there will be pressure on CPO availability throughout the projection period. This is due to the total CPO demand for all consumption sectors, including exports, which exceeds overall CPO production. Hence, CPO demand for food cannot be met if the mandatory biodiesel blending rate is forced to be raised.

Figure 16. Results of Scenario 2d

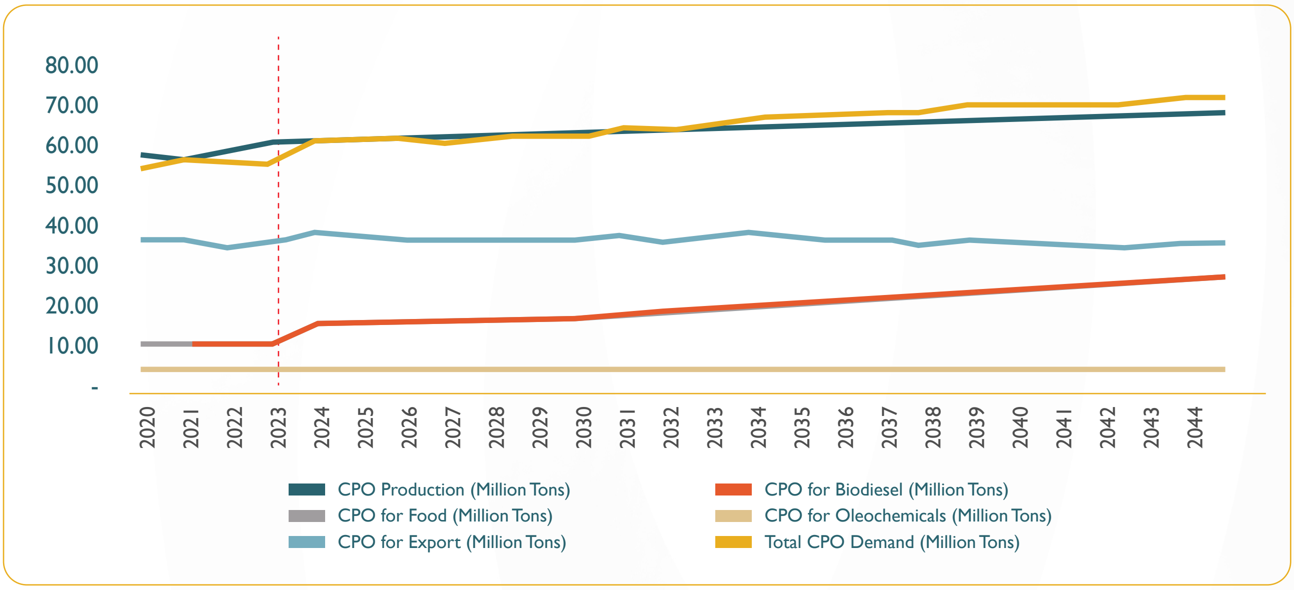


Scenario 2d assumes constant growth of oil palm plantation land of 1% until 2045, with the use of a blend of B30 in 2023, B35 in 2024, B40 from 2025 to 2028, B50 from 2029 to 2034, and B100 from 2035 to 2045. During the analysis period, the CPO production is projected to be greater than the demand in 2023, 2026, 2027, and 2028. However, the production is forecast to experience a deficit from 2029 or following the implementation of B100.

In 2045, it is projected that domestic CPO demand will reach 116.55 million tons and there will be a deficit of 38.27 million tons. CPO use in 2045 is expected to be divided into 71.1 million tons for biodiesel, 32.93 million tons for export, 9.47 million tons for food, and 3.49 million tons for oleochemical needs.

Based on Scenario 2d, during the 2024-2045 period, there will be a potential shortage of CPO to meet all CPO demand. The scarcity of CPO for food could occur due to the mandatory implementation of the B100 biodiesel blend use. If CPO exports continue according to the existing market mechanisms (without any changes in government policies on exports), there will be pressure on the availability of CPO for food. In this period, an increase in food prices that use CPO or its derivative products is likely to occur, and of course, pressure on demand for CPO will increase CPO prices globally and domestically.

