*FINAL RESEARCH REPORT*

# Determining the Upper Limit (Cap) for Oil Palm Plantations in Indonesia

From the Lens of Environmental Support and Load Capacities (D3TLH)

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# Determining the Upper Limit (Cap) for Oil Palm Plantations in Indonesia from the Lens of Environmental Support and Load Capacities (D3TLH)

Bandung, August 2024


## Research Team

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# Foreword

We thank the Almighty God for His blessings and grace, which enabled us to complete this final research report titled *"Determining the Upper Limit (Cap) Value for Oil Palm Plantations in Indonesia from the Lens of Environmental Support and Load Capacities (D3TLH)"*. This report is the result of research aimed at identifying the optimal limits of oil palm plantation areas that the environment can tolerate in various regions of Indonesia, while taking into account the ecosystem's ability to sustain oil palm plantation activities.

This research has the support of several parties. We would like to thank everyone who contributed to this research, whether through data, input, or technical and administrative assistance. Special thanks are extended to Perkumpulan Sawit Watch, Yayasan Satya Bumi, and Yayasan Madani Berkelanjutan for their financial support and assistance in carrying out this research. We also want to thank the entire research team and experts who helped us prepare this report.

We acknowledge that this research still has limitations and shortcomings. As a result, we enthusiastically welcome constructive suggestions and criticism for future enhancements. We hope that this report will be useful to interested parties, particularly those involved in the planning and management of sustainable oil palm plantations in Indonesia.

Finally, we hope that this report provides an important contribution to Indonesia's environmental management and sustainable development.

Bandung, September 2024
Sincerely,
The Research Team

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# Chapter 1 Introduction

## 1.1 Background

Palm oil is a major and leading plantation commodity in Indonesia. The area of palm oil plantations in Indonesia is estimated to reach 16.834 million hectares in 2023 (Directorate General of Plantation, Ministry of Agriculture of the Republic of Indonesia, 2022). Meanwhile, the Minister of Agriculture's Decree No. 833/KPTS/SR.020/M/12/2019 on the Determination of the Area of Indonesian Oil Palm Cover in 2019 establishes a total of 16.381 million hectares of oil palm plantation.

Global demand for palm oil rises by 4% per year (Sawit Watch, 2021). In addition to the demand for palm oil exports, the implementation of Indonesia's Biodiesel Program, known as B35, has led to an increase in the demand for palm oil. This program utilises 35% vegetable fuel, specifically palm oil mixed with diesel fuel. Areas of palm oil plantations have been expanded in response to increased demand for the product. Overall, there has been an increase in areas of oil palm plantations converted from forest cover on the islands of Sulawesi, Maluku, Papua, and other small islands (Sawit Watch, 2021).

The expansion of oil palm plantations can impact the decline of environmental services (ES), including biodiversity-supporting ES, food-providing ES, disaster regulation ES (increased flood disasters), and climate regulation ES (changes in air temperature) (Amalia et al., 2019). Changes in forest land cover caused by oil palm plantation expansion can also impact the FOLU Net Sink 2030 achievement targets, the emission reduction targets in the Enhanced NDC 2030, and the low-carbon climate-resilient development targets in the RPJPN 2025-2045. As a result, it is necessary to study the upper limit (cap) value for the coverage of oil palm plantations from the perspectives of environmental support and load capacity (D3TLH) to limit the expansion of oil palm plantations and achieve a balance that supports human life and other living beings.

## 1.2 Research Question

Based on that context, the main aim of this research is to answer the question, "what is the upper limit (cap) on the area of oil palm plantations from the lens of D3TLH in Indonesia, and what is the status of existing oil palm plantation areas in relation to that upper limit?"

## 1.3 Research Objectives

This research aims to determine the upper limit (cap) for oil palm plantations in Indonesia from the lens of Environmental Support and Load Capacities (D3TLH).

## 1.4 Significance of the Research

This research provides extensive benefits in environmental, social, and economic aspects, as well as in government policy formulation. By using the Environmental Support and Load Capacities (D3TLH) approach, this research helps in identifying the upper limits (cap) of oil palm plantations in Indonesia, thus serving as a basis for more sustainable planning. Here are the benefits of this research in various aspects:

- Environmental Aspects

  This research contributes to the identification of safe limits for oil palm plantation expansion based on D3TLH across all Indonesian islands and archipelagos. By establishing an upper limit (cap), this research can reduce the risk of uncontrolled deforestation, land degradation, and biodiversity loss caused by the conversion of natural ecosystems into oil palm plantations. This study also ensures that the expansion of oil palm plantations does not exceed an acceptable ecological capacity, reducing negative impacts such as forest fires and increased carbon emissions. Thus, the findings of this research can be used to develop more data-driven environmental policies and support national targets for reducing greenhouse gas emissions.

- Social Aspect

  The D3TLH approach, which establishes an upper limit (cap) on oil palm plantations, can help reduce social conflicts caused by land expansion that does not comply with spatial planning or indigenous community rights. Many oil palm plantations are currently operating on land that could be used for other purposes, such as customary forests and community agricultural land. This research provides the government and stakeholders with a scientific basis for developing more equitable and sustainable land use policies while also protecting the interests of local communities.

- Economic Aspect

  This research helps to ensure that the palm oil industry grows more steadily and sustainably by taking into account the balance between productivity and environmental carrying capacity. By establishing an upper limit (cap), this research can help prevent excessive oil palm expansion, which in the long run can lead to a

decrease in productivity due to land degradation and conflicts of interest in resource utilisation. This study also advocates for more strategic economic policymaking by emphasising the findings of the CELIOS (2024) study, which found that a moratorium on permits and replanting is more beneficial than expanding new land. This study demonstrates that cap-based oil palm plantation management strategies, such as the EUDR regulations implemented by the European Union, can improve the palm oil industry's competitiveness in an increasingly sustainable global market.

- Government Policy Aspect

  This research provides a solid scientific foundation for the government to develop more sustainable policies for oil palm plantations. By establishing an upper limit (cap) based on D3TLH, this study can be used to inform the development of regulations governing the moratorium on new permits, productivity optimisation without expansion, and replanting policies. Furthermore, this research contributes to the government's efforts to meet carbon emission reduction targets and improve land use planning. Using the D3TLH-based approach, this research can help the government develop policies that not only increase the economic benefits of the palm oil industry, but also improve environmental and social governance in this sector.

With these various benefits, this research helps to bridge the gap between economic and environmental interests in Indonesian palm oil industry governance. Results of this research are expected to serve as a scientific foundation for the government, industry, and civil society to build a more productive, fair, and sustainable palm oil sector.

## 1.5 Report Structure

- **Chapter 1: Introduction**

  This chapter will provide an explanation of the research's background, problems, objectives, scope, and benefits.

- **Chapter 2: Literature Review**

  This chapter will explain the concept of D3TLH, followed by a discussion of previous research and a brief overview of the related policies that serve as the research's foundational framework.

- **Chapter 3: Research Methodology**

  The methods chapter will then go into detail about the required data and the data processing methods that were used.

- **Chapter 4: Research Results**

  The results chapter will display the results, including the upper limit of the national oil palm plantation "cap" and the results for each island, as well as explanations of the obtained results.

- **Chapter 5: Conclusion and Recommendations**

  This chapter contains the research findings, as well as recommendations for future research improvements and development. Then, recommendations will be presented, both technically related to the research methodology and substantive recommendations based on the obtained results.

# Chapter 2 Literature Review

## 2.1 Assessment of Oil Palm Plantation Land Using Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) is a commonly used method for assessing sustainable oil palm plantation land. MCA has been used successfully in strategic environmental studies, especially to balance competing land use demands in oil palm plantations. Wong et al. (2023) used multi-criteria analysis and data from unmanned aerial vehicles (UAVs) to map and classify land suitable for oil palm cultivation in Malaysia. The analysis took into account indicators of erosion protection on slopes, vegetation in transition areas between rivers and land, water clarity index, channel modification, and landscape connectivity and quality. Another method is to analyse land conversion trends using high-resolution data and environmental criteria. Zhao et al. (2024) state that the remaining land suitable for oil palm cultivation is limited, owing to environmental constraints such as climate, soil, landform/topography, protected areas, biomass, peatland, and land cover. Zhao et al. (2024) provide important insights for balancing economic development and ecosystem protection, as well as valuable data for policymakers to guide long-term plantation expansion. Another research project, conducted by Manorama et al. (2024), uses Multi-Criteria Decision Analysis (MCDA) within the Geographic Information System (GIS) framework to identify and map potential oil palm cultivation sites. The research considers environmental factors (annual rainfall, temperature, slope, duration of continuous dry periods, and soil depth) to assess land suitability for sustainable plantation development.

## 2.2 The Concept of Environmental Support and Load Capacities (D3TLH)

Environmental Support Capacity (DDLH) is the environment's ability to sustain human life, other living beings, and the balance between them (Law No. 32/2009). DDLH can be defined in ecological terms as the relationship between supply and demand in an ecosystem, where available ecosystem services become a limiting factor for population size and human activities that can be met by these ecosystem services (Rees 1990). The number of people and economic activities that the ecosystem can support is heavily reliant on the environment's ability to provide natural resources and ecosystem services required for survival.

Meanwhile, the Environmental Load Capacity (DTLH) is the environment's ability to absorb substances, energy, and/or other components that enter or are introduced into it (Law No. 32/2009). This concept refers to the environment's ability to absorb waste and emissions while preventing excessive ecosystem degradation. If this capacity is exceeded, pollution and environmental degradation will occur, threatening the ecosystem's long-term viability as well as human life in the area.

In the context of oil palm plantations, land use must consider DDLH and DTLH so that plantation expansion does not cause long-term environmental damage. Given human demand for palm oil products, both domestically and internationally, the expansion of the palm oil industry must be consistent with the ecosystem's ability to provide resources and absorb environmental impacts. If not properly managed, palm oil expansion that does not consider D3TLH can result in deforestation, forest fires, biodiversity loss, and increased carbon emissions, all of which have a negative impact on the environment and community welfare.

The importance of D3TLH in planning for oil palm plantations is also consistent with various Indonesian regulations. Article 12 Paragraph (2) of Law 32/2009 on Environmental Protection and Management (PPLH) states that if an Environmental Protection and Management Plan (RPPLH) has not been prepared, natural resource utilisation must be based on D3TLH. Furthermore, Law 26/2007 on Spatial Planning emphasises the importance of considering D3TLH when developing the Regional Spatial Plan (RTRW), in order to maintain the balance between development and environmental preservation.

D3TLH is also an important study component in evaluating RTRW, RPJP, RPJMN/RPJMD, and Strategic Environmental Assessment (KLHS). However, many development policies still fail to take this aspect into account, as evidenced by the frequent environmental disasters caused by ecosystem degradation and uncontrolled natural resource extraction. As a result, D3TLH-based environmental planning and management have emerged as critical steps towards more sustainable development.

Understanding the capacity of D3TLH allows the palm oil industry to operate within ecological and socially safe limits. This study lays the groundwork for more data-driven policies aimed at determining the upper limits of areas for oil palm plantations, limiting unsustainable expansion, and increasing productivity while maintaining environmental balance. Thus, incorporating the D3TLH concept into oil palm plantation management not only contributes to ecosystem sustainability, but also helps to achieve national economic development goals and reduce carbon emissions.

## 2.3 Ecological Footprint

The ecological footprint is a method of quantifying human resource needs in relation to the amount of productive land available to provide those resources (Wackernagel & Rees, 1996). Because the Earth's surface is limited, there is a limited amount of productive land and resources that can be produced each year. As a result, area units were chosen as a measure of resource provision to represent how the Earth's surface provides various ecosystem services and ecological resources (Wackernagel et al., 2005).


*Figure 2. 1 Ecological footprint illustration*
*(Source: WWF Japan and Global Footprint Network; Ecological Footprint for Sustainable Living in Japan)*

On the demand side, the ecological footprint calculates each person's requirement for plant-based food, fibre, livestock, fish, wood, and other forest resources; space and infrastructure; and forests that absorb carbon emissions. From the supply side, biocapacity represents land and water productivity, which includes forest land, agricultural land, fisheries, grasslands, and built-up areas (Global Footprint Network, 2024).

The limitation of land area determines the environment's ability to produce resources to meet various human needs. Due to DDLH, land must be allocated using the ecological footprint approach to avoid exceeding its capacity. The ecological footprint approach connects human resource needs (in this case, palm oil) with available productive land areas and DDLH capacity.

## 2.4 Land Physical Suitability

Land suitability assessment is an important step in land management (McDonald & Brown, 1984). Land suitability assessment is defined as the process of determining the most appropriate spatial patterns of land cover/use based on regulations, preferences, or predictions for specific activities (Malczewski, 2004; Stoms et al., 2002). The primary data sources for land suitability assessment are land use information and physical data (Roberts et al., 1979). Land suitability assessment is represented as a model that considers specific criteria to evaluate land suitability.

Based on the methodology used, land suitability models can be either deterministic models or stochastic (probabilistic) models (Demers, 1997). The deterministic model is based on known relationship functions and interactions, while the stochastic model is based on statistical probabilities. The probabilistic model is developed due to the uncertainty in the relationships or interactions between the components of it. According to (Verburg et al., 2013), uncertainty in modelling can arise due to the modeller's incomplete knowledge, incomplete data, and/or numerous simplifications in representing the model. Specifically in the field of the environment, uncertainty arises because environmental impacts are location-specific, and environmental changes affect land in different ways for each location, resulting in spatially varying uncertainty in assessment outcomes. Spatial assessment with uncertainty is primarily aimed at static data and physical models (Heuvelink et al., 2010; Nol et al., 2010), and some are integrated with scenario-based assessments (Verburg et al., 2013).

In this research, the upper limit of palm oil plantation area must consider both the needs and the physical suitability of the location. According to the Palm Oil Plantation Fund Management Agency (Palm Oil Plantation Fund Management Agency, 2021), oil palm plantations typically grow under three (3) conditions: climate, topography, and soil. Table 3.2 in subsection 3.1 details the 12 physical parameters used to assess the suitability of land for oil palm plantations.

## 2.5 Related Policies and Regulations

Changes in forest land cover caused by the expansion of oil palm plantations have the potential to impede the achievement of national environmental targets related to carbon emission reduction, such as the FOLU Net Sink 2030, emission reduction targets in the Enhanced NDC 2030, and low-carbon climate-resilient development in the RPJPN 2025-2045. Several policies govern land cover change into oil palm plantations, including:

1. Law No. 32/2009 on Environmental Protection and Management;

2. Government Regulation No. 23/2021 on The Organization of Forestry;
3. President Regulation No. 98/2021 on Carbon's Economic Value;
4. President Directive No. 8/2018 on the Moratorium and Evaluation of the Licensing of Palm Oil Plantations and Productivity Increases for Palm Oil Plantations (Palm Oil Moratorium); and
5. Minister of Environment and Forestry Regulation Nomor P.83/MENLHK/SETJEN/KUM.1/10/2016 on Social Forestry.

In addition, there are related planning documents governing palm oil plantations, such as the National Forestry Plan (RKTN) for 2011-2030 and the National Strategic Plan for Reducing Emissions from Deforestation and Forest Degradation (REDD+).

# Chapter 3 Research Methodology

## 3.1 Data

This research uses three (3) types of data: statistical data for the ecological footprint calculator, physical parameter data, and limiting variables. The details of each data point, as well as their sources, are listed below.

1. Statistical data for calculator needs

In general, there is statistical data for the ecological footprint calculator needs that cover a variety of topics, including human needs for food, clothing/textiles, living space and public space (infrastructure), and energy, which requires land to produce the resources used to meet those life needs. Table 3.1 provides additional information about the statistical data.

*Table 3.1 Statistical data for the needs of the ecological footprint calculator*

| Demand Sector | Data Type | Data Source |
|---|---|---|
| Food | Data on food consumption of the population | Food Security Statistical Data for 2020 and 2022 (Ministry of Agriculture, 2023)* |
| | Data on the energy content of foodstuffs | Food Security Statistical Data for 2014 (Ministry of Agriculture, 2015)* |
| | Food Composition Data List (DKBM) | Food Security Statistical Data for 2014 (Ministry of Agriculture, 2015) and Yogyakarta State University (https://staffnew.uny.ac.id/upload/132318122/pendidikan/DKBM-Indonesia.pdf)* |
| | Data on the quantity produced for each type of food | Agricultural Statistics Page, Ministry of Agriculture (https://bdsp2.pertanian.go.id/bdsp)* |
| | Data on the harvest area of each type of food crop | Agricultural Statistics Page, Ministry of Agriculture (https://bdsp2.pertanian.go.id/bdsp)* |
| | Data footprint intensity for a variety of food products | Literature on ecological footprint development by the University of Michigan (2003) and from the Working Guidebook to the National Footprint Accounts by the Global Footprint Network (Lin et al., 2017)* |
| | Data on the area of irrigated and non-irrigated rice fields | Agricultural Land Statistics for 2022 (Ministry of Agriculture, 2023)* |
| | Fish production data | Statistics Indonesia, 2023 (Provinces in Figures Year 2022)* |
| | Pond area data | Land Cover Map |
| Clothing/textiles | Data on cotton production quantity | National Plantation Statistics 2021-2023* |
| | Data on cotton harvest area | National Plantation Statistics 2021-2023* |
| | Data on cotton production intensity over 1 year | National Plantation Statistics 2021-2023* |
| Infrastructure and wood (housing | Standard space requirements for each person for housing | Minister of Settlement and Regional Infrastructure Decision No. 403/KPTS/M/2002* |

| Demand Sector | Data Type | Data Source |
|---|---|---|
| and public spaces) | Standard space requirements for public facilities and infrastructure | SNI 03-1733-2004* |
| | Round wood footprint intensity data | Literature on ecological footprint development by the University of Michigan (2003) and from the Working Guidebook to the National Footprint Accounts by the Global Footprint Network (Lin et al., 2017) and calculation results (2018).* |
| Energy | Electricity consumption per capita and per customer | PLN Statistics, 2021* |
| | Facilities for the provision of PLN electricity | PLN Statistics, 2022* |
| Palm Oil | Consumption for food | Databoks, 2024 (https://databoks.katadata.co.id/datapublish/2024/03/14/konsumsi-sawit-untuk-biodiesel-meningkat-lampaui-pangan)* |
| | Consumption for biodiesel | Databoks, 2024 (https://databoks.katadata.co.id/datapublish/2024/03/14/konsumsi-sawit-untuk-biodiesel-meningkat-lampaui-pangan)* |
| | Consumption for oleochemistry | Databoks, 2024 (https://databoks.katadata.co.id/datapublish/2024/03/14/konsumsi-sawit-untuk-biodiesel-meningkat-lampaui-pangan)* |
| Emission | Emission factors and energy consumption | Bappenas, 2014 (Technical Guidelines for Calculating Baseline Emissions of the Energy-Based Sector)* |
| | Emission factors for each type of forest | UNFCC (National Forest Referencce Emission Level for Deforestation and Forest Degradation)* |
| Water availability | Statistical data on surface water availability in Indonesia | Ministry of Public Works and Public Housing, 2016* |
| Land Cover | Land cover map | KLHK, 2022 |
| | Forest area map | KLHK, 2021 |
| | Palm oil distribution data | Sawit Watch, 2022 |

**open data*

2. Physical parameter data:

Table 3.2 shows data on land cover and ecoregions, as well as 12 physical parameters, to assess the suitability of land for oil palm plantations.

*Table 3.2 Physical parameter data used to assess the suitability of land for oil palm plantations.*

| No | Variable | Data Source |
|---|---|---|
| 1 | Land cover | KLHK, 2022 |
| 2 | Ecoregion | KLHK, 2021 |
| 3 | Palm oil distribution | Sawit Watch, 2024 |
| 4 | Rainfall | CHIRPS, 2022* |
| 5 | Bulk density | FAO, 2023* |
| 6 | Water availability | Ministry of Public Works and Public Housing |
| 7 | Soil surface temperature | Landsat 8 OLI NASA* |
| 8 | Organic carbon content | FAO, 2023* |

| No | Variable | Data Source |
|---|---|---|
| 9 | Soil pH | FAO, 2023* |
| 10 | Slope | SRTM NASA, 2000* |
| 11 | Elevation | SRTM NASA, 2000* |
| 12 | Total nitrogen content | FAO, 2023* |
| 13 | Terrain ruggedness index | SRTM NASA, 2000* |
| 14 | Topographic Wetness Index | SRTM NASA, 2000* |

**open data*

3. Constraint variable

This research on limiting palm oil plantations employs constraining variables that have significant value for the continuation of life, both directly (springs, built-up areas, etc.) and indirectly (peat hydrological units, karst, mangroves, etc.). These constraining variables serve to sustain efforts to protect biodiversity and habitats from the expansion of palm oil plantations. The application of constraint variables to the palm oil plantation site candidate model (output stage 3) produces palm oil plantation locations that are free of those constraint variables. The constraint variables are shown in Table 3.3.

*Table 3.3 Constraint variables used in the research*

| No | Variable | Data Source | Description |
|---|---|---|---|
| 1 | Environmental support capacity (DDLH) of water suppliers based on water district (WD) | Ministry of Public Works and Public Housing, 2016 | Taken WD that has a DDLH water provider that has been in deficit. |
| 2 | Peat Hydrological Unit (PHU) | KLHK, 2023 | Peatland ecosystems linked by water flows (both surface and underground), including deep peatlands with protective peat functions and cultivated peat. |
| 3 | Karst | Ministry of Agriculture, 2023 | The dissolution of limestone creates geological formations and underground river flows. |
| 4 | Mangrove | KLHK, 2023 | The coastal forest ecosystem helps to prevent coastal erosion and abrasion. |
| 5 | Conservation areas and protected forests. | KLHK, 2023 | Conservation areas include:<br>● Natural Reserve Area (KSA): Nature Reserve and Wildlife Sanctuary<br>● Nature Conservation Area (KPA): National Parks, Nature Tourism Parks, Grand Forest Parks, and Hunting Parks |
| 6 | Cover of primary and secondary forest land | KLHK, 2022 | The land cover includes primary dryland forests, secondary dryland forests, primary mangrove forests, primary swamp forests, secondary mangrove forests, and secondary swamp forests. |
| 7 | Spring | KLHK, 2022 | Natural cracks in rock layers allow groundwater to flow to the Earth's surface. |

| No | Variable | Data Source | Description |
|---|---|---|---|
| 8 | Slope above 30% | DEM SRTM NASA, 2000* | Land slope or slope with an inclination greater than 30 degrees. It is prone to erosion, landslides, and soil degradation due to its steepness. |
| 9 | Critical Land | KLHK, 2023 | Land that has been damaged to the point where its function is disrupted, as evidenced by high levels of erosion, infertile and non-vegetated soil, and dry/waterlogged conditions. |
| 10 | Protected wildlife | KLHK, 2023 and IUCN, 2023* | A home range of protected wildlife, such as:<br>● Sumatran elephant (*Elephas maximus sumatranus*) (*Critically Endangered* (CR))<br>● Sumatran orangutan (*Pongo abelii*) (CR)<br>● Kalimantan orangutan (*Pongo pygmaeus*) (CR)<br>● Tapanuli orangutan (*Pongo tapanuliensis*) (CR)<br>● Sumatran tiger (*Panthera tigris sumatrae*) (CR)<br>● Pangolin (*Manis javanica*) (CR)<br>● Honey bear (*Helarctos malayanus*) (VU)<br>● Bird-of-paradise (*Paradisaea* spp.) (endemic and declining population) |
| 11 | Indigenous community | BRWA, 2024 | Area of indigenous people's settlements and customary forest areas. |
| 12 | Key Biodiversity Areas (KBA) | *Key Biodiversity Areas, 2023* | Regions play an important role in biodiversity conservation and contribute significantly to the survival of terrestrial, freshwater, and marine ecosystems. These regions are established based on the endemic, rare, or vulnerable status of a species and ecosystem in a given region. |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | Yayasan Lokahita, 2023 | High JLH water regulation, habitat and biodiversity support, carbon regulation (with a high JLH index value >= 3.4) |
| 14 | Built-up areas | KLHK, 2022 | The distribution of built-up areas based on land cover. |

**open data*

## 3.2 Method

To ensure ecosystem sustainability, the threshold for oil palm plantation area in Indonesia is determined using an ecological footprint approach that takes into account the environmental support capacity (DDLH). The area of palm oil plantations is one of several land cover/use (PPL) classifications that are taken into account when modelling PPL allocations. The modelling of PPL allocations to determine the upper limit "cap" of Indonesian oil palm plantations is generally divided into two (2) sub-models: (1) calculation of PPL area allocation and (ii) modelling of PPL locations. This modelling is done for each island/island group, so the upper limit value of oil palm plantations in Indonesia is determined by the accumulation of each island/island group.

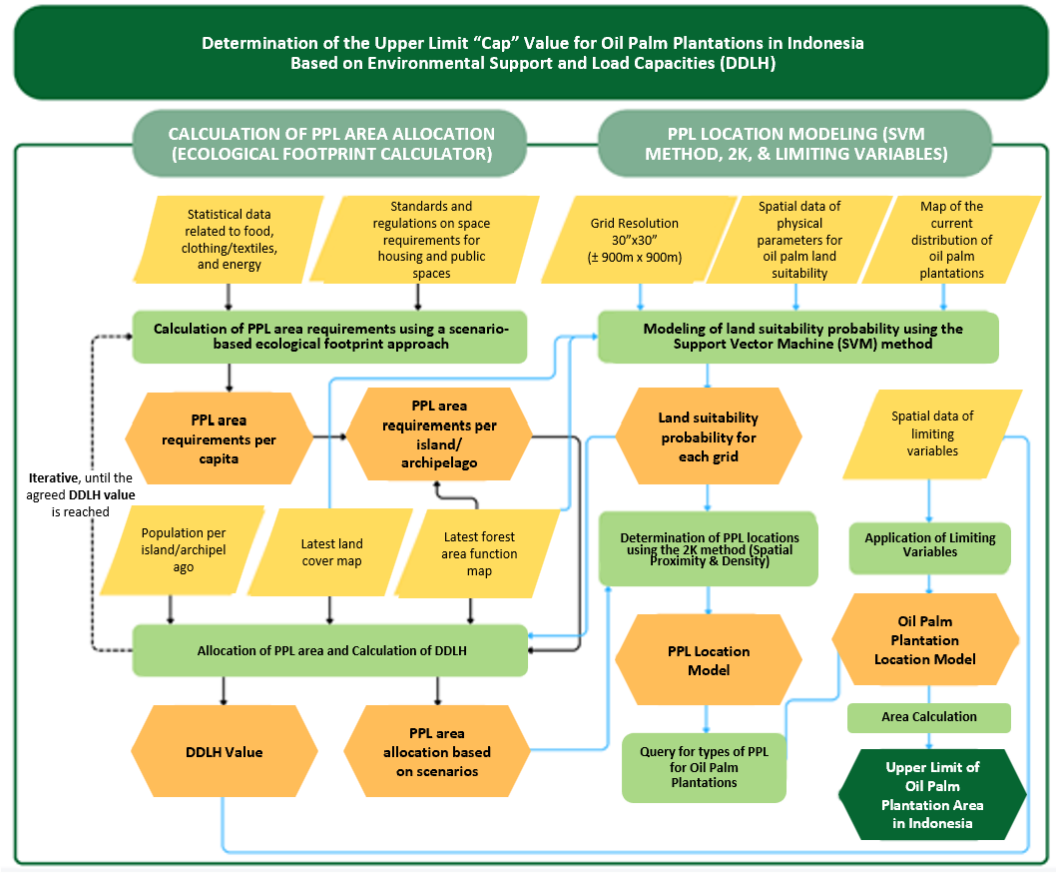



*Figure 3. 1 Methodology for determining the upper limit value of oil palm plantations in Indonesia (Source: adapted and developed from (Safitri et al., 2021; Taradini, 2018))*

**1. Calculation of PPL Location Allocation (Ecological Footprint Calculator)**

Modelling land cover/use allocation (PPL) is done in two steps: (i) calculating the PPL area requirements using a scenario-based ecological footprint approach, and (ii) allocating the PPL area and calculating DDLH. Wackernagel and Rees (1996) developed the ecological footprint approach, which is used to calculate the land area required for land cover/use allocation (PPL). Human needs for food, clothing/textiles, living and public space (infrastructure), and energy necessitate the use of land to produce the resources required to meet those needs. This phenomenon is quantified using the ecological footprint approach. There are resource provisioning scenarios that can be adjusted when calculating PPL area requirements. The scenario can have a value of 100% (all needs met by resources available in the study area), <100% (some needs met by resources from other areas), or >100% (all needs met by resources in the study area and resources supplied to other areas).

The allocation of PPL area and DDLH calculation were performed using the calculated PPL area requirements. The allocation of PPL area is done using the calculated PPL area requirements and the current PPL area. PPL is allocated using the method developed by Lane et al. (2014), with adjustments to the land allocation rules. The results of the PPL area allocation are then compared to the per capita PPL area requirement, yielding the DDLH value, which represents the number of people whose needs can be met by the ecosystem or land in the study area. The DDLH value is calculated using the same method as in the research (Lane et al., 2014). The DDLH value is a parameter that determines whether the planned supply scenario meets the desired DDLH value. If not, this process is iterative, adjusting the scenarios until the desired/agreed-upon DDLH value is reached. Following that, the allocation of PPL area with the DDLH value adjusted to the desired/agreed value is used as input to determine the location of the PPL area allocation.

**2. Modeling PPL Location (SVM Method, 2K, and Constraint Variables)**

The modelling of PPL locations is used to determine the location of oil palm plantations based on the previously calculated plantation area allocation and, more specifically, the likelihood of land physical suitability for oil palm plantations.

Modelling was done in a grid analysis unit with a resolution of 30"x30" (± 900 m x 900 m). There were four stages: (i) land suitability probability modelling using the Support Vector Machine (SVM) method, (ii) determining PPL locations using the 2K method (Proximity and Spatial Density), (iii) querying for Oil Palm Plantation PPL types, and (iv) applying Constraint Variables. Land suitability probability is modelled using 12 physical parameters, including elevation, slope, ecoregion, surface soil temperature, rainfall, Total Nitrogen Content, water availability, soil organic carbon content, soil pH, bulk density, Topographic Wetness Index

(TWI), and Terrain Ruggedness Index (TRI). Land suitability is assessed probabilistically using the SVM (Support Vector Machine) method, which compares the current land use to the 11 physical parameters on each grid. As a result, each grid will be assigned a probability value (0-100%) indicating its suitability for a specific PPL, particularly oil palm plantations.

In the second stage, the land suitability probability values in each grid are used as one of the references to identify alternative potential location candidates for deficit PPL types based on the previous stage's area allocation calculation results. Deficit PPL types (those with a larger area allocation than the current area) require more locations (grids) to meet their allocation. The additional locations will refer to each grid's land suitability probability value and take into account their proximity and spatial density (2K), resulting in the PPL location model for each island/island group.

In the third stage, a query or selection is made on the type of Oil Palm Plantation PPL, resulting in a model of the location and area of oil palm plantations as the upper limit value for oil palm plantations in Indonesia. Given that the 12 parameters used in land suitability probability modelling are still general for all types of PPL, the fourth stage is completed, which involves the application of more specific or characteristic constraints for Palm Oil Plantations. Table 3.3 shows several identified constraint variables.

The application of constraint variables to the candidate model for oil palm plantation locations (output stage 3) yields oil palm plantation locations free of those constraints. The location of the palm oil plantations is then calculated for their area, resulting in the upper limit value of the "cap" of palm oil plantations in Indonesia.

# Chapter 4 Research Results

## 4.1 Upper Limit (Cap) Value on Indonesian Oil Palm Plantations

According to the Environmental Support and Load Capacity (D3TLH) perspective, Indonesia's upper limit (cap) for oil palm plantations is 18,148,602.96 hectares, or approximately **18.15 million hectares**. This figure depicts the accumulation of upper limit modelling results for oil palm plantations on each Indonesian island/archipelago, as described in subsection 4.2. The upper limit values are distributed as follows: 10.70 million hectares on Sumatra, 0.04 million hectares on Java, 0.61 million hectares on Kalimantan, 0.48 million hectares on Sulawesi, 0.03 million hectares in the Maluku Islands, and 0.29 million hectares on Papua (Figure 4.1). This upper limit value (cap) is a little less than the total area of palm oil plantations in 2022, which was 18,215,083.93 hectares, or about 18.22 million hectares. This shows that the growth of oil palm plantations in many areas has reached, if not gone beyond, the level of environmental damage that should be avoided.


*Figure 4. 1 Upper limit value (cap) of oil palm plantations on each island/island group in Indonesia based on the perspective of environmental support and load capacities (D3TLH)*
*(Source: Analysis results, 2024)*

This modelling takes into account the Environmental Support Capacity (DDLH) value for oil palm plantations, which measures the number of people or needs that can be met by existing resources without permanently damaging the environment. DDLH is calculated by comparing the land requirements for oil palm plantations on each island/archipelago to the maximum (cap) for oil palm plantations. According to the modelling results (Figure 4.2), only Sumatra Island and Kalimantan Island have DDLH values greater than 100%, indicating that both islands can still meet palm oil needs, both domestic and export. However, it is important to note that the development of oil palm plantations on these two islands must be done in a sustainable manner to avoid long-term environmental damage and to maintain balance with their D3TLH capacity.

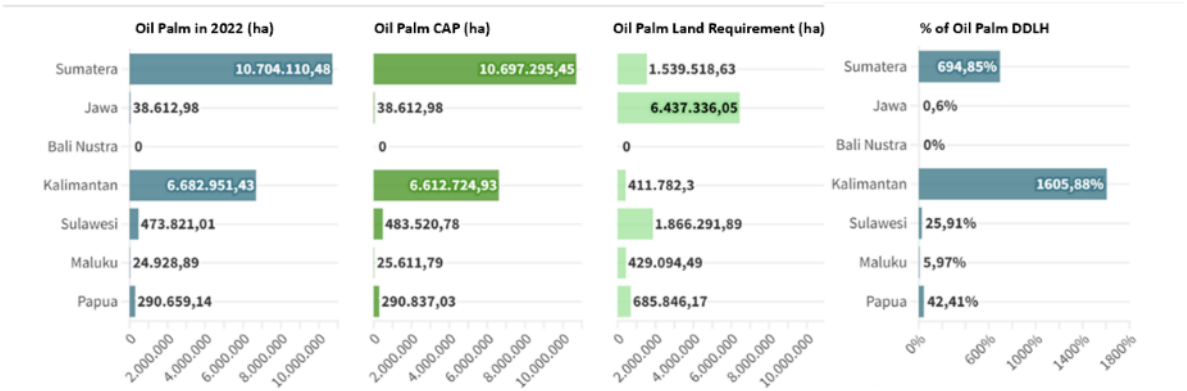



*Figure 4. 2 Area of palm oil plantations in 2022, upper limit value (cap) of oil palm plantations, land requirements for oil palm plantations, percentage of carrying capacity of oil palm plantations to meet the needs of the population on each island/island group in Indonesia*
*(Source: Analysis results, 2024)*

Although Sumatra and Kalimantan Islands have sufficient capacity to support further palm oil plantation development, the overall situation in Indonesia shows that palm oil plantations are approaching or even slightly exceeding the established environmental carrying capacity limits. As a result, efforts to increase production through land efficiency improvements and the implementation of sustainable agricultural practices are critical to maintaining a balance between economic growth in the palm oil sector and environmental sustainability. The establishment of this upper limit should be viewed as an important step towards ensuring that the expansion of palm oil plantations does not result in irreversible environmental damage.

## 4.2 Upper Limit Value 'Cap' of Oil Palm Plantations for Each Island/Archipelago

### 4.2.1 Sumatra Island

Palm oil plantations on the island of Sumatra are currently one of Indonesia's main centres for palm oil production, making the country the world's largest producer. Sumatra Island has a large area of palm oil plantations, totalling 10,704,110.48 hectares spread across several provinces, including Riau, North Sumatra, Jambi, South Sumatra, and Aceh. The majority of the plantations are owned by large corporations, but there are also numerous small-scale people's plantations that contribute to national palm oil production.

**a. Land Cover/Land Use Demands**

In addition to meeting export needs, local palm oil requirements must be considered, given the high demand for food, energy, and other domestic consumption. Palm oil from Sumatra Island is not only exported to the global market; it is also widely used domestically, including for the needs of the Sumatran population, for food products such as cooking oil, and for biodiesel production as part of the national renewable energy program. Palm oil plantations are undoubtedly required as production land for various raw material needs. However, when calculating the land area required for palm oil plantations, other basic needs must be considered to ensure that various basic sector needs, such as food, clothing, infrastructure/housing, and energy, are met, each of which necessitates specific types of productive land. Therefore, an ecological footprint approach is used to calculate land cover/use requirements (PPL).

In calculating PPL needs, a scenario of 100% self-sufficiency for all types of needs is used, which means that all of the population's needs are met using the resources available on the island of Sumatra, with no imports or exports from other areas. Except for the rice supply scenario, which uses a figure of 113%, Sumatra Island is also a rice production hub in Indonesia. A scenario with a value of more than 100% indicates that some rice commodities are distributed outside of Sumatra Island.

According to the calculations, with a population of 59,982,570 in 2022, the land requirement for oil palm plantations on the island of Sumatra is 1,539,518.63 hectares, or approximately 1.54 million hectares. 64.0% of that need, or approximately 0.98 million hectares of oil palm plantations, is required for energy production, specifically biodiesel. Meanwhile, 20.5% of the need for oil palm plantations, or approximately 0.32 million hectares, is for food supply, while the remaining 15.6%, or approximately 0.24 million hectares, is for oleochemical supply (Figure 4.3).

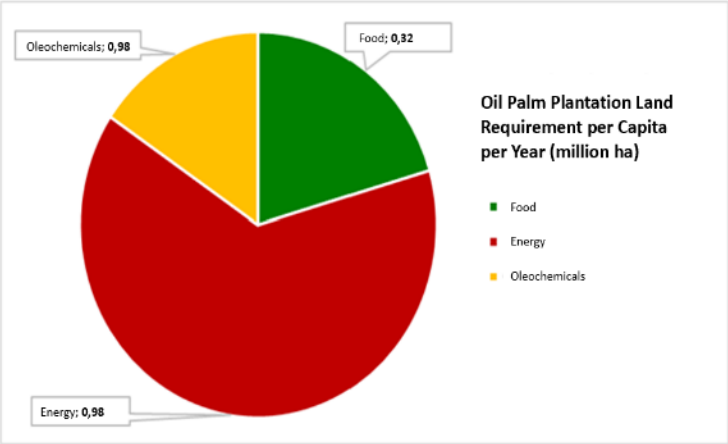



*Figure 4. 3 Area of Oil Palm Plantation Land Requirements in Sumatra Island in 2022 Based on Demand Categories (Source: analysis results, 2024)*

In addition, the land requirements for PPL other than palm oil plantations were calculated, and the results are shown in Table 4.1. Each PPL area requirement is compared to the current PPL area in 2022. Of the eight (8) types of PPL, two (2) are in deficit: wetland agriculture (rice fields) and fish ponds. According to the previously established scenario, additional land area is still required to meet Sumatra Island's rice and prawn pond commodities. Meanwhile, the remaining six types of PPL, including palm oil plantations, are in surplus. This means that no additional land area is required to meet the related commodities; rather, it has the potential to be partially repurposed to meet Sumatra Island's deficient land needs, subject to its suitability.

*Table 4.1 Area of Needs and Existing PPL on Sumatra Island in 2022*

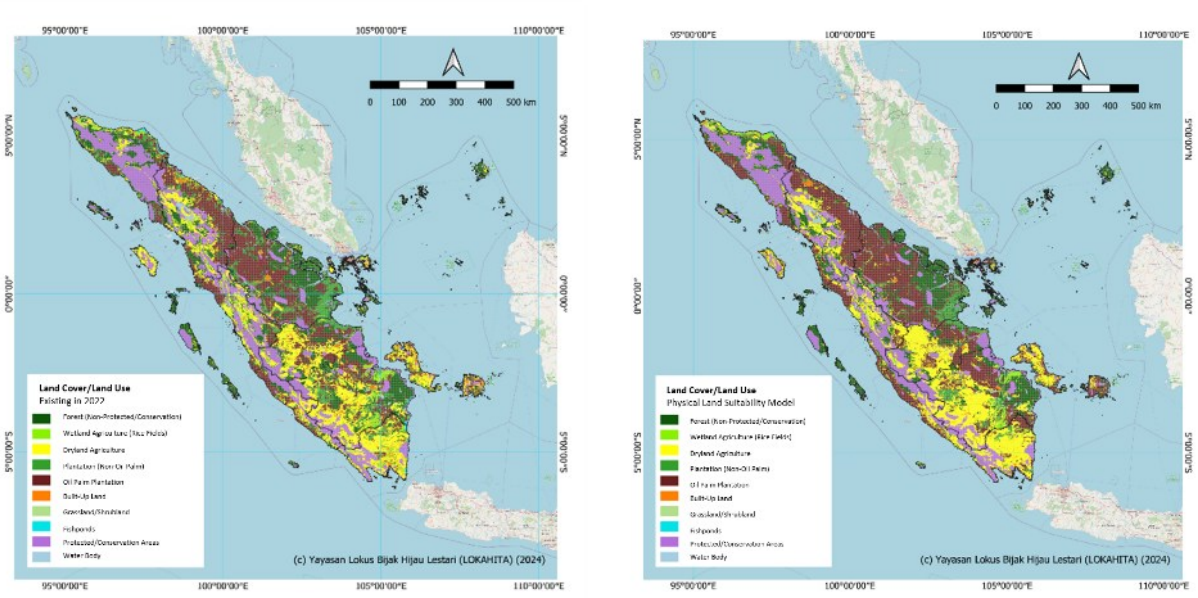
| | Types of Land Cover/Land Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forest (non-Protected/Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| Land Requirement (ha) | 72.191,18 | 1.586.754,79 | 3.556.023,98 | 1.082.508,55 | 1.539.518,63 | 83.975,60 | 102.671,04 | 227.424,67 |
| Existing PPL Area (ha) | 9.179.480,46 | 1.576.928,48 | 9.679.811,01 | 3.966.333,07 | 10.704.110,49 | 1.040.038,85 | 146.404,35 | 151.377,48 |
| Surplus/Deficit? | Surplus | Deficit | Surplus | Surplus | Surplus | Surplus | Surplus | Deficit |

Source: analysis results (2024)

Note: area calculated using the grid system, in the World Cylindrical Equal Area projection system

### b. Land Physical Suitability and Constraint Variables

In addition to addressing various basic needs other than palm oil, the physical suitability of the land is first modelled for all types of PPL. The ECOC-SVM method was used to assess land physical suitability by comparing each type of existing PPL in 2022 (Figure 4.4(a)) to 11 physical parameters on the Sumatra island. Figure 4.4(b) depicts the land physical suitability model results for Sumatra Island.




*(a)* *(b)*

*Figure 4. 4 Land Cover/Land Use Map of Sumatra Island*
*(a) Existing in 2022 and (b) Physical Land Suitability Model (Source: analysis results, 2024).*

According to the results of the land suitability modelling, each type of PPL is either suitable for maintenance or has the potential to be converted to another type of PPL, as shown in Table 4.2. The diagonal elements in Table 4.2 (grey cells) represent the area of existing PPL types that are most likely to be retained or are not potential candidates for repurposing. For example, on Sumatra, there are 6.19 million hectares of existing forests (non-protected/conservation) that are best suited to be kept as forests; 6.87 million hectares of dryland agriculture that are best kept as dryland agriculture; and 8.33 million hectares of existing palm oil plantations that are best kept as palm oil plantations.

Meanwhile, each row in the non-diagonal elements indicates the physical suitability of each existing type of PPL for conversion into other types of PPL. For example, row 1 in Table 4.2 contains 1.54 million hectares of forest (non-protected/conservation) with physical suitability to be converted into oil palm plantations, while row 5 contains 1.23 million hectares of oil palm plantations with physical suitability to be converted into dryland agriculture.

*Table 4.2 Area of physical land suitability in Sumatra Island in 2022*

| | | Area of Physical Land Suitability without Considering Limiting Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 6.191.461,21 | 73.298,56 | 1.177.491,95 | 177.761,30 | 1.538.933,39 | 11.173,71 | 6.702,73 | 2.657,59 |
| | 2 | 125.103,40 | 538.375,72 | 426.883,03 | 64.925,92 | 401.641,47 | 13.244,59 | 1.702,28 | 5.052,06 |
| | 3 | 1.072.614,25 | 108.610,35 | 6.867.708,73 | 188.275,15 | 1.412.634,56 | 21.188,81 | 7.138,99 | 1.640,16 |
| | 4 | 478.852,69 | 63.080,33 | 657.938,92 | 1.237.433,24 | 1.513.882,16 | 11.655,89 | 681,13 | 2.808,70 |
| | 5 | 680.283,17 | 82.484,02 | 1.228.441,84 | 364.846,56 | 8.327.921,07 | 12.892,11 | 426,68 | 6.815,02 |
| | 6 | 76.062,09 | 56.313,10 | 347.876,15 | 56.320,66 | 271.581,21 | 227.935,01 | 85,11 | 3.865,53 |
| | 7 | 46.796,78 | 3.660,09 | 31.644,38 | 3.157,98 | 27.303,97 | 969,10 | 32.670,30 | 201,76 |
| | 8 | 23.996,10 | 22.792,15 | 9.703,17 | 4.745,46 | 46.151,29 | 3.236,25 | 0,26 | 40.752,80 |

Source: Analysis results (2024)

The land physical suitability modelling results remain general for all types of PPL, implying that the 11 physical parameters are treated or calculated in the same way for all types of PPL. Given that this study focuses on oil palm plantations, a refinement was made by including variables closely related to oil palm plantations, known as limiting variables (LV). There are 14 limiting variables considered, and Table 4.3 shows the area of each type of limiting variable on Sumatra.

*Table 4.3 Variable Constraint Area on the Island of Sumatra in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Sumatra Island's total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water providers based on water district (WD) | 604.841,06 | 1,27% |
| 2 | Peat Hydrological Unit (KHG) | 9.195.693,06 | 19,33% |
| 3 | Karst | 857.782,08 | 1,80% |
| 4 | Mangrove | 836.229,42 | 1,76% |
| 5 | Conservation areas and protected forests. | 10.862.831,46 | 22,83% |
| 6 | Cover of primary and secondary forest land | 11.542.618,88 | 24,26% |
| 7 | Spring | 10.644,20 | 0,02% |
| 8 | Slope above 30% | 802.140,56 | 1,69% |
| 9 | Critical Land | 4.348.658,67 | 9,14% |
| 10 | Protected wildlife | 16.936.635,74 | 35,59% |
| 11 | Indigenous community | 2.725.626,04 | 5,73% |
| 12 | Key Biodiversity Areas (KBA) | 6.814.225,30 | 14,32% |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 25.937.639,89 | 54,51% |
| 14 | Built-up areass | 1.070.361,12 | 2,25% |

Source: Analysis results (2024)
Note: area calculated using the grid system, in the World Cylindrical Equal Area projection system

Each constraint variable is plotted on a grid with a resolution of 30"x30" (± 900 m x 900 m). If the area of each type of constraint variable overlaps with ≥50% of the grid area, the grid is declared to have a constraint variable (VP = 1); otherwise, if the area of the overlapping constraint variable is <50% of the grid area, the grid is not declared to have a constraint variable (VP = 0). The grids with boundary variables are then combined (spatial union), and Figure 4.5 depicts the map created by combining 14 different types of boundary variables based on these criteria on the Sumatra island.

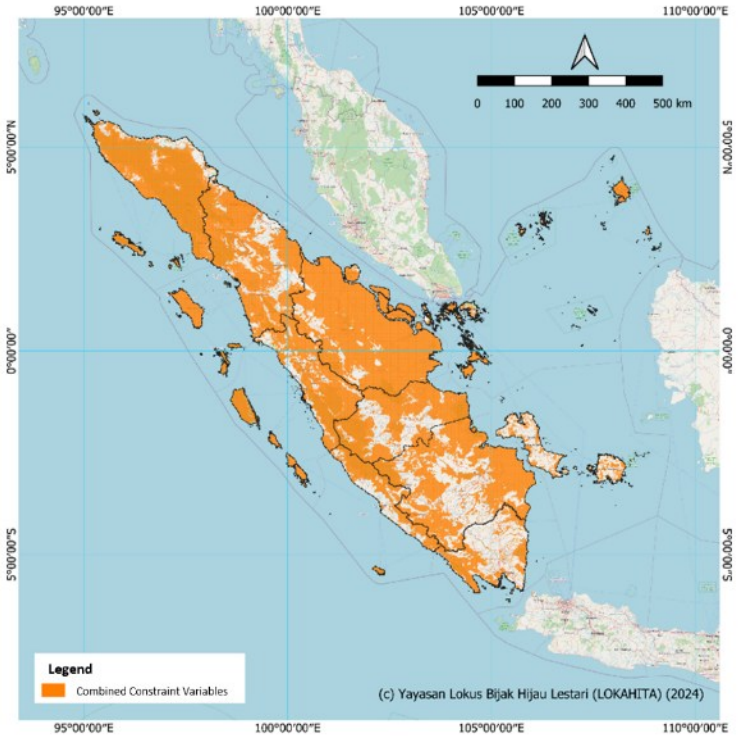
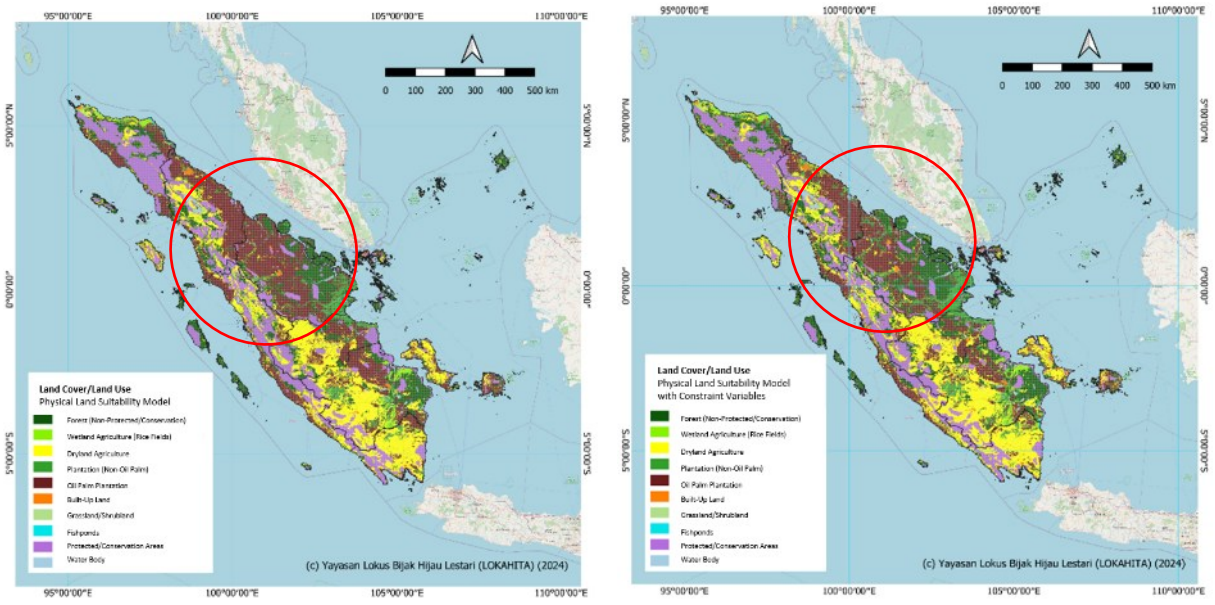



*Figure 4. 5 Combined Map of Constraint Variables on Sumatra Island in 2022 (Source: analysis results, 2024)*

The combined map of constraint variables (Figure 4.5) was then applied to the physical land suitability model map (Figure 4.4(b)), yielding a physical land suitability model map that includes the constraint variables (Figure 4.6(b). In general, areas with limited variables should not be converted to oil palm plantation land. If the land suitability model results indicate oil palm plantations but the area has limiting variables, the land will not be allocated for oil palm plantations and will revert to existing PPL.