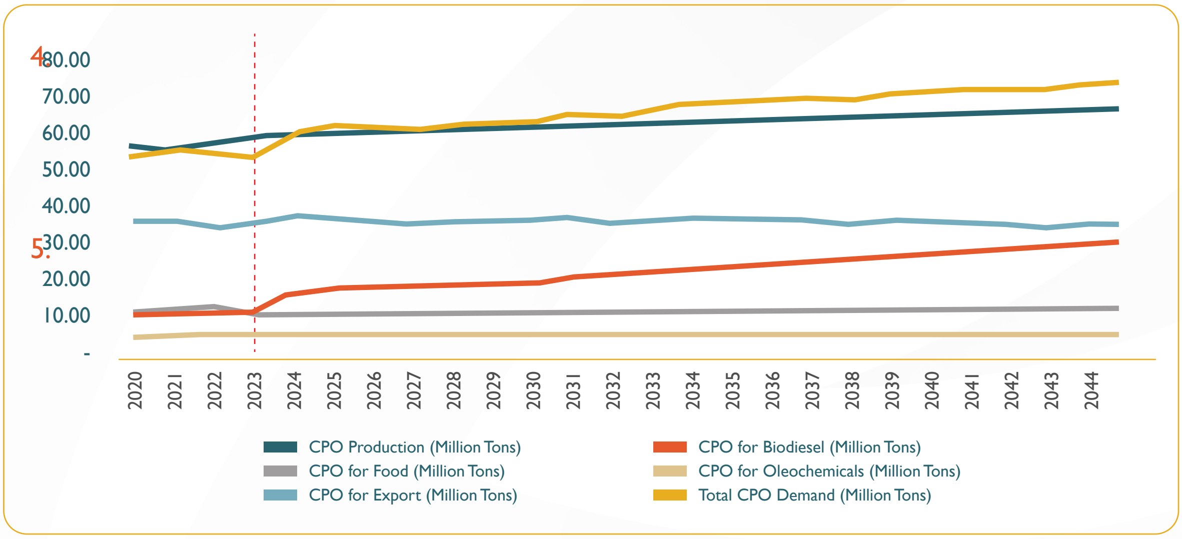
Figure 17. *Results of Scenario 3a*



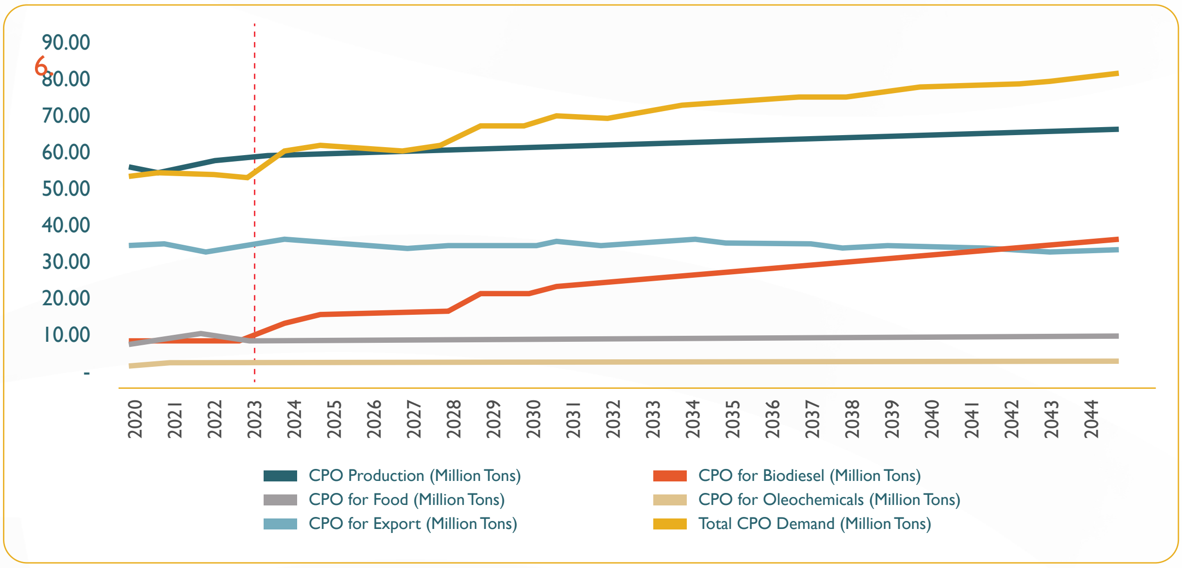
Scenario 3a sets the oil palm plantation land area to grow by 1.74% in 2023, and the land area in 2024-2045 to remain the same as that in 2023. The biodiesel blend is set at 30% (B30) in 2023 and 35% (B35) in 2024-2045. The simulation shows that CPO production will experience a general deficit. During the 2023-2045 period, a surplus is forecast to occur only in 2026-2030, while in other years, there will be a deficit. In 2045, the CPO deficit is projected to reach 4.31 million tons.

The simulation results of Scenario 3a demonstrate that without land expansion from 2024, CPO production cannot meet the demand even with the B35 biodiesel blend policy. The scarcity of CPO, especially for food, may occur more quickly if the land expansion policy is abolished and CPO exports continue as usual. This pressure is likely to increase domestic and global prices of CPO and its derivative products.

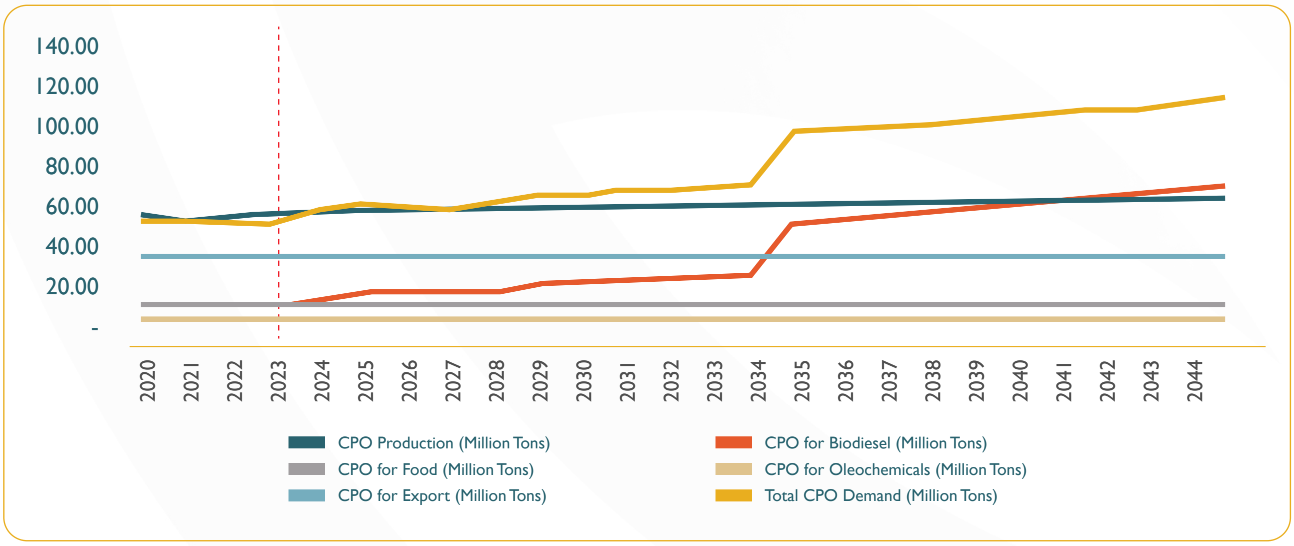
Figure 18. Simulation Results



a. Scenario 3b



b. Scenario 3c



c. Scenario 3d

Simulation results of Scenarios 3b, 3c, and 3d show a CPO deficit from 2024, with oil palm plantation land growth of 1.74% in 2023 and constant plantation land area from 2024 to 2045.

- **Scenario 3b**: In 2045, the CPO deficit is projected to reach 7.87 million tons with a total demand of 73.39 million tons and production of 65.53 million tons. The CPO demand for B40 biodiesel in 2045 is estimated at 28.44 million tons. The biodiesel blend policies implemented are B30 in 2023, B35 in 2024, and B40 from 2025 to 2045.
- **Scenario 3c**: As it applies the B30 biodiesel blend policy in 2023, B35 in 2024, B40 between 2025 and 2028, and B50 from 2029 to 2045, the CPO deficit in 2045 will reach 14.98 million tons with a demand of 80.50 million tons and production of 65.53 million tons. The CPO demand for B50 biodiesel in 2045 is forecast to be 35.55 million tons.
- **Scenario 3d**: The CPO deficit in 2045 is projected to reach 50.53 million tons with a demand of 116.05 million tons and production of 65.53 million tons. The scenario sets out B30 biodiesel blend policy implementation in 2023, B35 in 2024, B40 in 2025-2028, B50 in 2029-2034, and B100 in 2035-2045.

Conclusion and Recommendations

The simulation results of three scenarios demonstrate that Indonesia has experienced a CPO production deficit since 2024 (upon the implementation of the B35 blend policy), meaning that the total CPO demand - for food, biodiesel, oleochemicals, and export - exceeds the amount of CPO production from the same area of land in 2023. The CPO production deficit shows that there may be pressure on CPO demands for food. Assuming that there is no expansion of oil palm plantation land, the pressure on CPO availability for food will occur earlier - especially in periods of lower biodiesel blend use - and it will exacerbate as the biodiesel blend rate continues to be raised and CPO exports carry on according to market mechanisms (without changes in government policies on exports).