*(a)* *(b)*

*Figure 4. 6 Map of Sumatra Island's Land Cover and Use*
*(a) physical land suitability model; (b) land suitability model with constraint variables.*
*(Source: Analysis Results, 2024)*

As can be seen in both maps in Figure 4.6, the use of constraint variables reduces the area of physical land suitability for oil palm plantations, as shown in the red-circled area. Overall, Sumatra Island has approximately 3.44 million hectares of land that had physical suitability for oil palm plantations but are now unsuitable due to limiting variables. The area includes 1.34 million hectares of forest (non-protected/conservation), 0.19 million hectares of rice fields, 0.43 million hectares of dryland agriculture, 1.20 million hectares of plantations (non-palm oil), 0.25 million hectares of built-up land, 0.02 million hectares of grassland/shrubland, and 0.03 million hectares of ponds. Finally, based on the results of land suitability modelling and the application of limiting variables, each type of PPL is either suitable for maintenance or has the potential to be converted into another type of PPL, as shown in Table 4.4.

*Table 4.4 Physical land suitability area in Sumatra Island in 2022 considering constraint variables*

| | | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 7.527.490,73 | 73.298,56 | 1.177.491,95 | 177.761,30 | 202.903,87 | 11.173,71 | 6.702,73 | 2.657,59 |
| | 2 | 125.103,40 | 725.004,32 | 426.883,03 | 64.925,92 | 215.012,86 | 13.244,59 | 1.702,28 | 5.052,06 |
| | 3 | 1.072.614,25 | 108.610,35 | 7.297.186,84 | 188.275,15 | 983.156,45 | 21.188,81 | 7.138,99 | 1.640,16 |
| | 4 | 478.852,69 | 63.080,33 | 657.938,92 | 2.432.978,12 | 318.337,28 | 11.655,89 | 681,13 | 2.808,70 |
| | 5 | 680.283,17 | 82.484,02 | 1.228.441,84 | 364.846,56 | 8.327.921,07 | 12.892,11 | 426,68 | 6.815,02 |
| | 6 | 76.062,09 | 56.313,10 | 347.876,15 | 56.320,66 | 24.594,89 | 474.921,32 | 85,11 | 3.865,53 |
| | 7 | 46.796,78 | 3.660,09 | 31.644,38 | 3.157,98 | 7.739,54 | 969,10 | 52.234,73 | 201,76 |
| | 8 | 23.996,10 | 22.792,15 | 9.703,17 | 4.745,46 | 20.647,05 | 3.236,25 | 0,26 | 66.257,03 |

Source: analysis results (2024)

According to the results of the land physical suitability model in Sumatra Island, there will be existing oil palm plantation land in 2022 covering an area of 5,972,494.67 ha, or approximately 5.97 million ha, located in areas with limiting variables (Figure 4.7). This could indicate that the location can no longer be developed, and that the existing oil palm plantations are sufficient because they are located in areas with limited variables. Furthermore, those locations require sustainable oil palm plantation management. The goal is to prevent further permanent damage if oil palm plantations in these areas continue to grow without proper management. The goal is to prevent further permanent damage if the oil palm plantation in this area continues to grow without proper management.

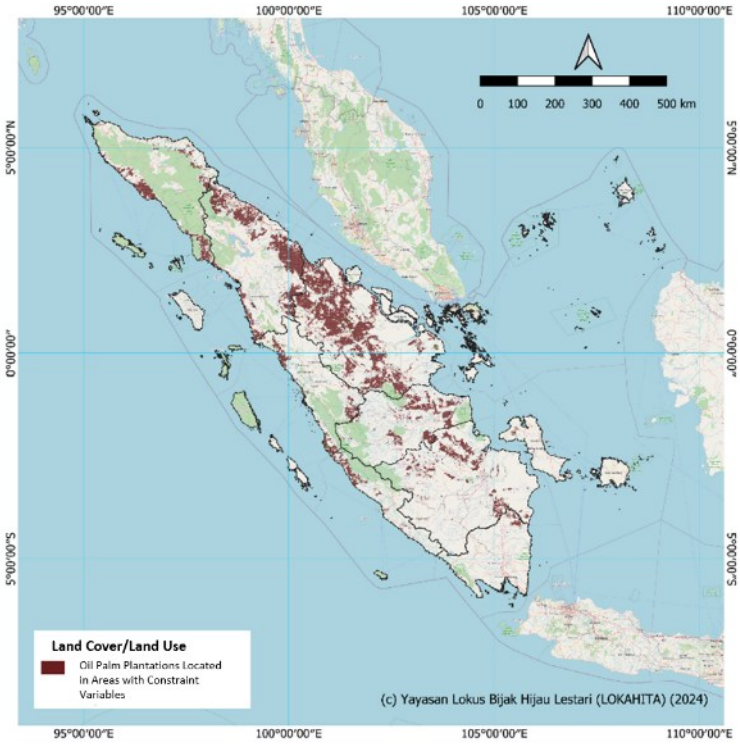



*Figure 4. 7 Map indicating the boundaries of existing Oil Palm Plantation development on Sumatra Island (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Sumatra Island

Finally, by taking into account the aspects of need (subsection 4.2.1.a) and suitable land availability (subsection 4.2.1.b), the land area allocation for each type of PPL was determined using the proportions shown in Figure 4.8 and Table 4.5. According to the D3TLH perspective, the upper limit (cap) for oil palm plantations on Sumatra Island is 10,697,295.45 ha, or 22.48% of the total area of the island.

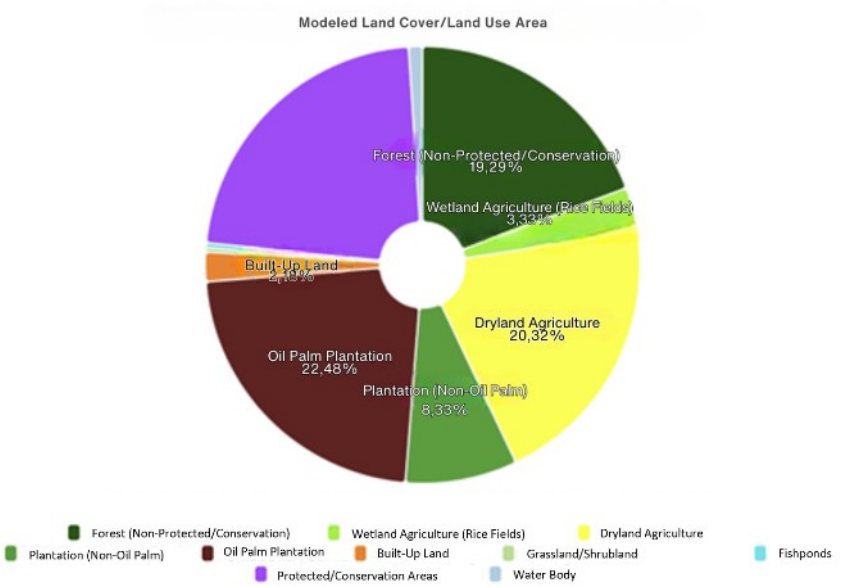



*Figure 4. 8 Proportion of PPL area allocation based on land physical suitability modeling considering constraint variables on Sumatra Island in 2022 (Source: analysis results, 2024)*

*Table 4.5 Area and proportion of land allocation, existing PPL, and the difference in Sumatra Island*

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |
| Forest (non-Protected/Conservation) | 9.176.822,86 | 9.179.480,45 | 2.657,59 | 19,29% | 19,29% | 0,01% |
| Wetland Agriculture (Rice Fields) | 1.586.754,79 | 1.576.928,48 | -9.826,32 | 3,33% | 3,31% | -0,02% |
| Dryland Agriculture | 9.668.344,53 | 9.679.811,00 | 11.466,48 | 20,32% | 20,34% | 0,02% |
| Plantations (non-Palm Oil) | 3.963.524,37 | 3.966.333,07 | 2.808,70 | 8,33% | 8,34% | 0,01% |
| Oil Palm Plantation | **10.697.295,45** | 10.704.110,48 | 6.815,02 | 22,48% | 22,50% | 0,01% |
| Built-up areas | 1.036.173,32 | 1.040.038,85 | 3.865,53 | 2,18% | 2,19% | 0,01% |
| Grassland/Scrubland | 146.202,59 | 146.404,35 | 201,76 | 0,31% | 0,31% | 0,00% |
| Pond | 169.366,23 | 151.377,48 | -17.988,76 | 0,36% | 0,32% | -0,04% |
| Protected/Conservation Area | 10.647.476,99 | 10.647.476,99 | 0,00 | 22,38% | 22,38% | 0,00% |
| Water Body | 490.286,31 | 490.286,31 | 0,00 | 1,03% | 1,03% | 0,00% |
| **SUMATRA ISLAND** | **47.582.247,45** | **47.582.247,45** | | **100,00%** | **100,00%** | |

Source: analysis results, 2024

Thus, establishing a maximum area for oil palm plantations on Sumatra is critical to maintaining the balance between economic productivity and environmental sustainability. The current situation (the area of existing palm oil plantations in 2022), which has slightly exceeded the ecosystem capacity (the upper limit/cap of oil palm plantations), indicates that without immediate intervention, oil palm plantations are at risk of causing permanent environmental damage, such as soil degradation, water quality decline, and biodiversity loss. As a result, concrete efforts are required to ensure that this upper limit is met, with a focus on land intensification and sustainable practices that can boost productivity without expanding the land area.

To manage oil palm plantations sustainably, the next steps must include a comprehensive approach involving all stakeholders, including the government, businesses, and local communities. Only in this way will Sumatra Island be able to continue to contribute significantly to the national economy while also ensuring environmental sustainability for future generations.

### 4.2.2 Java Island

**a. Land Cover/Land Use Demands**

The land provision requirements are calculated for food, clothing/textiles, infrastructure and wood, energy, and other palm oil consumption. The scenario for meeting the needs is 100%, which means that all of the population's needs are met using the resources available on the island of Java, with no imports or exports from other regions. The per capita annual land requirement for palm oil plantations in Java Island is 417.37 $m^2$, according to this calculation scenario. Figure 4.9 shows that the largest land requirement for oil palm plantations on the island of Java is for energy fulfilment, with 274.78 $m^2$ per capita per year. Palm oil plantations require 75.78 $m^2$ per capita per year for food, and 66.81 $m^2$ per capita per year for oleochemicals. If we add up all of the needs based on the population of Java Island, which in this case is 154,236,790 people, the required oil palm plantation area is 6,437,336.05 hectares.

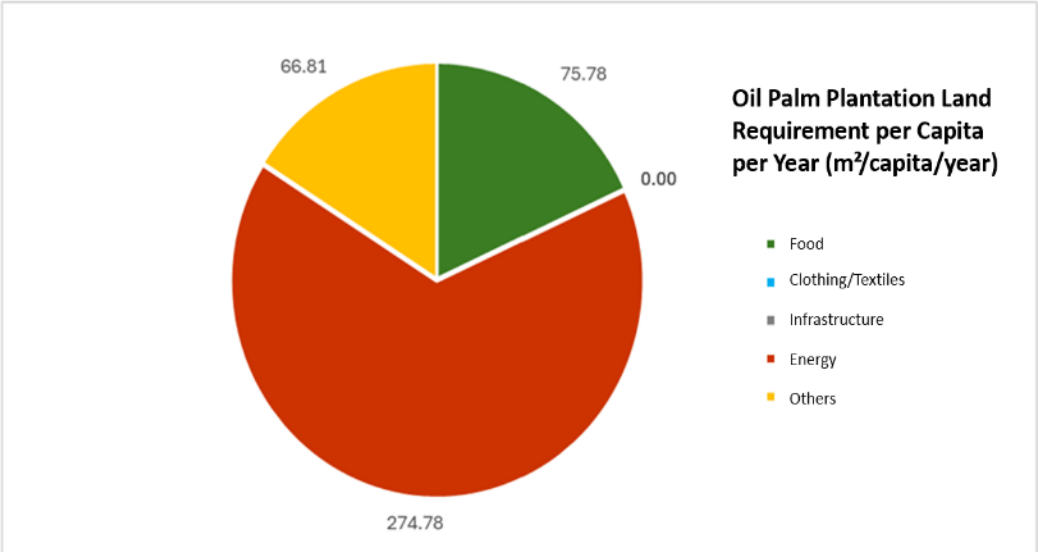



*Figure 4. 9 Area of palm oil plantation land requirement per capita per year in Java Island in 2022 based on demand categories (Source: analysis results, 2024)*

Figure 4.10 depicts the existing land cover/use on the island of Java in 2022, with detailed areas for each type of land cover/use listed in Table 4.6. Dryland Agriculture accounts for 4,299,700.31 ha, or approximately 32.43%, of Java Island's total land area of 13,259,641.71 ha. Other land cover/use types with significant areas include wetland agriculture (rice fields), which covers 3,740,428.08 ha or approximately 28.21%; forests (non-protected/conservation), which covers 1,892,216.92 ha or approximately 14.27%; and built-up land, which covers 1,395,071.80 ha or approximately 10.52%. Meanwhile, the area used for oil palm plantations on Java Island in 2022 was 38,612.98 ha, or 0.29%.

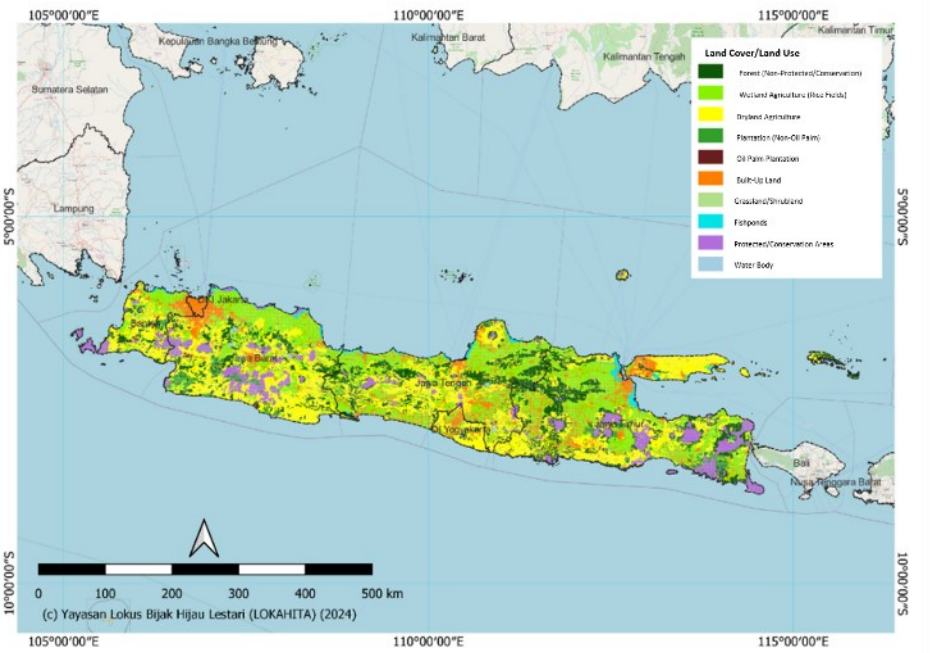



*Figure 4. 10 Map of existing land cover/use in Java Island in 2022*
*(Source: analysis results, 2024)*

*Table 4.6 Area of existing land cover/use types in Java Island in 2022*

| PL Types | Area (ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 1,892,216.92 | 14.27% |
| Wetland Agriculture (Rice Fields) | 3,740,428.08 | 28.21% |
| Dryland Agriculture | 4,299,700.31 | 32.43% |
| Plantations (non-Palm Oil) | 435,955.22 | 3.29% |
| Oil Palm Plantation | 38,612.98 | 0.29% |
| Built-up areas | 1,395,071.80 | 10.52% |
| Grassland/Scrubland | 15,982.81 | 0.12% |
| Pond | 203,314.91 | 1.53% |
| Protected/Conservation Area | 1,191,813.96 | 8.99% |
| Water Body | 46,544.73 | 0.35% |
| **JAVA ISLAND** | **13,259,641.71** | **100.00%** |

Source: analysis results, 2024

The existing oil palm plantation land, which is only 38,612.98 ha, does not meet the land requirement for oil palm plantations on Java Island, which is 6,437,336.05 ha. With the deficit condition, in which the land requirement for oil palm plantations exceeds the existing land area, additional land from other types of PPL must be allocated as oil palm plantations on Java Island. Table 4.7 shows a comparison of the needed area and the existing PPL on Java Island in 2022. In addition to land requirements for oil palm plantations, Java Island

has a deficit in land requirements for dryland agriculture, non-oil palm plantations, and grassland/shrubland. As a result, in the modelling to find additional land for oil palm plantations, alternatives from land cover/use that are in deficit, such as dryland agriculture, non-oil palm plantations, and grassland/shrubland, cannot be considered.

*Table 4.7 Area of demands and existing PPL in Java Island in 2022*

| | Type of Land Cover/Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Forest (non-Protected/ Conservation)** | **Wetland Agriculture (Rice Fields)** | **Dryland Agriculture** | **Plantations (non-Palm Oil)** | **Oil Palm Plantation** | **Built-Up Areas** | **Grassland/ Shrubland** | **Pond** |
| **Land demand (ha)** | 1.006.180,05 | 2.885.519,79 | 5.193.767,02 | 2.833.255,07 | 6.437.336,05 | 215.931,51 | 468.931,22 | 76.714,31 |
| **Existing PPL Area (ha)** | 1.892.216,92 | 3.740.428,08 | 4.299.700,31 | 435.955,22 | 38.612,98 | 1.395.071,80 | 15.982,81 | 203.314,91 |
| **Status** | Surplus | Surplus | Deficit | Deficit | Deficit | Surplus | Deficit | Surplus |

Source: analysis results, 2024

### b. Land Physical Suitability and Constraint Variables

The modelling of land physical suitability is intended to identify additional land candidates in order to meet the demand for Palm Oil Plantation land. However, in addition to the land requirements for palm oil, other land needs must be met, so this land suitability modelling is applicable to all types of land cover/use, not just palm oil plantations. As explained in the previous subsection, in addition to oil palm plantation land, Java Island has land classified as deficit for dryland agriculture, non-oil palm plantations, and grassland/shrubland. This means that when looking for land candidates for new Palm Oil Plantations, land from Dryland Agriculture, Plantations (non-oil palm), and Grassland/Shrubland cannot be used because the condition of the land is also poor. The ECOC-SVM method was used to assess land physical suitability by comparing each type of existing PPL in 2022 (Figure 4.10) to 11 physical parameters on the Java island.

Based on land suitability modelling, another type of PPL that can be classified as Oil Palm Plantations on the island of Java is non-oil palm plantations with a relatively small area, namely only about 84.88 ha. The results of this land suitability modelling demonstrate that the demand for oil palm plantation land cannot be met. Aside from its relatively high deficit value, other land candidates for allocation as Oil Palm Plantations are limited to non-oil palm plantations with small areas. Table 4.8 shows the area allocation and distribution of each type of PPL in Java Island based on the land suitability model, while Figure 4.11 shows the distribution of PPL types resulting from the land suitability on the map.

*Table 4.8 Allocation of the area for each type of PPL based on the land physical suitability model in Java Island in 2022*

| | | Area of Physical Land Suitability (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 986,606.11 | 141,061.69 | 745,208.88 | 3,392.86 | | 10,823.38 | 84.65 | 5,039.34 |
| | 2 | 69,546.18 | 3,108,848.99 | 499,897.26 | 1,271.78 | | 50,832.95 | 75.51 | 9,955.40 |
| | 3 | 210,102.97 | 444,197.69 | 3,601,644.51 | 5,596.29 | | 31,309.34 | 423.33 | 6,426.17 |
| | 4 | 25,881.10 | 63,511.64 | 274,875.67 | 69,618.65 | 84.88 | 1,612.00 | 338.64 | 32.64 |
| | 5 | 2,207.72 | 1,697.65 | 29,613.69 | 169.63 | 4,924.28 | | | |
| | 6 | 32,820.29 | 689,148.40 | 224,197.61 | 1,610.33 | | 440,367.55 | | 6,927.62 |
| | 7 | 1,106.45 | 2,906.86 | 4,431.30 | 423.33 | | 2,895.87 | 3,835.64 | 383.37 |
| | 8 | 4,965.81 | 68,783.26 | 10,453.72 | 84.99 | | 4,194.09 | 84.82 | 114,748.21 |

Source: analysis results, 2024

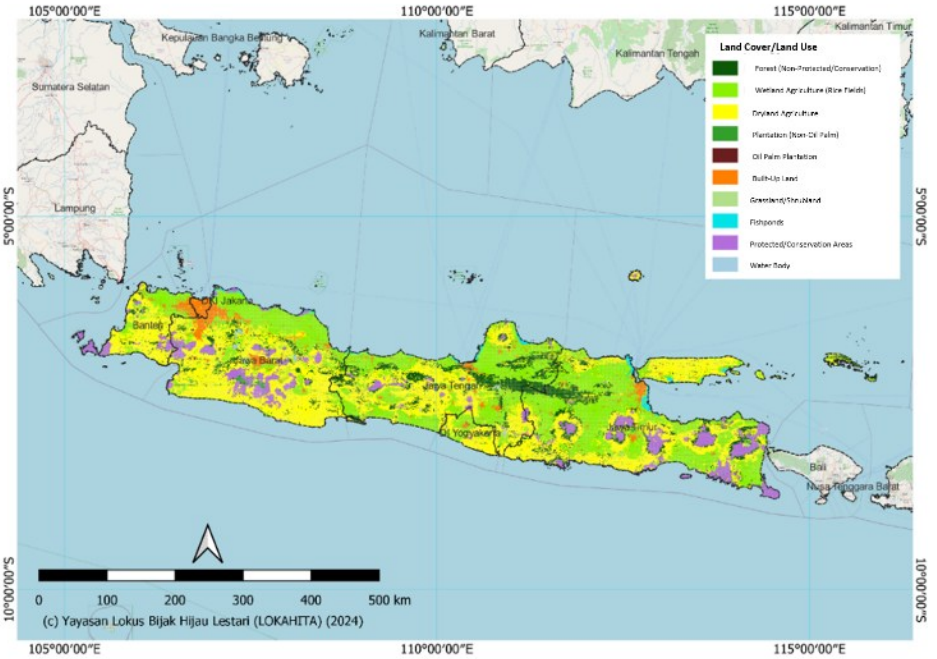



*Figure 4. 11 Map of the physical land suitability model results for Java Island (Source: analysis results, 2024)*

In addition to land suitability, when selecting additional locations for oil palm plantations, other factors that limit the land's ability to be used as oil palm plantation land must be considered, which are known as Constraint Variables (CV) in this modelling. In addition to being land constraints that cannot be used for oil palm plantations, VP is also used to preserve environmental sustainability, important ecosystems, and indigenous territories. Table 4.9 shows the 14 parameters used as VP in the modelling.

*Table 4.9: Variable Constraint Area on Java Island in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Java Island's total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water providers based on water district (WD) | 3.277.119,24 | 24,71% |
| 2 | Peat Hydrological Unit (KHG) | - | |
| 3 | Karst | 912.308,22 | 6,88% |
| 4 | Mangrove | 37.576,16 | 0,28% |
| 5 | Conservation areas and protected forests. | 1.182.129,07 | 8,92% |
| 6 | Cover of primary and secondary forest land | 885.472,01 | 6,68% |
| 7 | Spring | 15.113,36 | 0,11% |
| 8 | Slope above 30% | 148.529,18 | 1,12% |
| 9 | Critical Land | 2.114.771,50 | 15,95% |
| 10 | Protected wildlife | 1.164.756,84 | 0,88% |
| 11 | Indigenous community | 8.615,57 | 0,06% |
| 12 | Key Biodiversity Areas (KBA) | 875.668,48 | 6,60% |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 2.225.752,73 | 16,79% |
| 14 | Built-up areas | 1.852.164,71 | 13,97% |

Source: analysis results, 2024

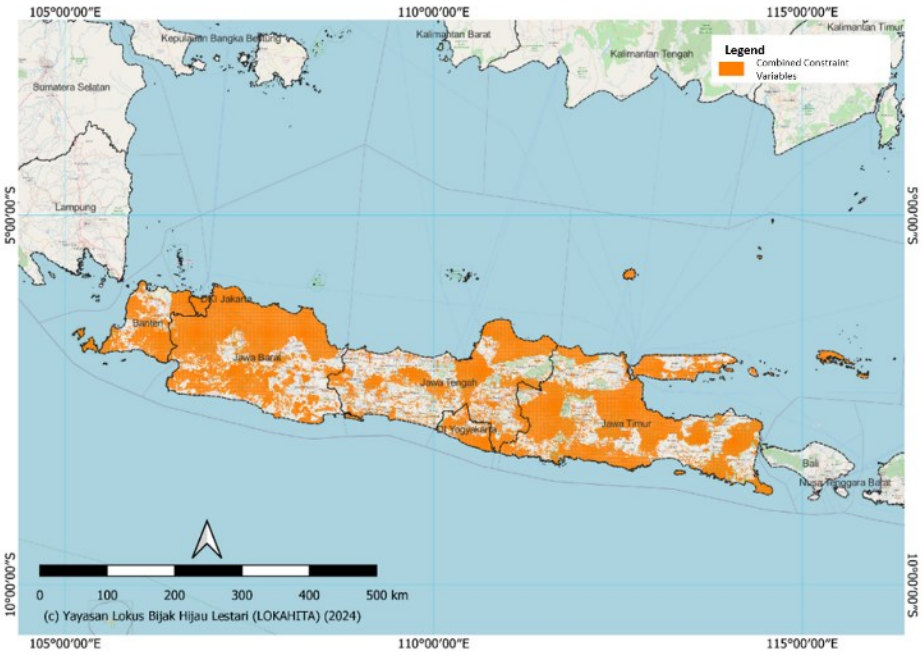



*Figure 4. 12 Combined Map of Constraint Variables on Java Island in 2022 (Source: analysis results, 2024)*

In general, areas with VP should not be converted into oil palm plantation land. If the land suitability model results indicate Oil Palm Plantations but the area has Limiting Variables, the land will not be allocated as Oil Palm Plantations and will revert to the existing PPL. In several other islands, incorporating VP into the model can produce significant results in

terms of land suitability. However, on the island of Java, the use of VP has no significant impact because the land suitability model produced, whether with or without VP, is the same. This is also due to the fact that the land candidates that can be allocated as oil palm plantation land are very small, and the areas that are eligible for oil palm plantation land allocation are not VP regions. Table 4.10 shows the area allocation and distribution of each type of PPL based on the land physical suitability model with VP on the island of Java, while Figure 4.13 shows the distribution of PPL types resulting from land physical suitability on a map.

*Table 4.10 Allocation of the area for each type of PPL based on the land physical suitability model considering Limiting Variables on the island of Java in 2022*

| | | Area of Physical Land Suitability Considering Constraint Variables (CV) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 986,606.11 | 141,061.69 | 745,208.88 | 3,392.86 | | 10,823.38 | 84.65 | 5,039.34 |
| | 2 | 69,546.18 | 3,108,848.99 | 499,897.26 | 1,271.78 | | 50,832.95 | 75.51 | 9,955.40 |
| | 3 | 210,102.97 | 444,197.69 | 3,601,644.51 | 5,596.29 | | 31,309.34 | 423.33 | 6,426.17 |
| | 4 | 25,881.10 | 63,511.64 | 274,875.67 | 69,618.65 | 84.88 | 1,612.00 | 338.64 | 32.64 |
| | 5 | 2,207.72 | 1,697.65 | 29,613.69 | 169.63 | 4,924.28 | | | |
| | 6 | 32,820.29 | 689,148.40 | 224,197.61 | 1,610.33 | | 440,367.55 | | 6,927.62 |
| | 7 | 1,106.45 | 2,906.86 | 4,431.30 | 423.33 | | 2,895.87 | 3,835.64 | 383.37 |

Source: analysis results, 2024

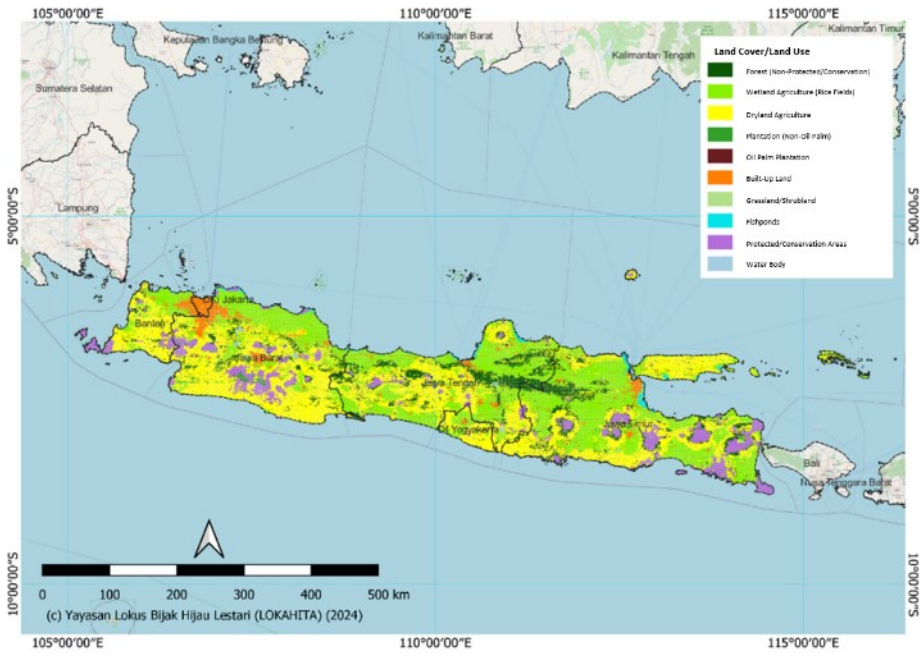



*Figure 4. 13 Map of the physical land suitability model results with Limiting Variables of Java Island (Source: analysis results, 2024)*

In addition to being a factor in determining new locations for Oil Palm Plantations, the use of VP can also identify the locations of existing Oil Palm Plantations within the VP. On the island of Java, an area of 2,123.05 hectares of existing oil palm plantations within the VP region has been discovered, spread across the provinces of Banten and West Java, as illustrated in Figure 4.14. This could indicate that there is a risk of environmental disruption at that location as a result of land conversion into palm oil plantations. On that land, mitigation is required to ensure that the Oil Palm Plantation does not cause environmental damage to the surrounding area, as well as supervision to prevent the Palm Oil Plantation from expanding into areas with VP.

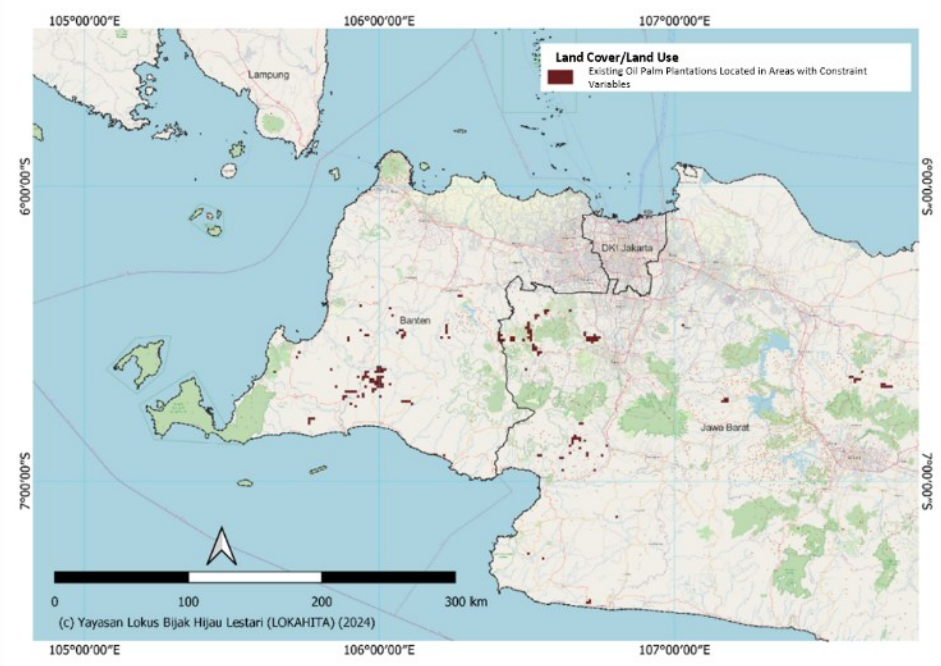



*Figure 4. 14 Map indicating the boundaries of existing Palm Oil Plantation development on the island of Java (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Java Island

The modelling results revealed that the upper limit (cap) of oil palm plantations on the island of Java based on the D3TLH perspective is 38,612.98 ha, or approximately 0.29% of the island's total area. The upper limit (cap) value equals the area of the existing oil palm plantations on Java. This is due to the lack of other land candidates that can be designated as oil palm plantation land based on the results of the physical land suitability assessment and the application of VP, with the exception of non-plantation land (non-oil palm), which is only 84.88 ha in size.

Figure 4.15 depicts the proportion of the area covered by each type of land cover on the island of Java, based on land physical suitability modelling with VP. The area of Palm Oil Plantations, which accounts for only 0.29% of the Java Island region's physical characteristics, indicates that only a small portion of the land is suitable for oil palm plantation development. This outcome is undoubtedly influenced by the limitations of the methods and training data used, in which candidates for oil palm plantation land are identified and tailored to the physical conditions of the existing oil palm plantations on the island of Java.

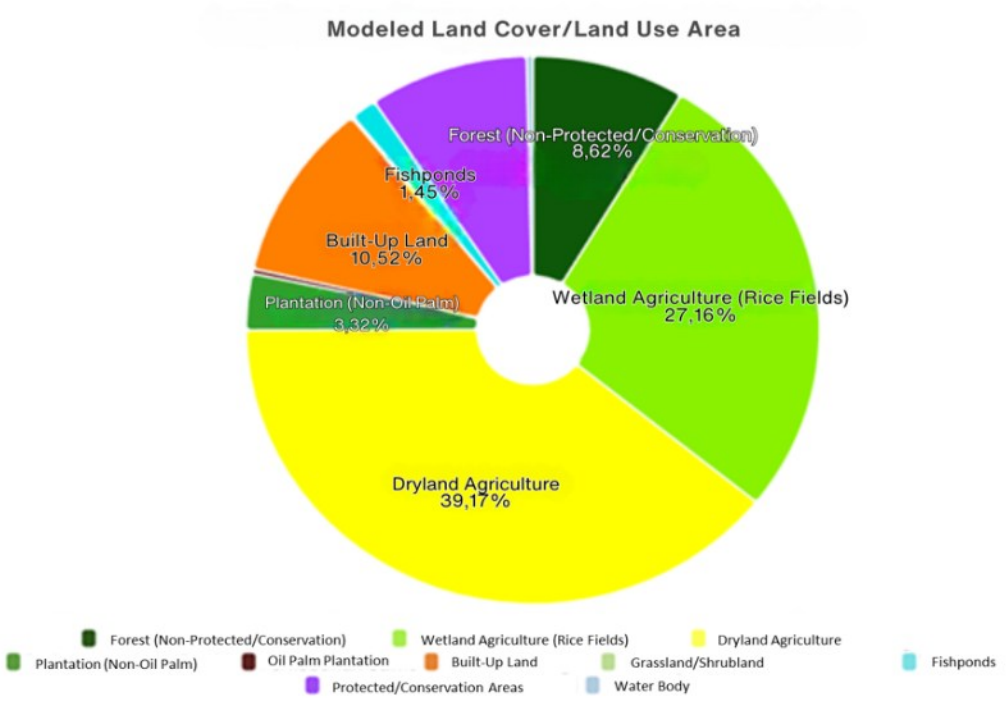



*Figure 4. 15 Proportion of PPL area from physical land suitability modeling considering constraint variables in Java Island in 2022*
*(Source: analysis results, 2024)*

*Table 4.11 Area and proportion of land allocation, existing PPL, and the difference in Java Island*

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | (%) | | |
| Forest (non-Protected/Conservation) | 1.143.530,53 | 1.892.216,92 | 748.686,39 | 8,62% | 14,27% | 5,65% |
| Wetland Agriculture (Rice Fields) | 3.600.676,68 | 3.740.428,08 | 139.751,40 | 27,16% | 28,21% | 1,05% |
| Dryland Agriculture | 5.193.767,02 | 4.299.700,31 | -894.066,71 | 39,17% | 32,43% | -6,74% |
| Plantations (non-Palm Oil) | 440.874,48 | 435.955,22 | -4.919,26 | 3,32% | 3,29% | -0,04% |

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | (%) | | |
| Oil Palm Plantation | 38.612,98 | 38.612,98 | 0,00 | 0,29% | 0,29% | 0,00% |
| Built-up areas | 1.394.902,17 | 1.395.071,80 | 169,63 | 10,52% | 10,52% | 0,00% |
| Grassland/Scrubland | 16.227,80 | 15.982,81 | -244,99 | 0,12% | 0,12% | 0,00% |
| Pond | 192.691,37 | 203.314,91 | 10.623,54 | 1,45% | 1,53% | 0,08% |
| Protected/Conservation Area | 1.191.813,96 | 1.191.813,96 | 0,00 | 8,99% | 8,99% | 0,00% |
| Water Body | 46.544,73 | 46.544,73 | 0,00 | 0,35% | 0,35% | 0,00% |
| **JAVA ISLAND** | **13.259.641,71** | **13.259.641,71** | **0,00** | **100,00 %** | **100,00%** | **0,00%** |

Sournce: analysis results, 2024

### 4.2.3 The Bali and Nusa Tenggara Islands

#### a. Land Cover/Land Use Demands

The Bali and Nusa Tenggara Islands are the only two of Indonesia's seven island regions without existing palm oil plantations. This is due to the ecosystem characteristics of the Bali and Nusa Tenggara Islands, which are dominated by Denudational Mountains made up of extrusive igneous rocks and monsoon savanna vegetation (KLHK, 2020). The soil layer in this ecosystem is very thin, so little vegetation, including oil palm, can grow. Small vegetation, such as savanna and grasslands, are suitable for living in this area. This is also evident in the land cover map of the Bali and Nusa Tenggara Islands, where dryland agriculture and grassland/shrubland occupy the second and fourth largest areas, respectively, with a total land area of both covering approximately 35% of the region's total land cover (Figure 4.16 and Table 4.12).

*Table 4.12 Area of existing land cover/use types in the Bali and Nusa Tenggara Islands in 2022*

| PL Types | Area (Ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 2,020,016.33 | 28.17% |
| Wetland Agriculture (Rice Fields) | 616,294.87 | 8.59% |
| Dryland Agriculture | 1,696,516.15 | 23.66% |
| Plantations (non-Palm Oil) | 14716 | 0.21% |
| Oil Palm Plantation | - | 0.00% |
| Built-up areas | 166,752.06 | 2.33% |
| Grassland/Scrubland | 928,562.14 | 12.95% |
| Pond | 32,495.85 | 0.45% |
| Protected/Conservation Area | 1,678,158.30 | 23.40% |

| PL Types | Area (Ha) | Area (%) |
|---|---|---|
| Water Body | 17,948.08 | 0.25% |
| **THE BALI AND NUSA TENGGARA ISLANDS** | **7,171,459.35** | **100.00 %** |

Source: analysis results, 2024

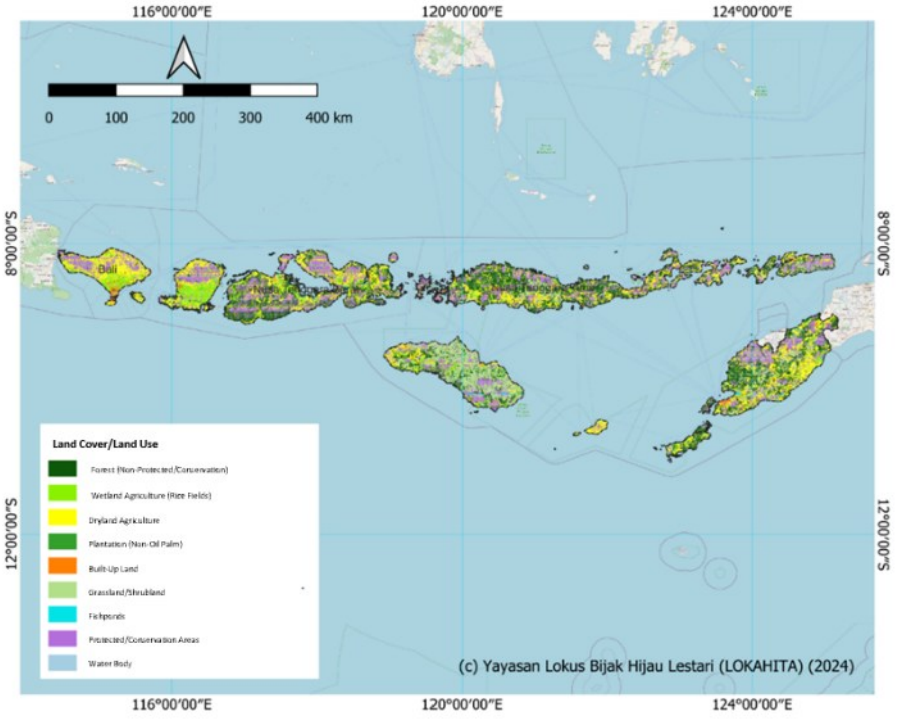



*Figure 4. 16 Map of existing land cover/use in the Bali and Nusa Tenggara Islands in 2022 (Source: analysis results, 2024)*

The fact that there are no palm oil plantations in the Bali and Nusa Tenggara regions is consistent with statistical data on palm oil production and consumption in those areas. The Ministry of Agriculture's production data shows a value of zero for the Bali and Nusa Tenggara regions, indicating a zero footprint intensity (productivity value). As a result, the land requirement for that region is also zero hectares (Table 4.13).

*Table 4.13 Area of demands and existing PPL in the Bali dan Nusa Tenggara Island in 2022*

| | Types of Land Cover/Land Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forest (non-Protected/Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| Land Requirement (ha) | 1,006,180.05 | 534,777.38 | 386,425.37 | 146,419.97 | 0.00 | 21,462.10 | 34,585.75 | 5,547.87 |
| Existing PPL Area (ha) | 2,020,016.33 | 616,294.87 | 1,696,516.15 | 14,715.56 | 0.00 | 166,752.06 | 928,562.14 | 32,495.85 |
| Surplus/Deficit? | Surplus | Surplus | Surplus | Deficit | - | Surplus | Surplus | Surplus |

Source: analysis results, 2024

### b. Land Physical Suitability and Constraint Variables

Although there are no existing oil palm plantations in the Bali and Nusa Tenggara Islands, land suitability modeling is still conducted. Existing palm oil plantations in the Maluku Islands were chosen as the modelling sample using a methodology based on ecoregional features akin to those of the Bali and Nusa Tenggara areas. Two grids in East Nusa Tenggara Province are appropriate for oil palm cultivation, according to the results of SVM modelling. The land suitability mapping results for the Bali and Nusa Tenggara regions are displayed in Figure 4.17. The brown color indicates the absence of oil palm plantation lands in the region.

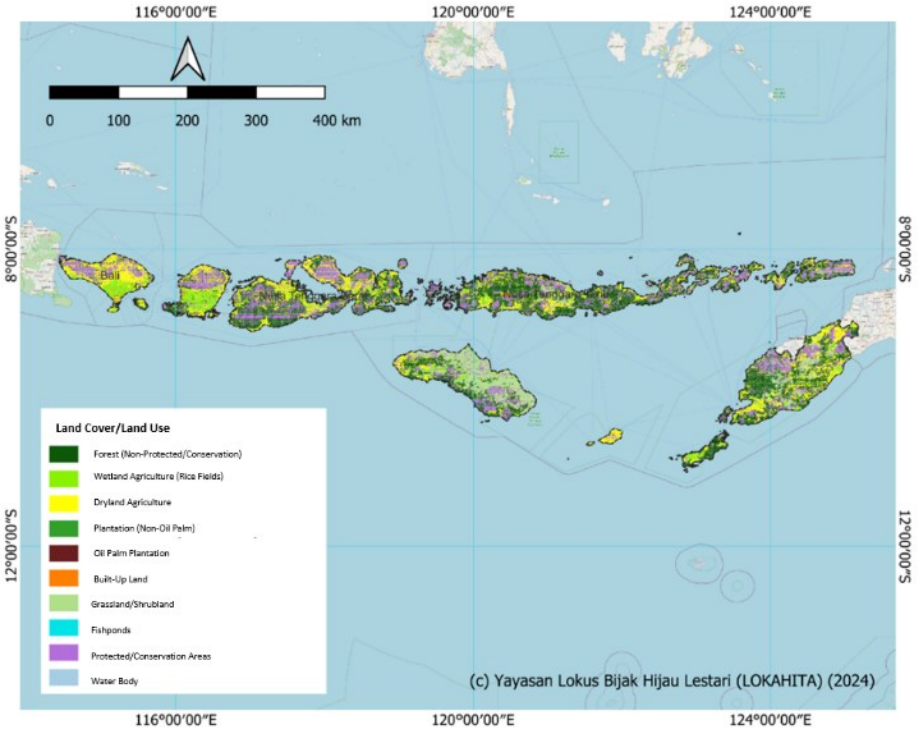



*Figure 4. 17 Map of the physical land suitability model for the Bali and Nusa Tenggara Islands (Source: analysis results, 2024)*

After including the constraint variable factors into the modelling findings (Figure 4.18), two grids that previously satisfied the physical suitability for oil palm plantations were unable to be employed as such due to their location in areas with constraint variables.

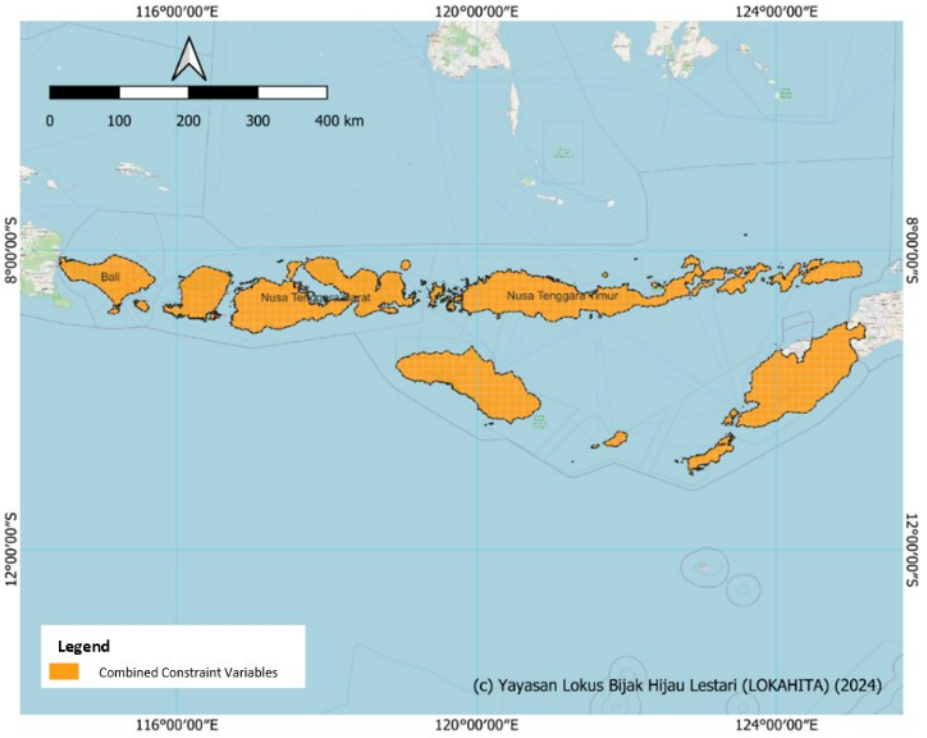



*Figure 4. 18 Combined Map of Constraint Variables in the Bali and Nusa Tenggara Islands in 2022 (Source: analysis results, 2024)*

According to physical rainfall data, the Bali and Nusa Tenggara regions receive comparatively little rainfall. Furthermore, according to data from the water deficit constraint variable, several locations in this region are experiencing water deficit (see Appendix map of Constraint Variables). These two variables may be additional reasons why oil palm is not appropriate for cultivation in the Bali and Nusa Tenggara regions. As a result, based on land physical suitability modelling and the presence of limiting variables, it is possible to conclude that no other types of PPL can be designated as Oil Palm Plantations in the Bali and Nusa Tenggara Islands (Table 4.14).