1. If the area of oil palm plantation land increases by 1.74% per year, the B30, B35, and B40 biodiesel blend policies will not result in a greater CPO demand, including for export, than the CPO volume produced. In other words, if the land continues to be consistently expanded by that percentage until 2045, the production will suffice the CPO demand for downstreaming at home and exports. The production will not be able to meet domestic and export demands if the B100 blend policy is in force. Once excess demand occurs, CPO availability for food will be threatened by biodiesel blend policies if exports, which constitute a large portion of the demand, carry on according to international market demand.
2. Limiting exports may be an alternative policy to ensure CPO availability for food when mandatory biodiesel blend policies cause the inability to produce CPO to meet all domestic demand. For instance, if B100 biodiesel production is forced to be carried out in accordance with the mandatory policy, the CPO supply for exports should be used to solve the shortage of CPO for food needs.
3. If there are no changes in export policies and excess CPO demand occurs, policies on biodiesel blends that use CPO as the raw material will affect CPO availability for food. Eventually, prices of food will soar and general inflation will occur. The prices of CPO, too, will certainly rise in global and domestic markets.

4. The time/year of implementation of biodiesel blend policies, especially B100, determines the time when excess demand occurs. The faster the policies are implemented, the faster the pressure on CPO provision for food arises.

5. With the situations of the simulated biodiesel blend policies, CPO production amount still determines the intensity of the pressure of demand on production. In this case, an increase or decrease in the area of oil palm plantation land affects the amount of CPO production. If the production rises and it can meet domestic and export demands, the supply of CPO for food will remain safe, and vice versa. Oil palm plantation land expansion is likely to cause deforestation and increase GHG emissions, which is contrary to the government's intention to reduce GHG emissions. One of the main reasons why Indonesia's palm oil-based biodiesel industry has not put pressure (especially in Scenario I) on food is the ongoing deforestation. Raising the biodiesel blend rate in a rapid and massive manner poses a threat to food security.

6. Blend policies, such as B30, B35, and the like, that implement lower biodiesel blends (for example, B35 is lower than B40) will lead to a shortage of CPO, where CPO demand exceeds CPO production, with a land growth that is lower over time. In other words, the scarcity of CPO for food needs will also occur faster.

The simulations indicate that Indonesia has experienced a CPO production deficit since 2024 (when the B35 blend policy began to take effect). The authors recommend that biofuel or biodiesel be produced using waste as the raw material, be it agricultural waste, domestic waste, or industrial waste such as used cooking oil. Utilizing waste as the raw material for biofuel can help reduce the impact on competition between CPO demands for biofuel and food production, and alleviate pressure on the environment. Furthermore, food crops such as oil palms are not the only plants that can cause pressure on land or land conflicts. Non-food crops, such as castor oil plants, also require land, which may threaten land availability for crops and, eventually, food prices. For this reason, it is necessary to develop the potential of biodiesel produced from waste as feedstock by providing support in the form of investment in new bioenergy technology that can enhance the efficiency of biodiesel production without sacrificing food supply, which may affect food security in Indonesia. Such a holistic approach is required so that impacts on food and the environment are considered in formulations of bioenergy policies. By focusing on using waste, biofuel may be a more sustainable solution for supporting energy supply without sacrificing food security or damaging the environment.

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Appendix

Model of CPO Production

CPO production is the amount of CPO and PKO produced by Indonesia. In this analysis, CPO production is a function of oil palm plantation land area (Equation 1).

PCPO = f(L) (1)
CPO production was estimated and projected using an error correction model with the following long-run equation:

$PCPO_t = \alpha 0 + \alpha 1 L_t + e1_t$ ……………………………………………………………(2) and the following short-run equation:

$DPCPO_t = \alpha 0 + \alpha 1 DL_t + e1_{t-1} + v_t$ …………………………………………………...…(3) in which PCPO is the CPO Production (tons) and L is the Land Area (ha).

The data on CPO production and oil palm plantation land area utilized were obtained from Statistics Indonesia from 2001 to 2022. The projected CPO production up to 2045 was calculated using several land scenarios that can be found in the simulation scenario section.