*Table 4.14 Allocation of the area for each type of PPL based on the land physical suitability model considering limiting variables in the Bali and Nusa Tenggara Islands in 2022*

| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 1,602,994.64 | 38,281.28 | 271,258.52 | | | 743.26 | 106,738.20 | 0.42 |
| | 2 | 85,357.95 | 301,883.00 | 193,115.42 | 84.27 | | 791.80 | 35,059.46 | 2.98 |
| | 3 | 546,585.68 | 88,938.07 | 973,529.62 | | | 1,449.77 | 86,013.01 | |
| | 4 | 2,014.02 | 201.72 | 2,773.52 | 758.72 | | | 8,967.58 | |
| | 5 | | | | | | | | |
| | 6 | 39,400.22 | 35,633.29 | 58,364.10 | | | 20,274.46 | 13,079.99 | |
| | 7 | 242,212.19 | 22,060.87 | 119,090.28 | 84.34 | | 684.23 | 544,430.24 | |

Source: analysis results, 2024

### c. Upper Limit Value of Oil Palm Plantations on the Bali and Nusa Tenggara Islands

In the end, the D3TLH perspective revealed that the highest limit (cap) value of the oil palm plantation area in the Bali and Nusa Tenggara Islands was 0 ha. This is because both statistical data on footprint intensity and the physical and ecological features of the region show that the Bali and Nusa Tenggara Islands are unsuitable for oil palm farming. To meet demand for palm oil in this area, supply from neighbouring Indonesian islands/archipelagos are required.

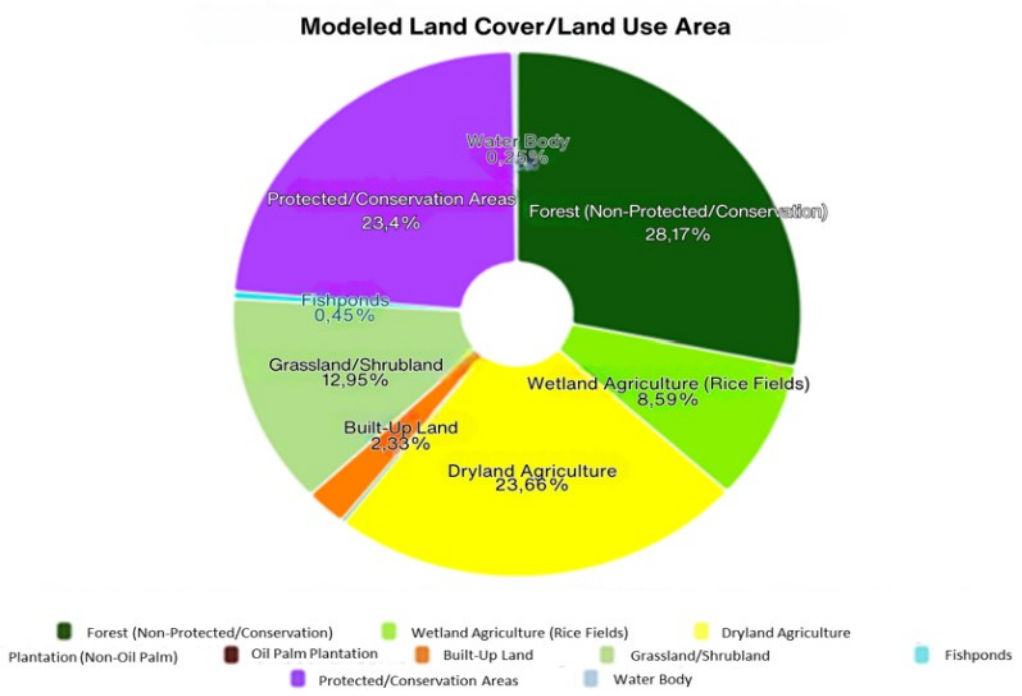



*Figure 4. 19 Proportion of PPL area from land suitability modeling considering constraint variables in the Bali and Nusa Tenggara Islands in 2022*
*(Source: analysis results, 2024)*

Figure 4.19 is a diagram of the proportion of PPL in the Bali and Nusa Tenggara Islands from the results of modelling land physical suitability by considering constraint variables. The diagram shows that there is no proportion of land suitable for planting oil palm. The majority of the land is suitable for forests (non-protected) and dryland agriculture, each with proportions of 28.17% and 23.66%, respectively. The area and proportion of land allocation, existing PPL, and the difference in Sulawesi Island can be seen in Table 4.15.

*Table 4.15 Area and proportion of land allocation, existing PPL, and the difference in the Bali and Nusa Tenggara Islands*

| PL Type | Allocation (%) | PL 2022 (%) | Difference (%) | Allocation (ha) | PL 2022 (ha) | Difference (ha) |
|---|---|---|---|---|---|---|
| Forest (non-Protected/Conservation) | 28.17% | 28.17% | 0.00% | 2,020,016.33 | 2,020,016.33 | 0.00 |
| Wetland Agriculture (Rice Fields) | 8.59% | 8.59% | 0.00% | 616,210.60 | 616,294.87 | 84.27 |
| Dryland Agriculture | 23.66% | 23.66% | 0.00% | 1,696,516.15 | 1,696,516.15 | 0.00 |
| Plantations (non-Palm Oil) | 0.21% | 0.21% | 0.00% | 14,884.17 | 14,715.56 | -168.61 |
| Oil Palm Plantation | 0.00% | 0.00% | 0.00% | **0.00** | 0.00 | 0.00 |
| Built-up areas | 2.33% | 2.33% | 0.00% | 166,752.06 | 166,752.06 | 0.00 |
| Grassland/Scrubland | 12.95% | 12.95% | 0.00% | 928,477.81 | 928,562.14 | 84.34 |
| Pond | 0.45% | 0.45% | 0.00% | 32,495.85 | 32,495.85 | 0.00 |
| Protected/Conservation Area | 23.40% | 23.40% | 0.00% | 1,678,158.30 | 1,678,158.30 | 0.00 |
| Water Body | 0.25% | 0.25% | 0.00% | 17,948.08 | 17,948.08 | 0.00 |
| **BALI NUSTRA ISLANDS** | **100.00%** | **100.00%** | **0.00%** | **7,171,459.35** | **7,171,459.35** | **0.00** |

Source: analysis results, 2024

### 4.2.4 Kalimantan Island

#### a. Land Cover/Land Use Demands

Based on the scenario of meeting demands such as food, clothing/textiles, infrastructure and timber, electricity, and other palm oil consumption, the land need for palm oil plantations per inhabitant per year on Kalimantan Island is 241.74 m2. Oil palm farms require approximately 22.53% (928,036,671.5 $m^2$) of land for food production, 62.31% (2,565,894,970 $m^2$) for energy, and 15.15% (623,891,349.8 $m^2$) for other palm oil demands. Figure 4.20 depicts the fraction of palm oil plantation land needs per inhabitant on Sulawesi Island in 2022, broken down by demand type. With a population of 17,033,900 in 2022, Sulawesi Island's total land required for oil palm plantations is 4,117,822,990.79 ha, or around 12.37% of Kalimantan Island's entire area.

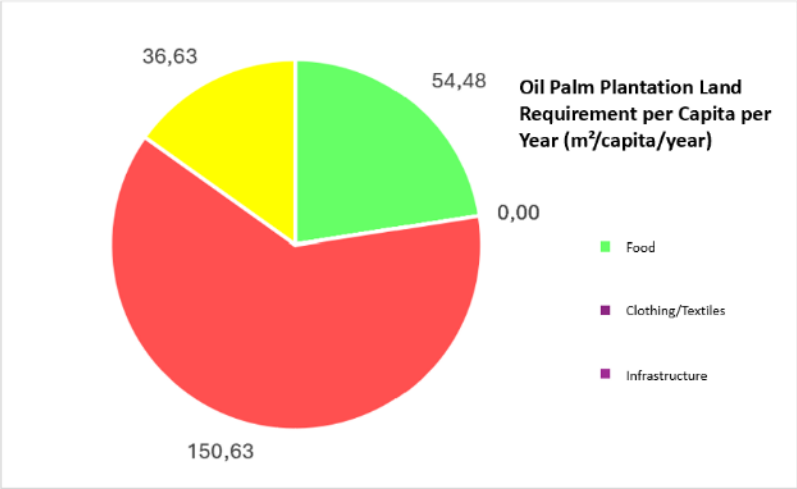



*Figure 4. 20 Area requirement for Palm Oil Plantation per capita per year in Kalimantan Island in 2022 based on demand categories*
*(Source: analysis results, 2024)*

Based on current PPL conditions, 44.40% of Kalimantan Island's total area of about 23,744,869.18 ha is forest (non-protected/conservation), 22.31% is protected/conservation area, and 13.15% is dryland agriculture. Meanwhile, the island of Kalimantan's present oil palm plantations would cover 6,682,951.43 ha in 2022, accounting for 12.50% of the total area. Figure 4.21 and Table 4.16 show the prevalence and area of each PPL type on Kalimantan Island in 2022.

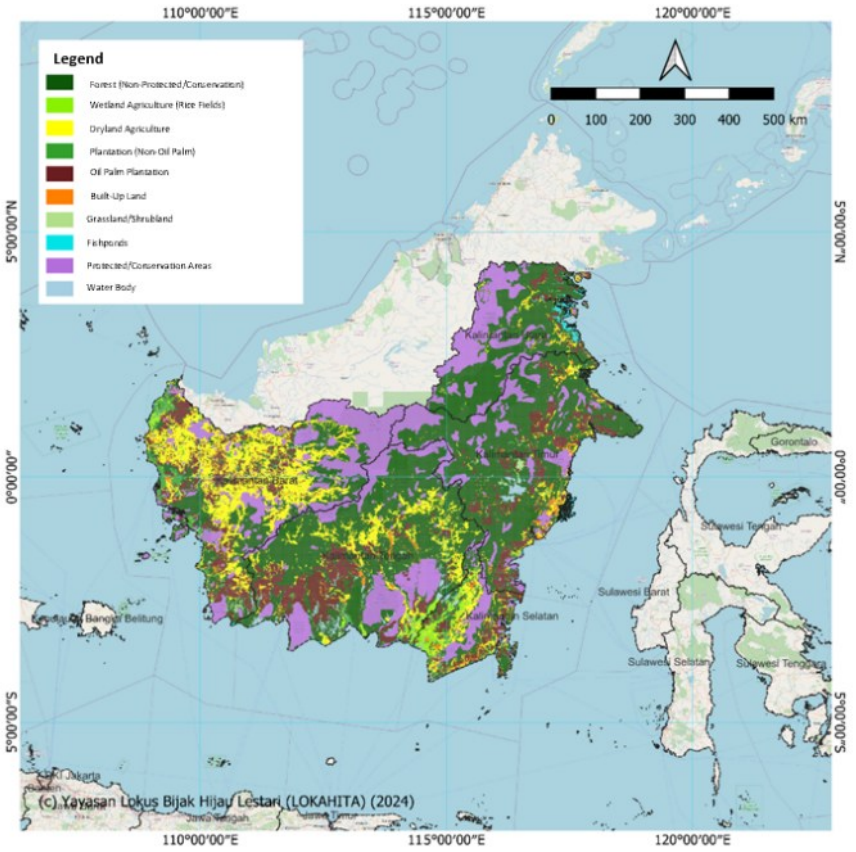



*Figure 4. 21 Map of existing land cover/use in Kalimantan Island in 2022 (Source: analysis results, 2024)*

*Table 4.16 Area of existing land cover/use types in Kalimantan Island in 2022*

| PPL Types | Area (ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 23,744,869.18 | 44.40% |
| Wetland Agriculture (Rice Fields) | 702,632.15 | 1.31% |
| Dryland Agriculture | 7,033,421.62 | 13.15% |
| Plantations (non-Palm Oil) | 1,478,391.12 | 2.76% |
| Oil Palm Plantation | 6,682,951.43 | 12.50% |
| Built-up areas | 710,187.07 | 1.33% |
| Grassland/Scrubland | 248,750.62 | 0.47% |
| Pond | 295,879.09 | 0.55% |
| Protected/Conservation Area | 11,931,303.83 | 22.31% |
| Water Body | 647,507.95 | 1.21% |
| **KALIMANTAN ISLAND** | **53,475,894.06** | **100,00%** |

Source: analysis results, 2024

According to the D3TLH perspective, the existing oil palm plantation land on Kalimantan Island, which covers 6,682,951.43 hectares, greatly surpasses the land requirement of 411,782.30 hectare. With the surplus condition, where the land requirement for oil palm plantations is less than the existing land area, there is no need for additional land from other types of PPL to be allocated as oil palm plantations on the island of Kalimantan, implying that there is no need for further expansion of oil palm plantations. Table 4.17 shows a comparison of the desired area and the existing PPL on Kalimantan Island in 2022.

*Table 4.17 Area of demands and existing PPL in Kalimantan Island in 2022*

| | Type of Land Cover/Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantations (non-Palm Oil) | Oil Palm Plantation | Built-Up Areas | Grassland/ Shrubland | Pond |
| **Land demand (ha)** | 51,136.46 | 859,595.57 | 2,397,834.72 | 144,679.26 | 411,782.30 | 23,847.46 | 27,378.93 | 506.84 |
| **Existing PPL Area (ha)** | 23,744,869.18 | 702,632.15 | 7,033,421.62 | 1,478,391.12 | 6,682,951.43 | 710,187.07 | 248,750.62 | 295,879.09 |
| **Status** | Surplus | Deficit | Surplus | Surplus | Surplus | Surplus | Surplus | Surplus |

Source: analysis results, 2024

## b. Land Physical Suitability and Constraint Variables

Based on land physical suitability modelling, there is a total of 2,549,273.90 ha of other types of PPL that can be designated as Oil Palm Plantations on Kalimantan Island. This allocation is mostly derived from the type of PPL Forest Agriculture (non-Protected/Conservation), which is approximately 1,155,003.53 ha, and Dryland Agriculture, which is approximately 780,990.53 ha. Table 4.18 and Figure 4.22 show the area allocation and distribution of each type of PPL on the island of Borneo using the land physical suitability model.

*Table 4.18 Allocation of the area for each type of PPL based on the land physical suitability model in Kalimantan Island in 2022*

| | | Area of Physical Land Suitability Without Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 21,697,329.84 | 73,088.01 | 739,162.81 | 33,014.18 | 1,155,003.53 | 20,779.06 | 2,813.72 | 23,678.02 |
| | 2 | 207,620.31 | 340,304.16 | 37,778.37 | 20,419.13 | 94,119.21 | 2,305.50 | | 85.47 |
| | 3 | 2,719,909.49 | 42,972.51 | 3,440,106.94 | 34,596.19 | 780,990.53 | 13,174.30 | 85.48 | 1,586.18 |
| | 4 | 644,516.47 | 43,764.42 | 265,700.11 | 196,552.85 | 318,160.71 | 7,856.44 | 1,025.18 | 814.94 |
| | 5 | 2,349,862.11 | 82,543.95 | 874,682.74 | 26,659.22 | 3,340,190.63 | 6,041.89 | 1,452.28 | 1,518.60 |
| | 6 | 264,016.20 | 14,847.53 | 105,467.91 | 12,697.44 | 135,735.72 | 176,609.40 | 256.39 | 556.49 |
| | 7 | 146,092.59 | 1,024.51 | 23,159.49 | 2,307.28 | 49,115.05 | 631.28 | 26,328.21 | 92.21 |
| | 8 | 195,707.69 | 3,273.61 | 2,660.65 | 2,198.61 | 16,149.16 | 702.98 | | 75,186.39 |

Source: analysis results, 2024

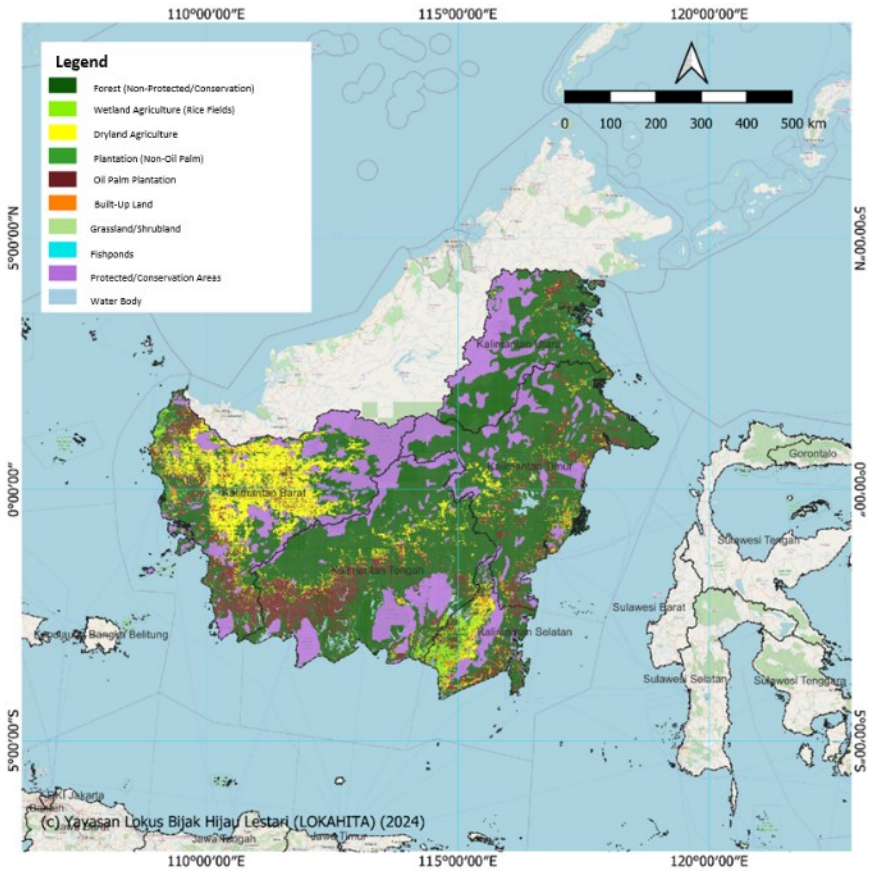



*Figure 4. 22 Map of the physical land suitability model for Kalimantan Island (Source: analysis results, 2024)*

In order to protect key ecosystems, biodiversity, and habitats from the spread of oil palm plantations on Kalimantan Island, the land suitability model is being enhanced by taking constraint variables into consideration. Kalimantan's thirteen constraint variables include Protected Wildlife and High Conservation Value (HCV), which cover more than half of the island's area. High conservation value areas cover approximately 36.75 million hectares, or 68.77% of Kalimantan Island's total area. Protected fauna comprises 34.72 million hectares, or 64.93% of Kalimantan Island's total area, dispersed throughout all provinces. The DDLH water supply constraint variable on the island of Borneo did not show that water availability is still surplus compared to needs. Table 4.19 displays the area of each constraint variable found on the island of Kalimantan. Meanwhile, Figure 4.23 depicts the combined positions of all constraint variables observed on the island of Kalimantan.

*Table 4.19 Variable Constraint Area on Kalimantan Island in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Kalimantan Island's total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water | 0.000 | 0.000 |

| No | Constraint Variable | Area (ha) | Area in relation to Kalimantan Island's total area (%) |
|---|---|---|---|
| | providers based on water district (WD) | | |
| 2 | Peat Hydrological Unit (KHG) | 8,434,414.321 | 15.772 |
| 3 | Karst | 870,819.650 | 1.628 |
| 4 | Mangrove | 577,750.263 | 1.080 |
| 5 | Conservation areas and protected forests. | 12,000,048.438 | 22.440 |
| 6 | Cover of primary and secondary forest land | 26,561,006.763 | 49.669 |
| 7 | Spring | 1,452.567 | 0.003 |
| 8 | Slope above 30% | 459,536.743 | 0.859 |
| 9 | Critical Land | 2,671,205.832 | 4.995 |
| 10 | Protected wildlife | 34,722,115.834 | 64.930 |
| 11 | Indigenous community | 1,246,95.591 | 0.233 |
| 12 | Key Biodiversity Areas (KBA) | 6,501,477.838 | 12.158 |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 36,775,651.283 | 68.771 |
| 14 | Built-up areas | 3,146,969.820 | 5.885 |

Source: analysis results, 2024

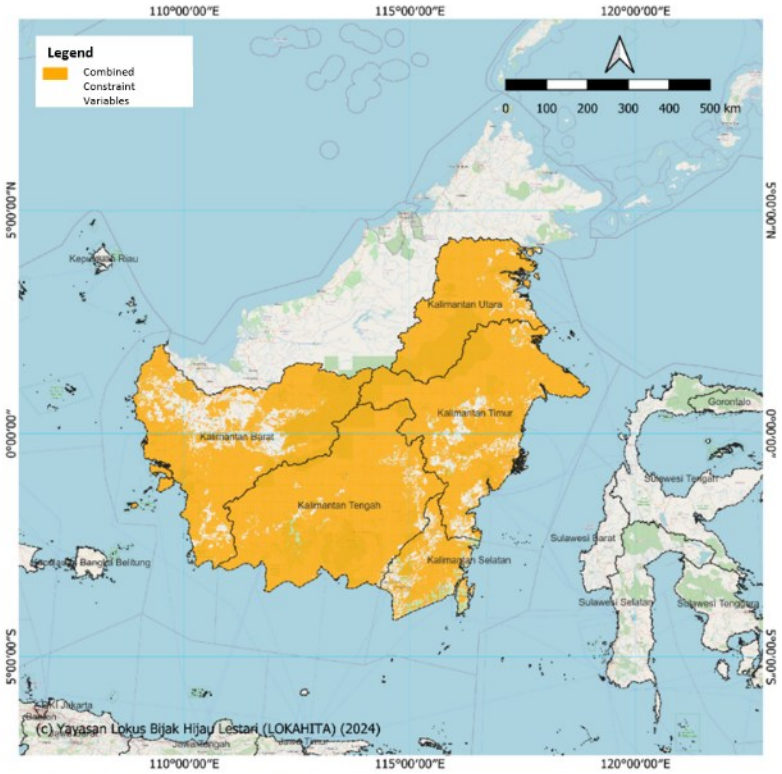



*Figure 4. 23 Combined Map of Constraint Variables on Kalimantan Island in 2022 (Source: analysis results, 2024)*

The existence of constraint variables reduced the allotment of oil palm plantation land from other types of PPL to 664,159.81 ha. This allocation is mostly derived from PPL Forest Agriculture (non-Protected/Conservation), which is around 155,931.99 ha, and Dryland Agriculture, which is approximately 344,477.24 ha. Table 4.20 shows the area allocated for each type of PPL on the island of Sulawesi based on the land physical suitability model, which has already taken the constraint variables into account. Figure 4.24 depicts the distribution of this area.

*Table 4.20 Allocation of Area for Each Type of PPL Based on Physical Land Suitability Model Considering Limiting Variables in Kalimantan Island in 2022*

| | | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 22,696,401.37 | 73,088.01 | 739,162.81 | 33,014.18 | 155,931.99 | 20,779.06 | 2,813.72 | 23,678.02 |
| | 2 | 207,620.31 | 383,431.14 | 37,778.37 | 20,419.13 | 50,992.24 | 2,305.50 | | 85.47 |
| | 3 | 2,719,909.49 | 42,972.51 | 3,876,620.21 | 34,596.19 | 344,477.27 | 13,174.30 | 85.48 | 1,586.18 |
| | 4 | 644,516.47 | 43,764.42 | 265,700.11 | 428,991.56 | 85,722.00 | 7,856.44 | 1,025.18 | 814.94 |
| | 5 | 2,349,862.11 | 82,543.95 | 874,682.74 | 26,659.22 | 3,340,190.63 | 6,041.89 | 1,452.28 | 1,518.60 |
| | 6 | 264,016.20 | 14,847.53 | 105,467.91 | 12,697.44 | 2,904.95 | 309,440.17 | 256.39 | 556.49 |
| | 7 | 146,092.59 | 1,024.51 | 23,159.49 | 2,307.28 | 14,612.83 | 631.28 | 60,830.43 | 92.21 |
| | 8 | 195,707.69 | 3,273.61 | 2,660.65 | 2,198.61 | 9,518.52 | 702.98 | | 81,817.03 |

Source: analysis results, 2024

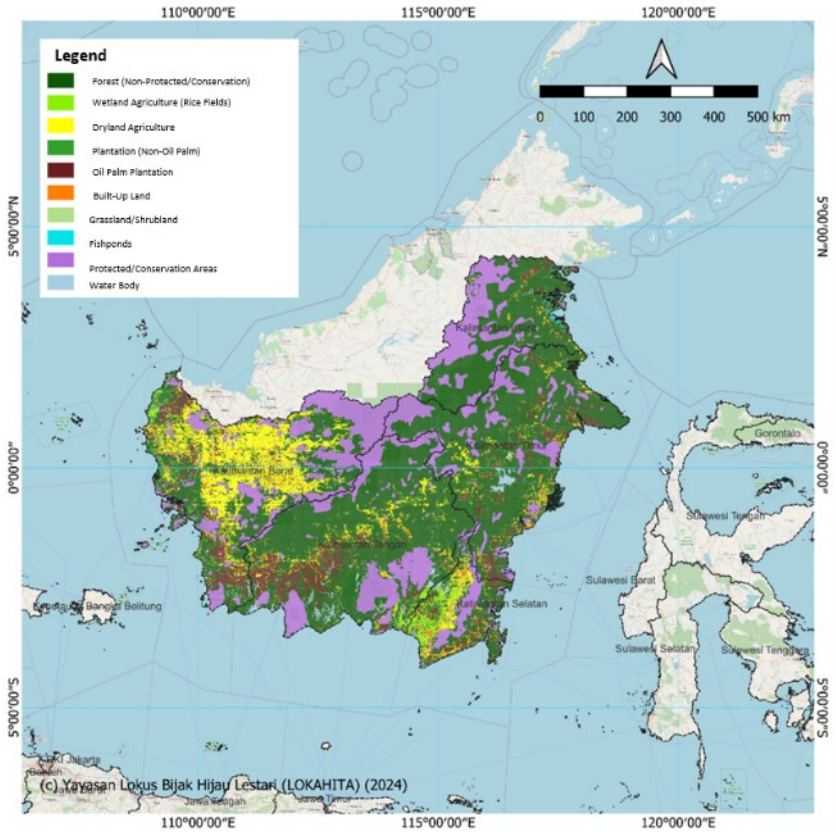



*Figure 4.24 Map of the physical land suitability model results with constraint variables of Kalimantan Island*

*(Source: analysis results, 2024)*

The area of constraint variables in Kalimantan reaches 46,572,790.18 ha out of 53,475,894.06 ha of Kalimantan's area or about 87.09%. If viewed from this perspective, the area of land that can be planted with palm oil (regardless of whether it is suitable or not with the physical characteristics of palm oil) is 12.91% or 6,903,103.88 ha. In reality, there are many areas of oil palm plantations that fall within the limiting variable areas. Here are the oil palm plantations that fall within the constraint variable.

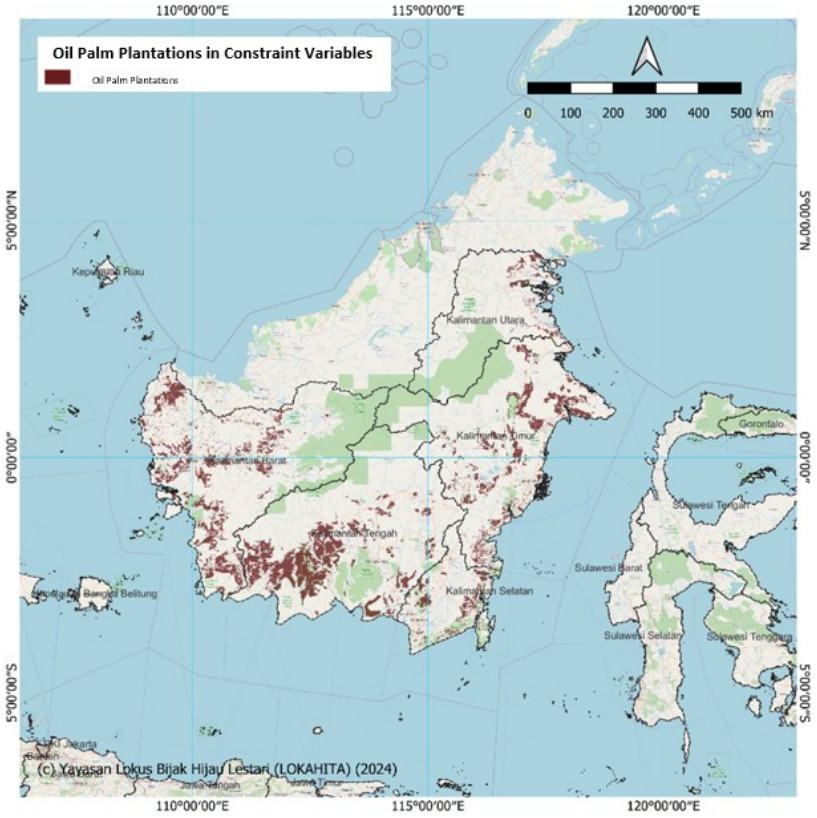



*Figure 4.25 Map indicating the boundaries of existing Oil Palm Plantation development on the island of Kalimantan (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Kalimantan Island

In the end, based on the D3TLH perspective, the maximum limit (cap) value of the oil palm plantation area on Kalimantan Island was determined to be 6,612,724.93 hectares, or 12.37% of the total area.

Figure 4.26 depicts the proportion of PPL in Kalimantan Island resulting from land suitability modelling with constraint variables. Table 4.21 shows the size and share of land allocation, the existing PPL, and the differential on Kalimantan island.

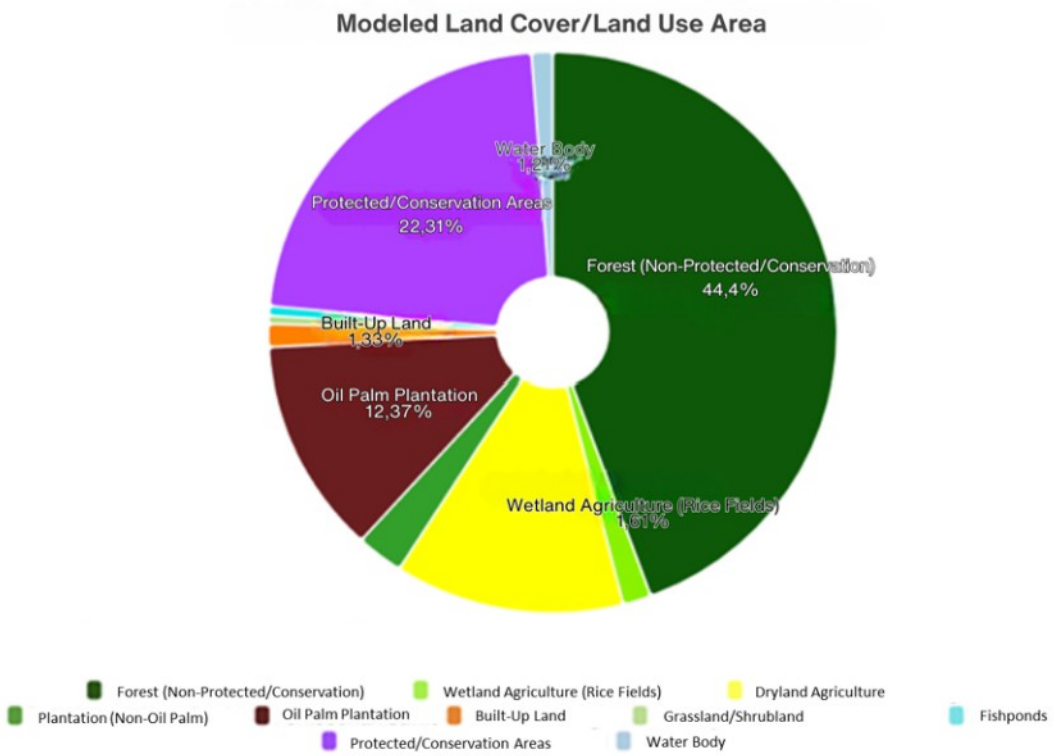



*Figure 4.26 Proportion of PPL area resulting from land physical suitability modeling considering constraint variables in Kalimantan Island in 2022*

*(Source: analysis results, 2024)*

*Table 4.21 Area and proportion of land allocation, existing PPL, and the difference in Kalimantan Island*

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |
| Forest (non-Protected/Conservation) | 5.382.234,39 | 23,744,869.18 | 0.00 | 44.40% | 44.40% | 0,05% |
| Wetland Agriculture (Rice Fields) | 1.347.875,34 | 702,632.15 | -156,963.43 | 1.61% | 1.31% | 0,00% |
| Dryland Agriculture | 4.217.010,10 | 7,033,421.62 | 42,972.51 | 13.07% | 13.15% | 0,00% |
| Plantations (non-Palm Oil) | 292.301,54 | 1,478,391.12 | 43,764.42 | 2.68% | 2.76% | 0,00% |
| Oil Palm Plantation | 483.520,78 | 6,682,951.43 | 70,226.50 | 12.37% | 12.50% | -0,05% |
| Built-up areas | 222.456,51 | 710,187.07 | 0.00 | 1.33% | 1.33% | 0,00% |
| Grassland/Scrubland | 243.409,88 | 248,750.62 | 0.00 | 0.47% | 0.47% | 0,00% |
| Pond | 199.725,54 | 295,879.09 | 0.00 | 0.55% | 0.55% | 0,00% |
| Protected/Conservation Area | 11,931,303.83 | 11,931,303.83 | 0.00 | 22.31% | 22.31% | 0,00% |
| Water Body | 647,507.95 | 647,507.95 | 0.00 | 1.21% | 1.21% | 0,00% |
| **KALIMANTAN ISLAND** | **18.623.574,68** | **18.623.574,68** | **0,00** | **100,00%** | **100,00%** | **0,00%** |

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |

Source: analysis results, 2024

The imposition of an upper limit (cap) on the size of oil palm plantations on the island of Kalimantan is critical, given that the demand for oil palm plantations is far lower than the area of existing oil palm plantations. Every new development must be based on an environmental carrying capacity analysis, which takes into account the ecosystem's ability to maintain oil palm plantations while preserving environmental functions.

If expansion is necessary, the first objective should be to increase the productivity of current oil palm farms by implementing sustainable agricultural technologies, such as superior varieties and efficient cultivation procedures. Thus, palm oil yields can be increased without considerably increasing the area, which could put pressure on Dryland Agriculture and Non-Palm Oil Plantations, both of which are critical to the local food system's sustainability. Furthermore, restrictions on expansion into sensitive areas such as wildlife habitats, primary forests, and critical ecosystem zones must be strictly enforced, given the importance of these areas in protecting biodiversity, maintaining ecosystem balance, and mitigating the effects of climate change and natural disaster risks in Kalimantan.

### 4.2.5 Sulawesi Island

#### a. Land Cover/Land Use Demands

Sulawesi Island's oil palm plantations require 917.82 $m^2$ of land per population per year to provide demands such as food, clothing/textiles, infrastructure, wood, electricity, and other palm oil usage. Oil palm plantations require around 73.40%, or 673.67 m2, of land for food, 21.40%, or 196.40 m2, for energy, and 5.20%, or 47.75 m2, for additional palm oil demands. Figure 4.27 depicts the fraction of oil palm plantation area required per inhabitant on Sulawesi Island in 2022 based on requirement categories. With a population of 20,333,900 in 2022, Sulawesi Island's total land demand for oil palm plantations is 1,866,291.89 hectares.

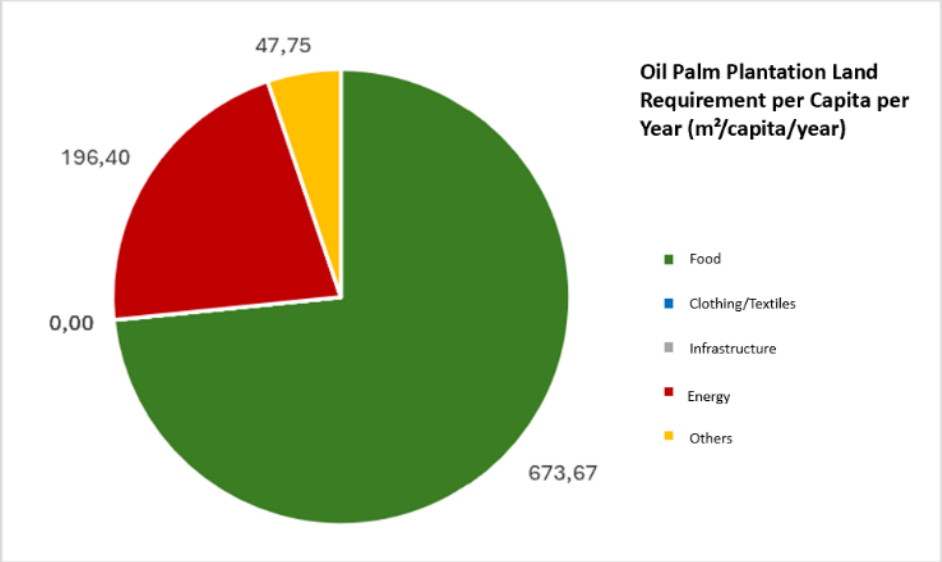



*Figure 4.27 Area of palm oil plantation land requirement per capita per year in Sulawesi Island in 2022 based on demand categories*
*(Source: analysis results, 2024)*

Based on the current PPL conditions, 33.00% of Sulawesi Island's total area of roughly 18,623,574.68 ha is protected/conservation areas, 28.95% is forest (non-protected/conservation), and 22.64% is dryland agriculture. Meanwhile, the present oil palm plantations on Sulawesi Island will cover 473,821 ha in 2022, accounting for 2.54% of the island's total area. Figure 4.28 and Table 4.22 show the distribution and area of each PPL type on Sulawesi Island in 2022.

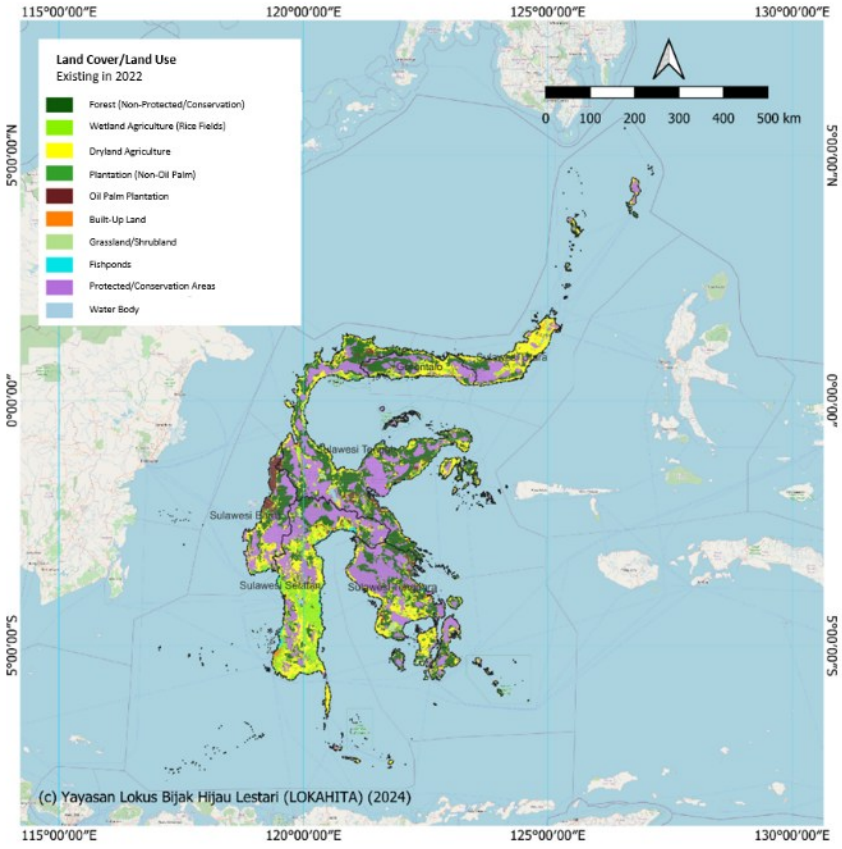



*Figure 4.28 Existing land cover/use map of Sulawesi Island in 2022 (Source: analysis results, 2024)*

*Table 4.22 Area of existing land cover/use types in Sulawesi Island in 2022*

| PPL Types | Area (ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 5.390.898,23 | 28,95% |
| Wetland Agriculture (Rice Fields) | 1.347.875,34 | 7,24% |
| Dryland Agriculture | 4.217.192,50 | 22,64% |
| Plantations (non-Palm Oil) | 292.813,86 | 1,57% |
| Oil Palm Plantation | 473.821,01 | 2,54% |
| Built-up areas | 222.456,51 | 1,19% |
| Grassland/Scrubland | 243.409,88 | 1,31% |
| Pond | 200.066,75 | 1,07% |
| Protected/Conservation Area | 6.146.292,90 | 33,00% |
| Water Body | 88.747,70 | 0,48% |
| **PULAU SULAWESI** | **18.623.574,68** | **100,00%** |

Source: analysis results, 2024

According to the D3TLH perspective, the existing Oil Palm Plantation land on Sulawesi Island, which covers 473,821 hectares, cannot yet meet the land demand of 1,866,291.89 hectares. With a deficit condition, where the land required for oil palm plantations exceeds the available land area, extra land from other types of PPL must be allocated as oil palm plantations on the island of Sulawesi. Table 4.23 shows a comparison of the requested area and the existing PPL on Sulawesi Island in 2022.

*Table 4.23 Area of demands and existing PPL in Sulawesi Island in 2022*

| | Type of Land Cover/Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Forest (non-Protected/ Conservation)** | **Wetland Agriculture (Rice Fields)** | **Dryland Agriculture** | **Plantations (non-Palm Oil)** | **Oil Palm Plantation** | **Built-Up Areas** | **Grassland/ Shrubland** | **Pond** |
| **Land demand (ha)** | 1.006.180,05 | 959.175,47 | 623.703,55 | 286.755,32 | 1.866.291,89 | 28.467,46 | 192.866,06 | 8.253,15 |
| **Existing PPL Area (ha)** | 5.390.898,23 | 1.347.875,34 | 4.217.192,50 | 292.813,86 | 473.821,01 | 222.456,51 | 243.409,88 | 200.066,75 |
| **Status** | Surplus | Surplus | Surplus | Surplus | Deficit | Surplus | Surplus | Surplus |

Source: analysis results, 2024

## b. Land Physical Suitability and Constraint Variables

Based on land physical suitability modelling, there is an area of 89,697.33 hectares of other types of PPL that can be designated as oil palm plantations on the island of Sulawesi. This allocation is primarily derived from PPL Dryland Agriculture (30.54%, or 27,393.09 hectares) and Non-Palm Oil Plantations (26.14%, or 23,442.66 ha). Table 4.24 and Figure 4.29 show the area allocation and distribution of each type of PPL on the island of Sulawesi using the land physical suitability model.

*Table 4.24 Allocation of the area for each type of PPL based on the land physical suitability model in Sulawesi Island in 2022*

| | | Area of Physical Land Suitability (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 4.669.476,84 | 44.579,80 | 645.427,11 | 1.623,21 | 15.000,25 | 1.190,52 | 8.663,84 | 4.936,66 |
| | 2 | 45.799,31 | 864.592,76 | 408.951,72 | 3.392,43 | 11.101,64 | 3.913,22 | 4.013,41 | 6.110,83 |
| | 3 | 805.424,64 | 218.814,36 | 3.141.009,98 | 4.795,66 | 27.393,09 | 2.904,54 | 9.041,91 | 7.808,31 |
| | 4 | 43.776,17 | 16.841,25 | 171.179,39 | 35.534,28 | 23.442,66 | 333,28 | 512,32 | 1.194,51 |
| | 5 | 59.956,40 | 14.917,96 | 156.361,96 | 2.364,09 | 237.518,42 | | 1.109,23 | 1.592,96 |
| | 6 | 25.594,88 | 56.013,93 | 94.828,80 | 1.213,93 | 3.608,41 | 34.994,85 | 2.077,71 | 4.124,01 |
| | 7 | 61.045,56 | 7.077,00 | 101.486,27 | 286,39 | 1.401,64 | 370,67 | 71.742,34 | |
| | 8 | 8.079,11 | 42.785,78 | 57.258,41 | 2.034,26 | 7.749,63 | 576,16 | 341,21 | 81.242,21 |

(Source: analysis results, 2024)

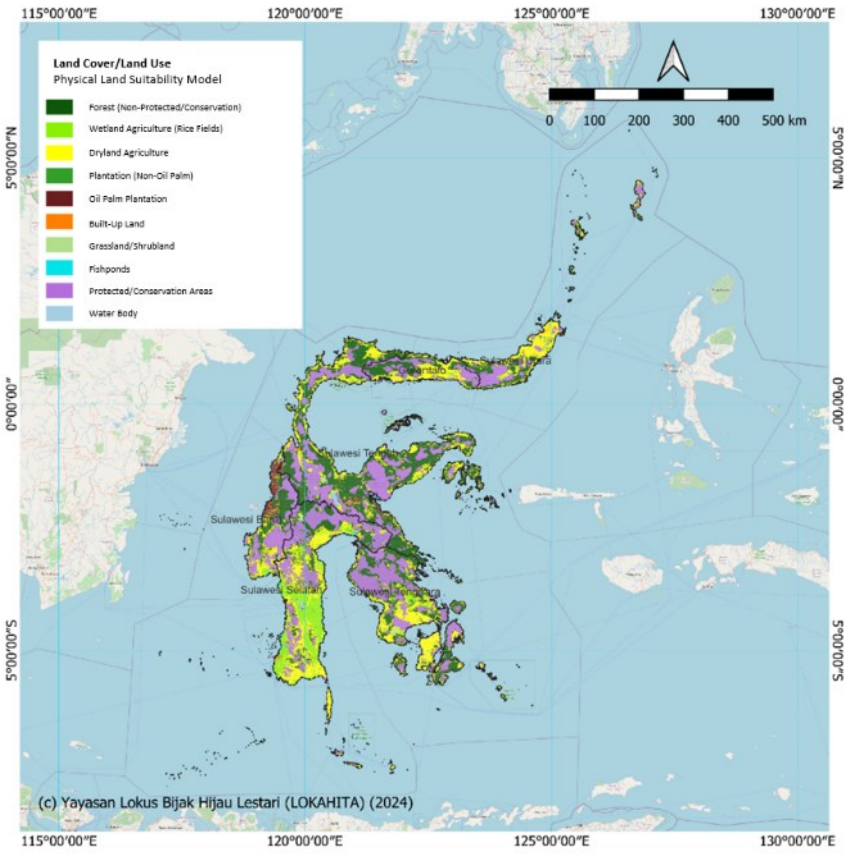



*Figure 4.29 Map of the physical land suitability model for Sulawesi Island (Source: analysis results, 2024)*

The land suitability model is being modified to account for constraint variables in order to protect key ecosystems, biodiversity, and habitats from the spread of oil palm plantations. Sulawesi Island had fourteen constraint variables, with Protected Wildlife and High Conservation Value accounting for more than half of the total area. Approximately 14.02 million hectares, or 75.29% of Sulawesi Island, are protected wildlife habitat areas, which include almost all of North Sulawesi, Central Sulawesi, and Southeast Sulawesi Provinces; the majority of Gorontalo and West Sulawesi Provinces, with the exception of coastal areas; and a small portion of South Sulawesi Province, specifically in the northern part. The High JLH Variable encompasses 10.43 million hectares, or 56.02% of Sulawesi Island's landmass, and is distributed in all provinces, particularly in the island's centre region. Table 4.25 displays the area of each constraint variable found in the island of Sulawesi. Meanwhile, Figure 4.30 shows the combined locations of all constraint variables observed on Sulawesi Island.

*Table 4.25 Area of Constraint Variables on Sulawesi Island in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Sulawesi Island's total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water providers based on water district (WD) | 1.868.321,01 | 10,03% |
| 2 | Peat Hydrological Unit (KHG) | 60.283,20 | 0,32% |
| 3 | Karst | 1.529.170,75 | 8,21% |
| 4 | Mangrove | 83.858,45 | 0,45% |
| 5 | Conservation areas and protected forests. | 6.136.717,02 | 32,95% |
| 6 | Cover of primary and secondary forest land | 9.185.488,35 | 49,32% |
| 7 | Spring | 20.306,11 | 0,11% |
| 8 | Slope above 30% | 2.318.513,58 | 12,45% |
| 9 | Critical Land | 1.693.436,41 | 9,09% |
| 10 | Protected wildlife | 14.022.576,80 | 75,29% |
| 11 | Indigenous community | 20.415,40 | 0,11% |
| 12 | Key Biodiversity Areas (KBA) | 4.657.088,55 | 25,01% |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 10.433.048,90 | 56,02% |
| 14 | Built-up areas | 2.331.559,92 | 12,52% |

Source: analysis results, 2024

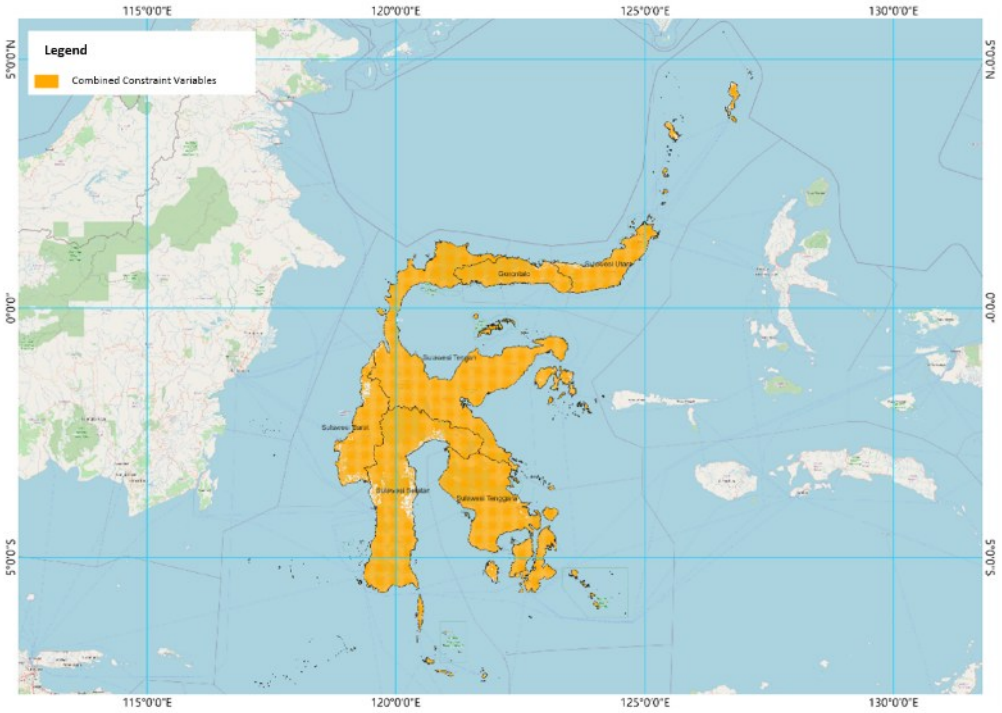



*Figure 4.30 Combined Map of Constraint Variables on Sulawesi Island in 2022*
*(Source: analysis results, 2024)*

In principle, regions containing constraint variables should not be converted to land for oil palm plantations. If the results from the land suitability model indicate oil palm plantations yet the region has constraint variables, the land will not be allocated as oil palm plantations and will revert to the previous PPL. Figure 4.31 depicts an example of land allocation on Sulawesi Island that is returned as an existing PPL because it is within the constraint variable.