Model of CPO Demand for Biodiesel

CPO demand for biodiesel is the amount of CPO utilized for producing biodiesel. CPO demand for biodiesel was projected using a mathematical model with the projection steps as follows:

1. Projecting the demand for biodiesel in 2023-2030. The data on and projections of biodiesel demand in this research were obtained from the Agricultural Outlook 2021-2030 (OECD, 2021). For the record, OECD's projections used the B30 policy assumption. The data and projections from the OECD were then employed to re-project the demand for biodiesel in 2031-2045 with the Holt-Winter/Triple Exponential Smoothing/Error, Trend, Seasonality method. The ETS equation is as follows:
   $\hat{y}_{t+h|t} = (P_t + hb_t)s_{t+h-m(k+1)}$ (4)
   with $\hat{y}_{t+h|t}$ being the forecast on h for future periods, P_t being the level at time t, b_t being the trend at time t, s_t being the seasonal factor at time t, m being the seasonal frequency, and k being an integer of (h−1)/m (Hyndman & Athanasopoulos, 2018).

2. Calculating the demand for biodiesel with formulas:
   $B_{n*} = B_n$ 100 × 40 ……………………………………………...………..……………(5)
   30 100
   $B_{n*} = B_n$ 100 × $n*$ ………………………………………………………..……………(6)
   n 100
   $B_{n*} = B_n$ $n*$ ……………………………………………………………………………..(7)
   n

   in which B_n is B30, meaning n as the value of 30. Meanwhile, B_{n*} is the biodiesel demand based on the biodiesel blend program, which means that $n*$ a natural number from 1 to 100 according to the mandatory government policy. The biodiesel blend scenario applied can be found in the simulation scenario section. The biodiesel blend program is a government program that requires blending biodiesel with diesel fuel. For example, the B20 program is a government program that requires blending 20% of biodiesel with 80% of diesel fuel.

3. Calculating the CPO demand for biodiesel production in each biodiesel blend scenario using the following formula:

   CPO Demand for Biofuel
   = $Bn*t$ ……(8)
   Volume of biofuel produced per 1 ton of $CPOt$

   The volume of biodiesel produced per 1 ton of CPO is assumed to be 0.7565 tons (Thifal et al., 2023), assuming that 1 liter equals 0.8 kg (Trihusodo, 2022).

Model of CPO Demand for Food

CPO demand for food is the amount of CPO used to produce food. The model of CPO demand projection for food utilized a mathematical model with the following projection steps:

1. Projecting the CPO demand for food (cooking oil from palm oil) in 2023-2030 with the formula on Equation 4.

   Demand for palm cooking oil = Number of population × Palm Cooking Oil Consumption Per Capita (4)

   Palm cooking oil consumption per capita is assumed to be 19.95 kg/capita/year, obtained from the average cooking oil consumption per capita between 2018 and 2022. The amount of consumption per capita is supported by research carried out by PASPI (2021), in which the consumption in 2020 amounted to 19.6 kg/capita/year (PASPI, 2021).
   The projected population in 2045 used in this research was obtained from the projection of Statistics Indonesia.

2. Calculating the CPO demand for food using the formula in Equation 10

   CPO Demand for Food = Demand for Cooking Oil ………….(10)

   t Volume of cooking oil produced per 1 ton of CPOt

   The volume of cooking oil produced per 1 ton of CPO is assumed to be 683 kg, and 1 liter of cooking oil is assumed to equal 0.8 kg (Trihusodo, 2022).

Model of CPO Demand for Oleochemicals

The model of CPO demand for oleochemicals was merely based on the historical composition of CPO for oleochemicals to CPO as a whole. The composition of CPO demand for oleochemicals until 2045 is assumed to be 3.91% of total CPO production, obtained from the average proportion of CPO demand for oleochemicals in 2020-2022.

Model of CPO Demand for Export

CPO demand for biodiesel is the amount of CPO exported. CPO demand for export is a function of global CPO prices (Equation 11).

CPOE = f(HCPO) (11)

The estimates and projections of CPO demand for export until 2045 were calculated using an error correction model with the long-run equation shown in Equation 12.

$LnCPOE_t = \gamma_0 + \gamma_1 LnHCPO_t + e_{2t}$ ……………………………………………..(11) and the following short-run equation,

$D(LnCPOE_t) = \gamma_0 + \gamma_1 D(LnHCPO_t) + \gamma_2 e_{2t-1} + v_{2t}$ …………………………...(11)

in which CPOE is CPO Demand for Export (thousand tons) and HCPO is the Global CPO Price (USD/mt).

The model of CPO demand for export used export data from the Indonesian Palm Oil Association (GAPKI) from January 2020 to October 2023 and data on monthly global CPO prices from the World Bank's Pink Sheet. The global CPO prices used as a shock to project CPO demand for export were obtained using the Holt-Winters/Triple Exponential Smoothing/Error, Trend, Seasonality method as in Equation 4. Meanwhile, to project the monthly CPO prices for November 2023 to December 2045, the authors utilized monthly price data from January 1960 to October 2023 taken from the World Bank's Pink Sheet.

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