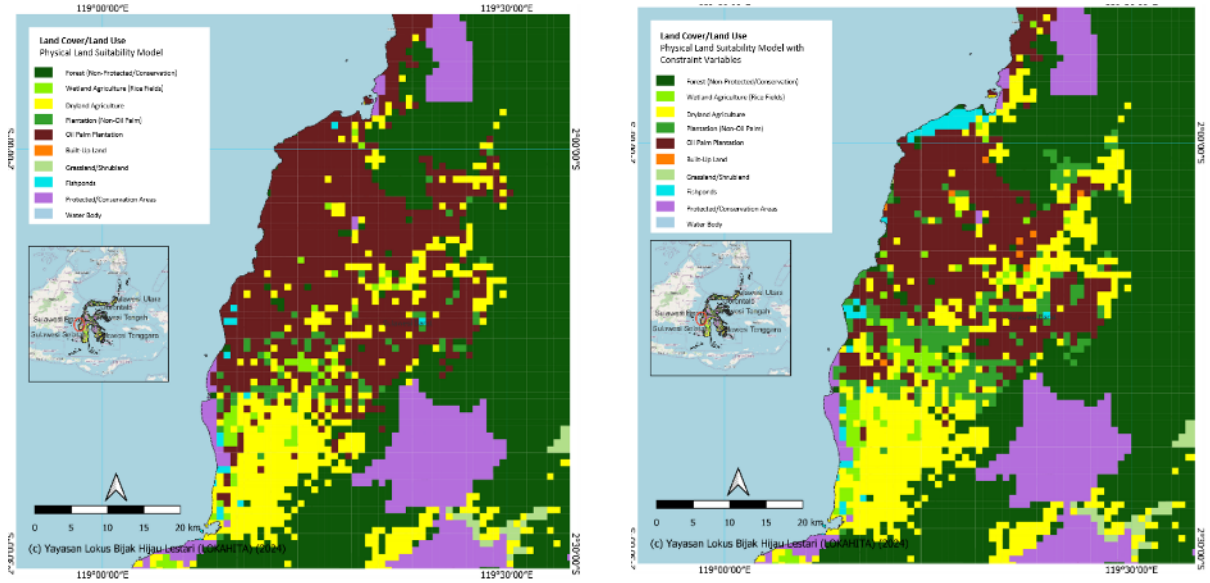



*Figure 4.31 Example of oil palm plantation land allocation in the physical land suitability model (a) returned as existing PPL because it falls within the Constraint Variable (b) on Sulawesi Island*
*(Source: analysis results, 2024)*

The presence of the constraint variable reduced the allocation of oil palm plantation land from other types of PPL to 9,699.76 ha. The allocation is based on the type of PPL: Dryland Agriculture (3,649.77 ha), Non-Palm Oil Plantations (2,670.83 ha), Fish Ponds (2,332.75 ha), Forests (non-protected/conservation) (534.18 ha), and Wetland Agriculture (512.22 ha). Table 4.26 shows the area allocated for each type of PPL on Sulawesi Island based on the land suitability model, which has already taken the constraint variables into account. Figure 4.32 depicts the distribution of this area. Table 4.26 shows the area allocated for each type of PPL on the island of Sulawesi based on the land suitability model that includes the constraint variables, with its distribution shown in Figure 4.32.

*Table 4.26 Allocation of the area for each type of PPL based on the land physical suitability model considering constraint variables on the Island of Sulawesi in 2022*

| Existing PPL Area (ha) | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 4.683.942,92 | 44.579,80 | 645.427,11 | 1.623,21 | 534,18 | 1.190,52 | 8.663,84 | 4.936,66 |
| 2 | 45.799,31 | 875.182,18 | 408.951,72 | 3.392,43 | 512,22 | 3.913,22 | 4.013,41 | 6.110,83 |
| 3 | 805.424,64 | 218.814,36 | 3.164.753,30 | 4.795,66 | 3.649,77 | 2.904,54 | 9.041,91 | 7.808,31 |
| 4 | 43.776,17 | 16.841,25 | 171.179,39 | 56.306,10 | 2.670,83 | 333,28 | 512,32 | 1.194,51 |
| 5 | 59.956,40 | 14.917,96 | 156.361,96 | 2.364,09 | 237.518,42 | | 1.109,23 | 1.592,96 |
| 6 | 25.594,88 | 56.013,93 | 94.828,80 | 1.213,93 | | 38.603,26 | 2.077,71 | 4.124,01 |
| 7 | 61.045,56 | 7.077,00 | 101.486,27 | 286,39 | | 370,67 | 73.143,98 | |
| 8 | 8.079,11 | 42.785,78 | 57.258,41 | 2.034,26 | 2.332,75 | 576,16 | 341,21 | 86.659,08 |

Source: analysis results, 2024

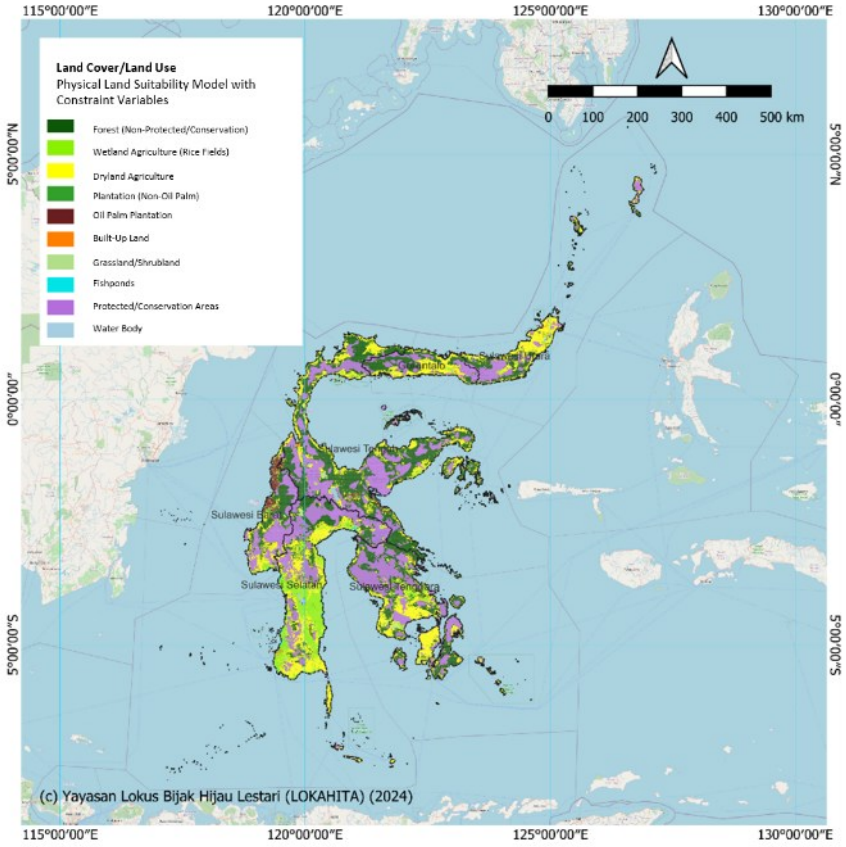



*Figure 4.32 Map of the physical land suitability model results with constraint variables of Sulawesi Island (Source: analysis results, 2024)*

Based on the results of the land physical suitability model with these constraint variables, it was discovered that in 2022, there is an existing oil palm plantation area of 201,708.05 ha in an area with constraint variables (Figure 4.33). This could indicate that there is a risk of environmental disruption at that location as a result of land conversion into oil palm plantations on the island of Sulawesi. On that land, mitigation is required to ensure that oil

palm plantations do not harm the environment in the surrounding areas, and supervision is required to prevent oil palm plantations from expanding into areas with constraint variables.


*Figure 4.33 Map indicating the boundaries of existing oil palm plantation development on Sulawesi Island (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Sulawesi Island

In the end, the upper limit (cap) value of the oil palm plantation area on Sulawesi Island based on the D3TLH perspective was determined to be 483,520.78 ha, or 2.60% of the island's total area.

Figure 4.34 depicts the proportion of PPL in Sulawesi Island resulting from land physical suitability modelling with constraint variables. There is approximately 2.60% of the area that is optimal for allocation as oil palm plantations, with the current area of oil palm plantations in 2022 being 2.54%, which is nearly identical to the optimal allocation area. Table 4.27 shows the area and proportion of land allocation, existing PPL, and differences on Sulawesi Island.

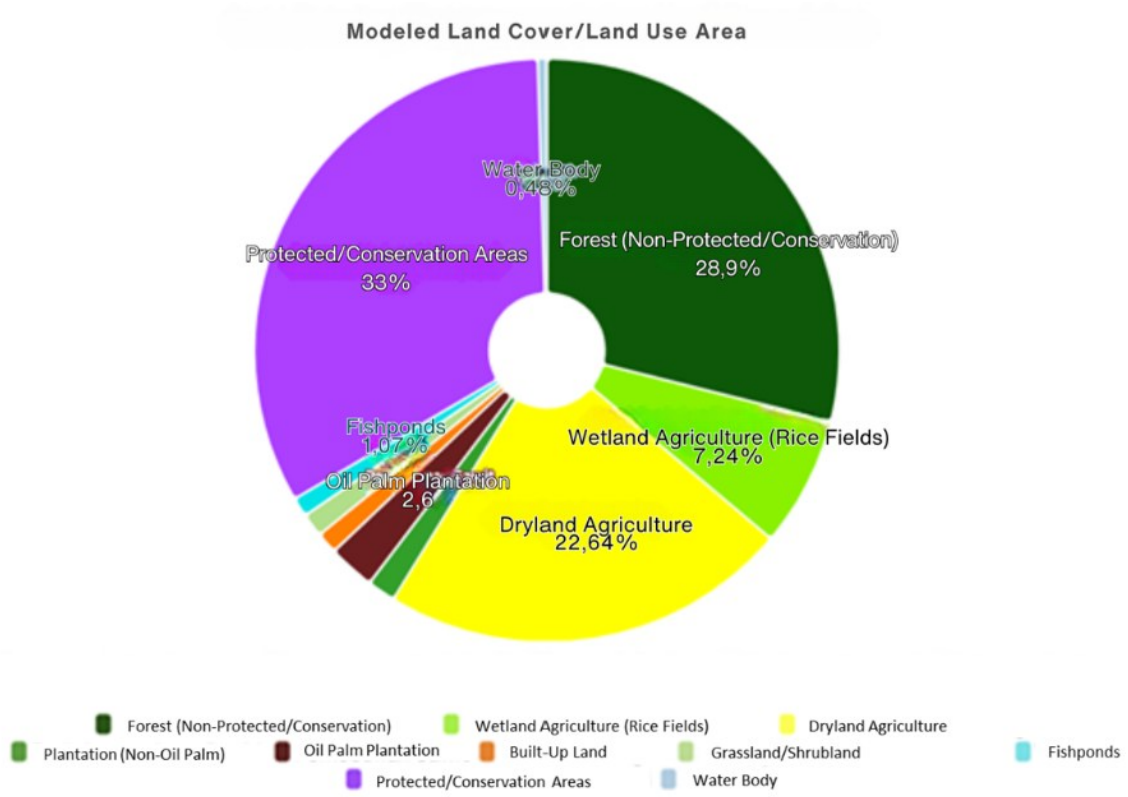



*Figure 4.34 Proportion of PPL area from land suitability modeling considering limiting variables on Sulawesi Island in 2022 (Source: analysis results, 2024)*

*Table 4.27 Area and proportion of land allocation, existing PPL, and the difference in Sulawesi Island*

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |
| Forest (non-Protected/Conservation) | 5.382.234,39 | 5.390.898,23 | 8.663,84 | 28,90% | 28,95% | 0,05% |
| Wetland Agriculture (Rice Fields) | 1.347.875,34 | 1.347.875,34 | - | 7,24% | 7,24% | 0,00% |
| Dryland Agriculture | 4.217.010,10 | 4.217.192,50 | 182,39 | 22,64% | 22,64% | 0,00% |
| Plantations (non-Palm Oil) | 292.301,54 | 292.813,86 | 512,32 | 1,57% | 1,57% | 0,00% |
| Oil Palm Plantation | 483.520,78 | 473.821,01 | (9.699,76) | 2,60% | 2,54% | -0,05% |
| Built-up areas | 222.456,51 | 222.456,51 | - | 1,19% | 1,19% | 0,00% |
| Grassland/Scrubland | 243.409,88 | 243.409,88 | - | 1,31% | 1,31% | 0,00% |
| Pond | 199.725,54 | 200.066,75 | 341,21 | 1,07% | 1,07% | 0,00% |
| Protected/Conservation Area | 6.146.292,90 | 6.146.292,90 | - | 33,00% | 33,00% | 0,00% |
| Water Body | 88.747,70 | 88.747,70 | - | 0,48% | 0,48% | 0,00% |

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |
| SULAWESI ISLAND | 18.623.574,68 | 18.623.574,68 | 0,00 | 100,00% | 100,00% | 0,00% |

Source: analysis results, 2024

The establishment of an upper limit (cap) on the area of oil palm plantations on Sulawesi Island is crucial, considering that the optimal land allocation for oil palm plantations is nearly equal to the area of existing oil palm plantations. Every new expansion must be based on an environmental support capacity study, which considers the ecosystem's capacity to support oil palm plantations without damaging environmental functions. On the island of Sulawesi, modelling results show that land suitable for oil palm plantation allocation generally consists of dryland agricultural land and non-oil palm plantations, so caution is needed in converting the function of this land. Land zoning policies that consider environmental and economic potential are crucial to ensure that the expansion of oil palm plantations does not sacrifice lands with conservation value or high productivity for other commodities.

The increase in productivity of existing oil palm plantations through the application of sustainable agricultural technology, such as superior varieties and efficient cultivation practices, should be the top priority. Thus, the increase in palm oil yields can be achieved without the need to significantly expand the land, which could instead suppress Dryland Agriculture and Non-Palm Oil Plantations that play an important role in the sustainability of the local food system. Moreover, restrictions on expansion into sensitive areas such as wildlife habitats, primary forests, and essential ecosystem zones must be strictly enforced, considering the importance of these regions in protecting biodiversity, maintaining ecosystem balance, and mitigating the impacts of climate change and natural disaster risks in Sulawesi.

### 4.2.6 Maluku Islands

#### a. Land Cover/Land Use Demands

Based on the scenario of providing land demands per capita per year in the Maluku Islands, the land requirement for palm oil plantations in the Maluku Islands was determined to be 429,094 Ha, as shown in Table 4.28. This land requirement is intended to meet the needs of the Maluku Islands' population of 3,213,540 in 2022. Figure 4.35 shows that oil palm plantations require 66.55% (888.58 $m^2$) of land for food, 26.91% (359.32 $m^2$) for energy, and

6.54% (87.37 $m^2$) for other palm oil needs. To address the deficit, another suitable land location should be designated as an oil palm plantation.

*Table 4.28 Area of demands and area of existing PPL in the Maluku Islands in 2022*

| | Land Cover/Land Use Types | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Forest (non-Protected /Conservation)** | **Wetland Agriculture (Rice Fields)** | **Dryland Agriculture** | **Plantations (non-Palm Oil)** | **Oil Palm Plantation** | **Built-up areas** | **Grassland/Scrubland** | **Pond** |
| **Kebutuhan lahan (ha)** | 1.006.180,05 | 22.618,36 | 276.804,62 | 25.056,76 | 429.094,49 | 4.498,96 | 2.205,93 | 1.167,82 |
| **Luas PPL Eksisting (ha)** | 4.361.100,89 | 29.947,33 | 1.290.136,53 | 23.540,87 | 24.928,89 | 50.784,51 | 134.601,79 | 732,00 |
| **Surplus/Deficit?** | Surplus | Surplus | Surplus | Deficit | Deficit | Surplus | Surplus | Deficit |

Source: analysis results, 2024

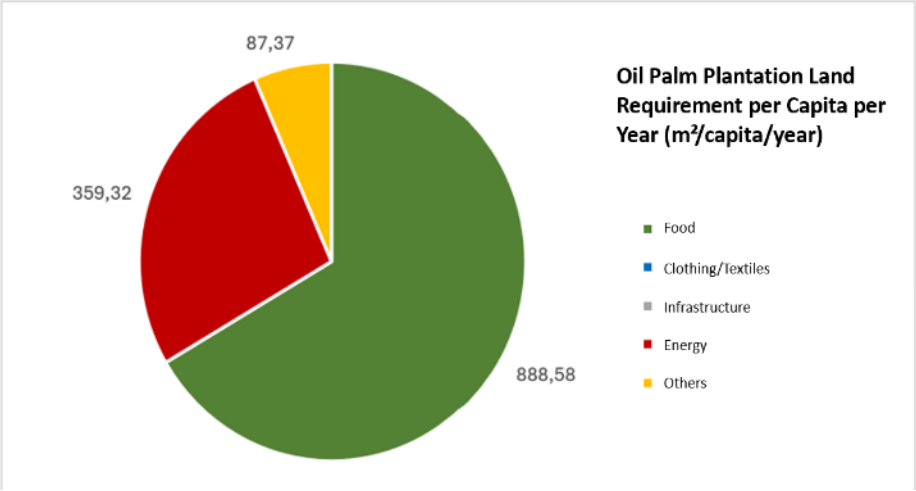



*Figure 4.35 The area of oil palm plantation land requirement per capita per year in the Maluku Islands in 2022 based on the category of need*
*(Source: analysis results, 2024)*

Figure 4.36 depicts the location allocation model for oil palm plantations, which makes use of existing land cover/use data (PPL) in the Maluku Islands for 2022. In 2022, the Maluku Islands had a total area of 7,757,324.10 hectares, with 56.22% or 4,361,100.89 hectares of Forest Land Cover (non-Protected/Conservation), 23.64% or 1,833,934.14 hectares of

Conservation Forest Land Cover, and 16.63% or 1,290,136.53 hectares of Dryland Agricultural Land Cover. Table 4.29 shows the area and proportion of existing PPL in the Maluku Islands in 2022. The current oil palm plantation area in the Maluku Islands is 24,928.89 hectares. The area of existing oil palm plantations is smaller than the analysis of oil palm plantation land requirements above, which is 25,056.76 hectares. To address the shortfall in palm oil plantation land requirements, an analysis of location allocation from other PPLs was conducted using physical land suitability and DDLH calculations.

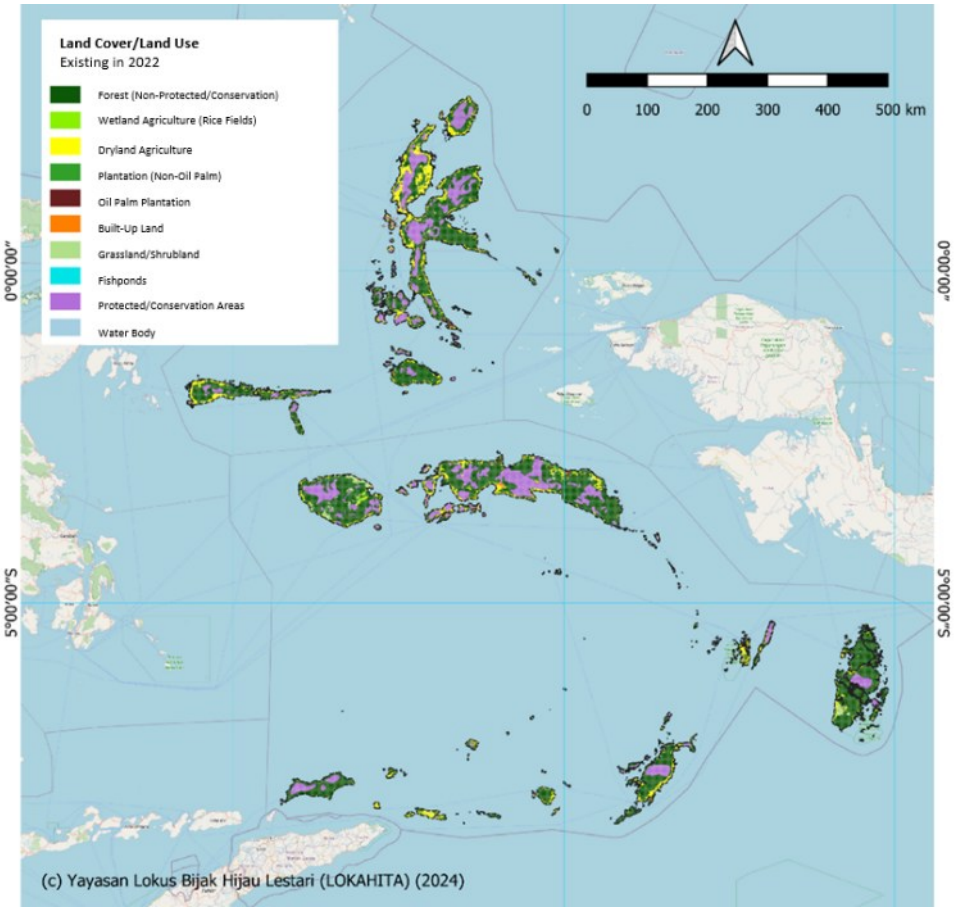



*Figure 4.36 Map of existing land cover/use in the Maluku Islands in 2022*
*(Source: analysis results, 2024)*

*Table 4.29 Area of existing land cover/use types in the Maluku Islands in 2022*

| PPL Types | Area (ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 4.361.100,89 | 56,22% |
| Wetland Agriculture (Rice Fields) | 29.947,33 | 0,39% |
| Dryland Agriculture | 1.290.136,53 | 16,63% |
| Plantations (non-Palm Oil) | 23.540,87 | 0,30% |
| Oil Palm Plantation | 24.928,89 | 0,32% |

| PPL Types | Area (ha) | Area (%) |
|---|---|---|
| Built-up areas | 50.784,51 | 0,65% |
| Grassland/Scrubland | 134.601,79 | 1,74% |
| Pond | 732,00 | 0,01% |
| Protected/Conservation Area | 1.833.934,14 | 23,64% |
| Water Body | 7.617,15 | 0,10% |
| **MALUKU ISLANDS** | 7.757.324,10 | 100,00% |

Source: analysis results, 2024

### b. Land Physical Suitability and Constraint Variables

To determine the best location for oil palm plantations in the Maluku Islands, a physical land suitability analysis is first conducted. This physical land suitability analysis makes use of existing PPL data as well as 12 physical parameter data from the Maluku Islands. According to land physical suitability modelling, there is an additional 3,013 Ha of land available for oil palm plantations. This allocation is primarily derived from the existing non-Protected/Conservation Forest Land (PPL) covering an area of 856 ha and the existing Grassland/Shrubland (PPL) covering an area of 703 ha. Table 4.30 and Figure 4.37 provide additional information on the Maluku Islands' land physical suitability model results.

*Table 4.30 Area of physical land suitability in the Maluku Islands*

| | | Area of Physical Land Suitability (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 4,180,330.44 | 1,621.65 | 171,787.62 | 1,390.85 | 856.37 | 762.83 | 4,351.13 | |
| | 2 | 4,695.78 | 16,305.30 | 6,896.94 | 597.55 | 256.09 | 939.55 | 256.13 | |
| | 3 | 611,093.21 | 2,133.40 | 670,802.92 | 1,258.62 | 425.89 | 2,889.04 | 1,533.46 | |
| | 4 | 10,718.22 | 1,024.38 | 4,797.62 | 6,232.21 | 597.56 | 170.87 | | |
| | 5 | 12,714.77 | 853.65 | 2,135.38 | 597.59 | 8,627.48 | | | |
| | 6 | 11,858.36 | 2,646.54 | 19,283.27 | 85.37 | 170.73 | 16,288.01 | 452.22 | |
| | 7 | 71,756.58 | 597.42 | 11,854.52 | 426.80 | 706.68 | 703.74 | 48,556.04 | |
| | 8 | 85.34 | | 305.16 | | | | | 341.50 |

Source: analysis results, 2024

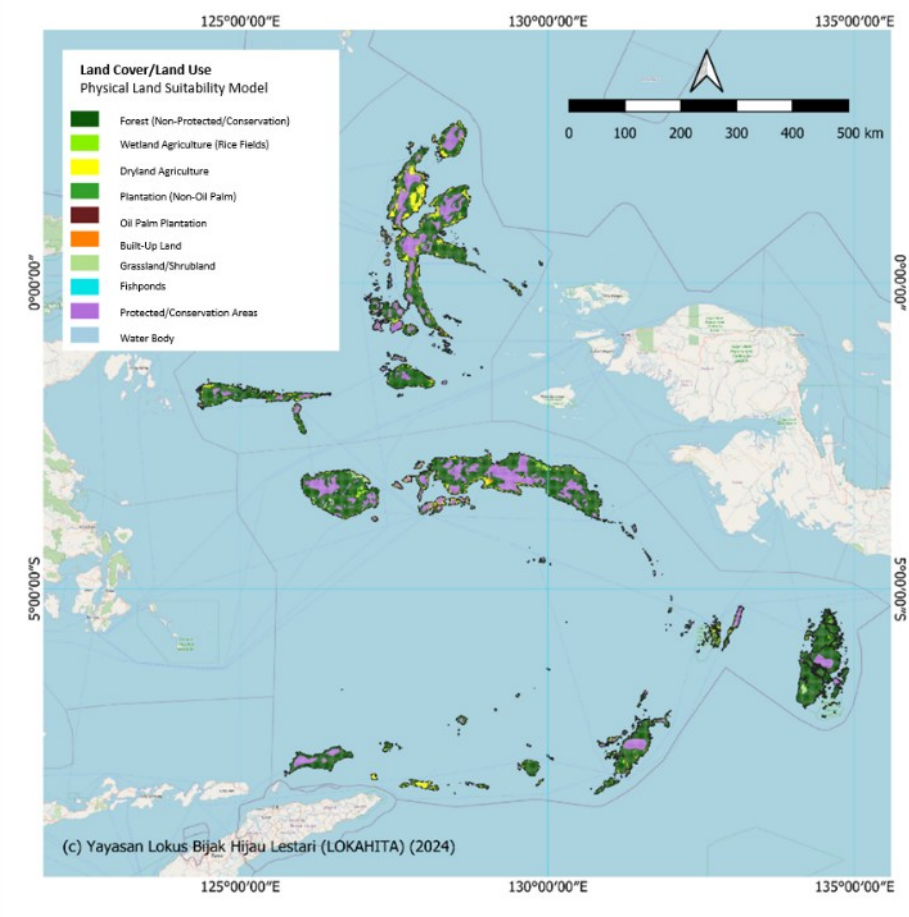



*Figure 4.37 Map of the physical land suitability model results for the Maluku Islands (Source: analysis results, 2024)*

The physical land suitability model described above was then refined by including constraint variables to ensure that oil palm plantations are not allocated in important ecosystems that must be protected. Out of 14 constraint variables, 12 were found in the Maluku Islands, with the most extensive being high ecosystem services (water regulation, habitat and biodiversity support, carbon regulation) and primary and secondary forest land cover, which cover 70% and 66% of the Maluku Islands, respectively. Table 4.31 and Figure 4.38 show that the combined distribution of all of the Maluku Islands' constraint variables covers 97% of the total area. The constraint variables were then overlaid with the physical suitability model results (Figure 4.39). If the physical land suitability results in oil palm plantations and falls within the constraint variable, no allocation or allocation based on the existing PPL will be made. This means that oil palm plantations will have their allocation reduced if they fall within the constraint variable and the existing PPL is not a oil palm plantation. Furthermore, there will be existing oil palm plantations, as evidenced by land suitability model results, but because they are in the constraint variable, the area will remain as oil palm plantations but cannot be developed further.

*Table 4.31 Area of Limiting Variables in the Maluku Islands in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Maluku Islands total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water providers based on water district (WD) | - | 0,00% |
| 2 | Peat Hydrological Unit (KHG) | - | 0,00% |
| 3 | Karst | 1.157.694,28 | 14,92% |
| 4 | Mangrove | 52.900,41 | 0,68% |
| 5 | Conservation areas and protected forests. | 1.818.432,76 | 23,44% |
| 6 | Cover of primary and secondary forest land | 5.122.244,81 | 66,03% |
| 7 | Spring | 14.550,23 | 0,19% |
| 8 | Slope above 30% | 1.006.272,88 | 12,97% |
| 9 | Critical Land | 605.346,78 | 7,80% |
| 10 | Protected wildlife | 1.523.064,55 | 19,63% |
| 11 | Indigenous community | 641.286,56 | 8,27% |
| 12 | Key Biodiversity Areas (KBA) | 2.269.796,89 | 29,26% |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 5.467.343,31 | 70,48% |
| 14 | Built-up areas | 45.798,60 | 0,59% |

Source: analysis results, 2024

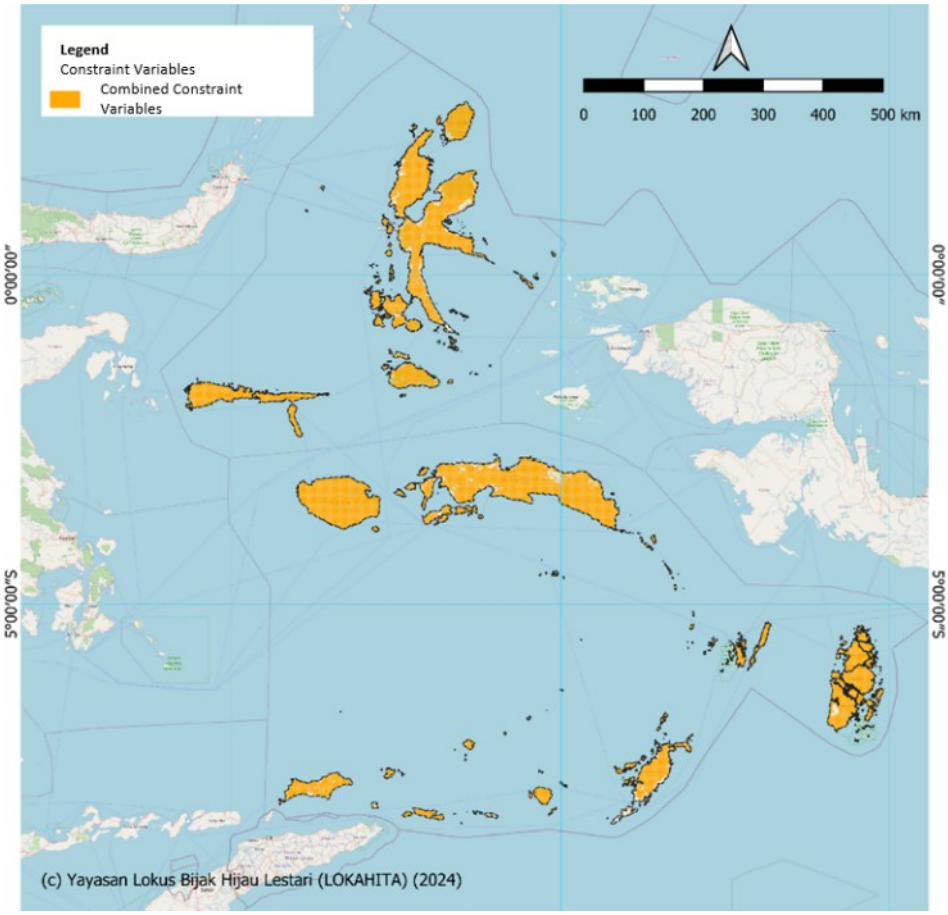



*Figure 4.38 Combined Map of Constraint Variables in the Maluku Islands in 2022 (Source: analysis results, 2024)*

In the Maluku Islands, the constraint variables that restrict land allocation for oil palm plantations are found in areas with high environmental services, critical land, or built-up land, particularly in South Halmahera Regency (North Maluku Province), Buru Island, and Seram Island. Figure 4.39 shows that the constraint variables must not be converted into oil palm plantation land. The constraint variable includes an existing oil palm plantation area of 11,261 Ha, which can no longer be developed. In the presence of constraint variables, the allocation of palm oil plantation land from other areas has been reduced to 682.9 ha. The allocation is based on existing non-protected/conservation forest land (PPL) covering 426 ha, existing grassland/shrubland (PPL) covering 170 ha, and existing Dryland Agricultural Land (PPL) covering 85 ha. Table 4.32 contains additional information about the Maluku Islands' land physical suitability model results. Figure 4.40 shows an example comparison of the PPL location allocation model's results before and after the constraint variable was applied.

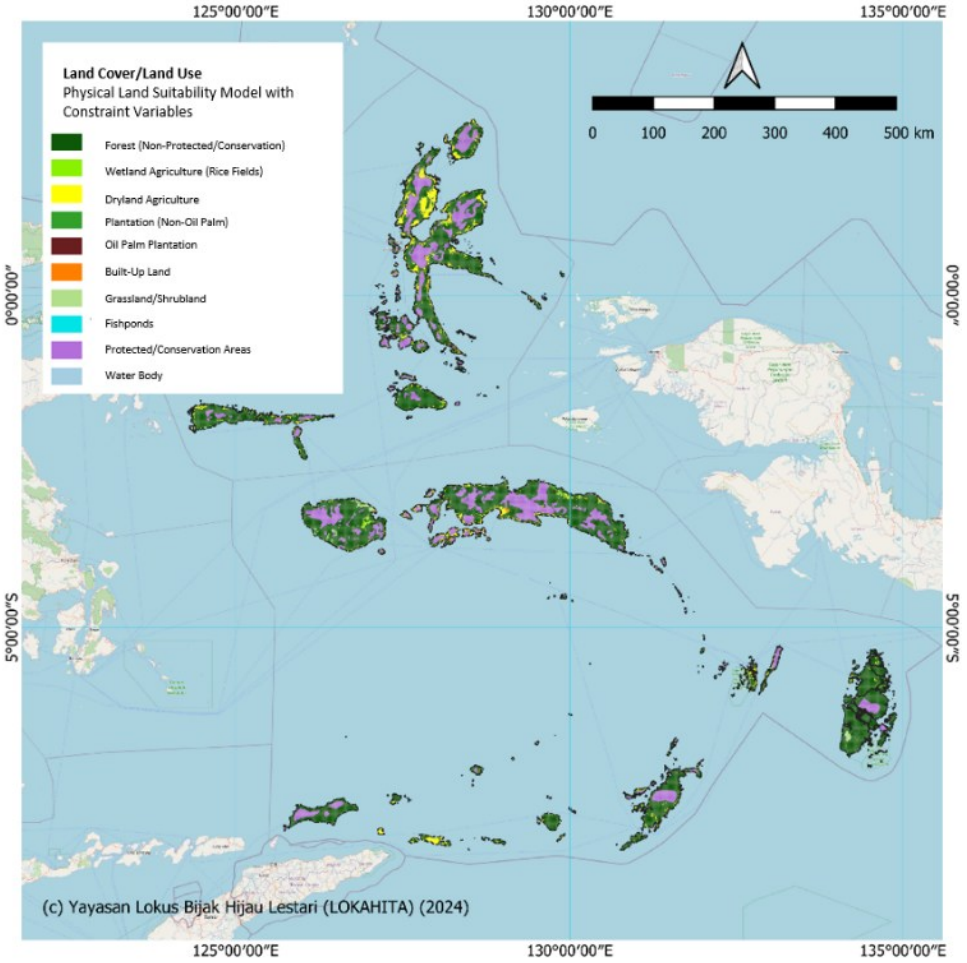
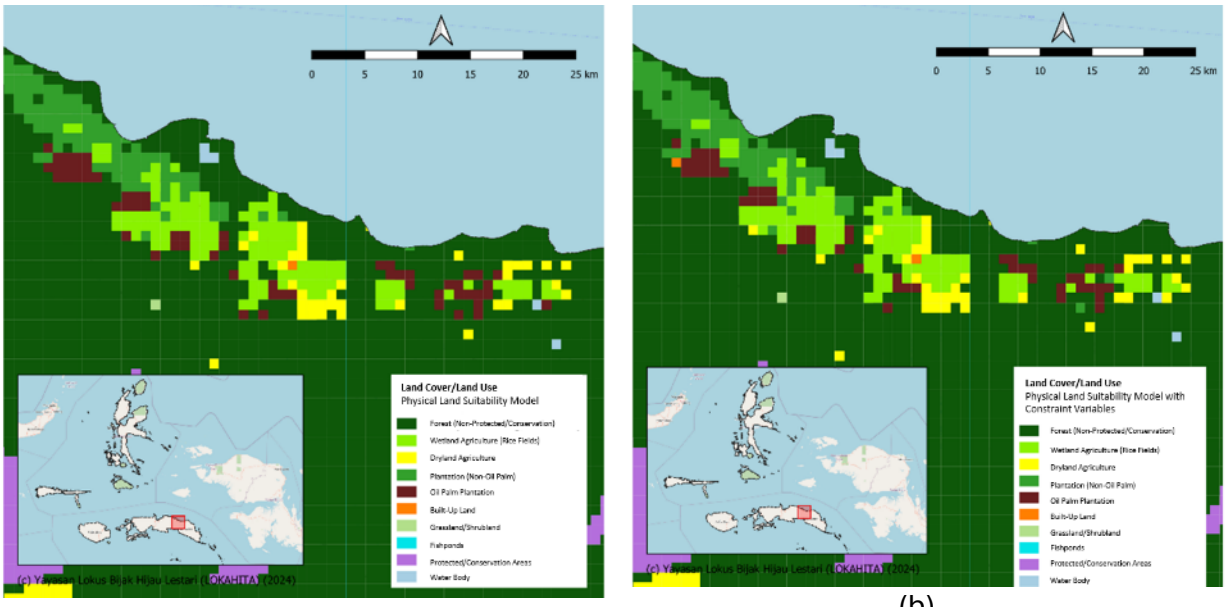



*Figure 4.39 Map of the physical land suitability model results with constraint variables of the Maluku Islands (Source: analysis results, 2024)*




(a) (b)

*Figure 4.40 Example of PPL allocation locations (a) before applying the constraint variables and (b) after applying them constraint variables in the Maluku Islands*
*(Source: analysis results, 2024)*

*Table 4.32 Area of land physical suitability considering constraint variables*

| | | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 4,180,760.00 | 1,621.65 | 171,787.62 | 1,390.85 | 426.81 | 762.83 | 4,351.13 | |
| | 2 | 4,695.78 | 16,561.39 | 6,896.94 | 597.55 | | 939.55 | 256.13 | |
| | 3 | 611,093.21 | 2,133.40 | 671,143.44 | 1,258.62 | 85.37 | 2,889.04 | 1,533.46 | |
| | 4 | 10,718.22 | 1,024.38 | 4,797.62 | 6,829.77 | | 170.87 | | |
| | 5 | 12,714.77 | 853.65 | 2,135.38 | 597.59 | 8,627.48 | | | |
| | 6 | 11,858.36 | 2,646.54 | 19,283.27 | 85.37 | | 16,458.75 | 452.22 | |
| | 7 | 71,756.58 | 597.42 | 11,854.52 | 426.80 | 170.73 | 703.74 | 49,091.99 | |

Source: analysis results, 2024

In 2022, there are approximately 11,261 ha of existing oil palm plantation land in the Maluku Islands that fall within the constraint variable of the land physical suitability model (Figure 4.41). The land in this area has been converted into oil palm plantations, which pose a threat to the environment. On land that has been converted into oil palm plantations, monitoring and prevention efforts are required to prevent further development and expansion of oil palm plantations into areas with constraint variables, thereby avoiding environmental damage.

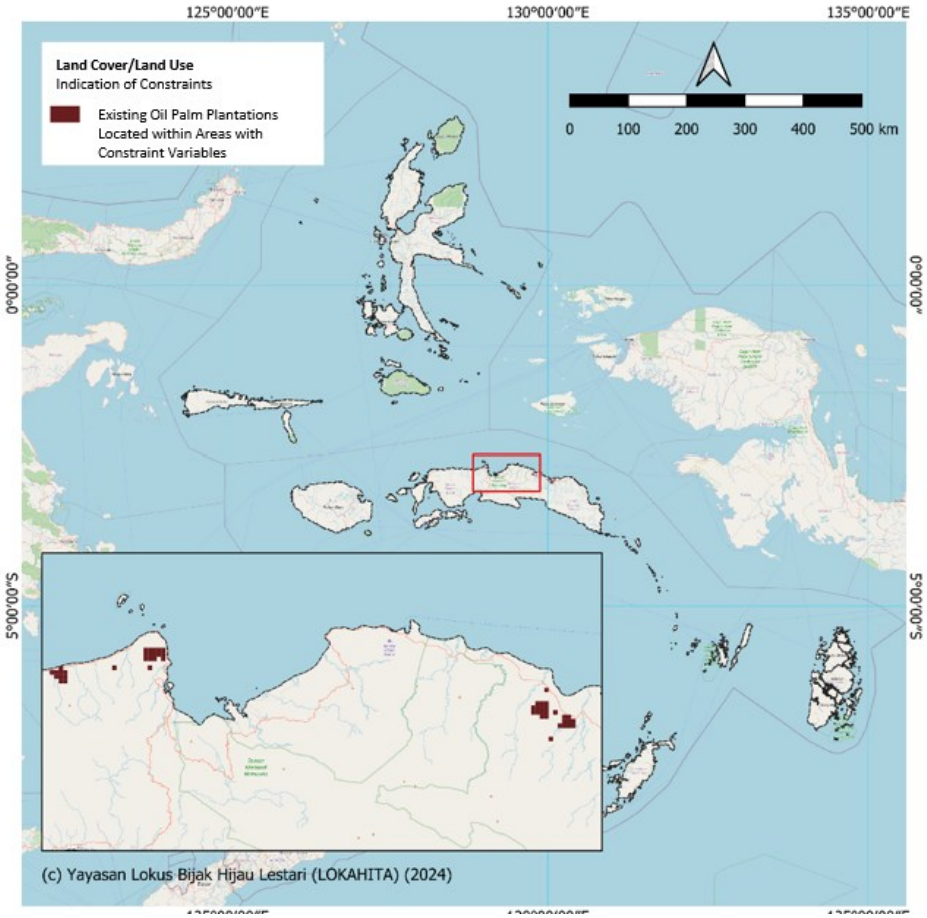



*Figure 4.41 Map indicating the boundaries of existing oil palm plantation development in the Maluku Islands (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Maluku Islands

The upper limit (cap) of oil palm plantation coverage based on Environmental Support Capacity and Environmental Load Capacity (D3TLH) is 25,611.79 Ha, or 0.33% of the Maluku Islands' total land area. Figure 4.42 depicts the proportion of oil palm plantations in the Maluku Islands, taking into account land suitability and limiting variables, whereas Table 4.33 shows the area and proportion of land allocation, existing oil palm plantations, and the difference in the Maluku Islands.

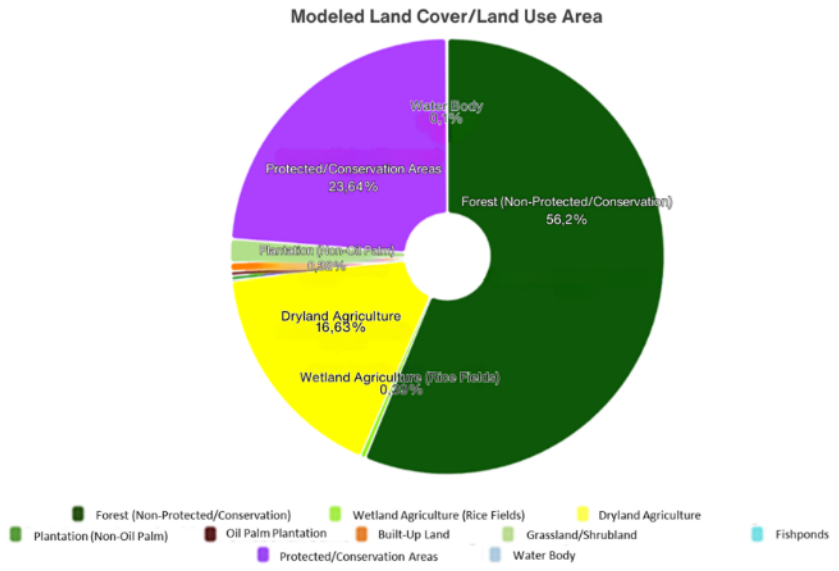



*Figure 4.42 Proportion of PPL area from physical land suitability modeling considering constraint variables in the Maluku Islands*
*(Source: analysis results, 2024)*

*Table 4.33 Area and proportion of land allocation, existing PPL, and the difference in the Maluku Islands*

| PPL Types | Allocation | PPL 2022 | Difference | Allocation | PPL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | % | | |
| Forest (non-Protected/Conservation) | 4.359.499,62 | 4.361.100,89 | 1.601,27 | 56,20% | 56,22% | 0,02% |
| Wetland Agriculture (Rice Fields) | 29.947,33 | 29.947,33 | (0,00) | 0,39% | 0,39% | 0,00% |
| Dryland Agriculture | 1.290.136,53 | 1.290.136,53 | - | 16,63% | 16,63% | 0,00% |
| Plantations (non-Palm Oil) | 25.056,76 | 23.540,87 | (1.515,89) | 0,32% | 0,30% | -0,02% |
| Oil Palm Plantation | 25.611,79 | 24.928,89 | (682,90) | 0,33% | 0,32% | -0,01% |
| Built-up areas | 50.784,51 | 50.784,51 | - | 0,65% | 0,65% | 0,00% |
| Grassland/Scrubland | 134.004,26 | 134.601,79 | 597,52 | 1,73% | 1,74% | 0,01% |
| Pond | 732,00 | 732,00 | 0,00 | 0,01% | 0,01% | 0,00% |
| Protected/Conservation Area | 1.833.934,14 | 1.833.934,14 | - | 23,64% | 23,64% | 0,00% |
| Water Body | 7.617,15 | 7.617,15 | - | 0,10% | 0,10% | 0,00% |
| **MALUKU ISLANDS** | 7.757.324,10 | 7.757.324,10 | 0,00 | 100,00% | 100,00% | 0,00% |

Source: analysis results, 2024

### 4.2.7 Papua Island

#### a. Land Cover/Land Use Demands

Papua's oil palm plantations require 1,227.10 $m^2$ per capita per year to meet total demands for food, clothing/textiles, infrastructure, wood, energy, and other palm oil consumption. Oil palm plantations use 84.91% of their land for food (1,041.89 $m^2$), 12.14% for energy (148.99 $m^2$), and 2.95% for other purposes (36.23 $m^2$). Figure 4.43 depicts the proportion of land required for oil palm plantations per capita on the island of Papua. Overall, the total land requirement for oil palm plantations on the island of Papua is 685,846.17 hectares to support the lives of the island's 5,589,160 inhabitants.

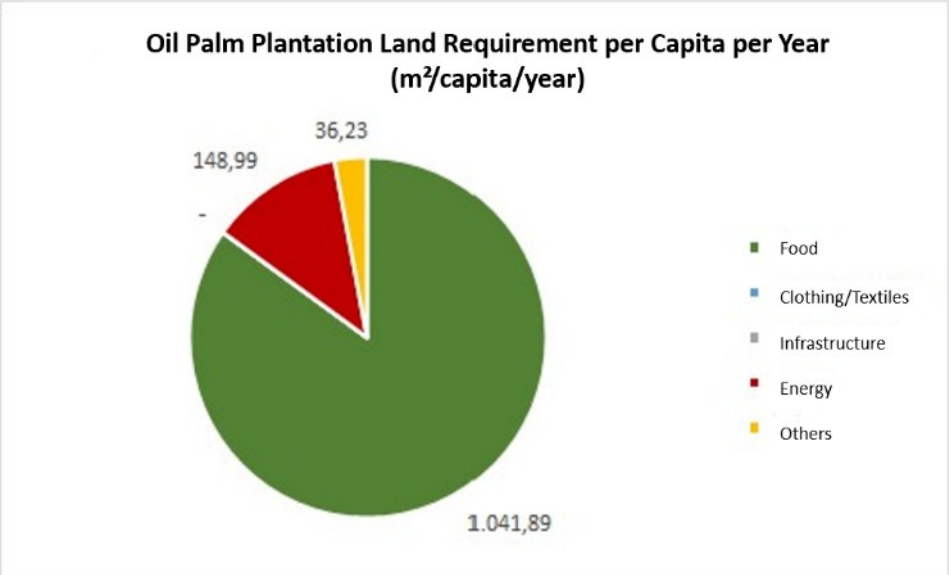



*Figure 4.43 Area of palm oil plantation land requirement per capita per year in Papua Island (Source: analysis results, 2024)*

Meanwhile, based on the existing Land Cover and Land Use (PPL) conditions in 2022 on the island of Papua (41,227,278.78 ha), Palm Oil Plantations account for 0.71% of the total area of Papua, or 290,659.14 ha. Other land cover/use types dominate the island of Papua, including forests (non-protected/conservation), which cover 50.57% of the island, or 20,848,719.86 ha, and protected/conservation areas, which cover 43.65% of the island, or 17,997,456.14 ha. Figure 4.44 and Table 4.34 show the distribution of each type of land cover/use (LULC) that existed in 2022.

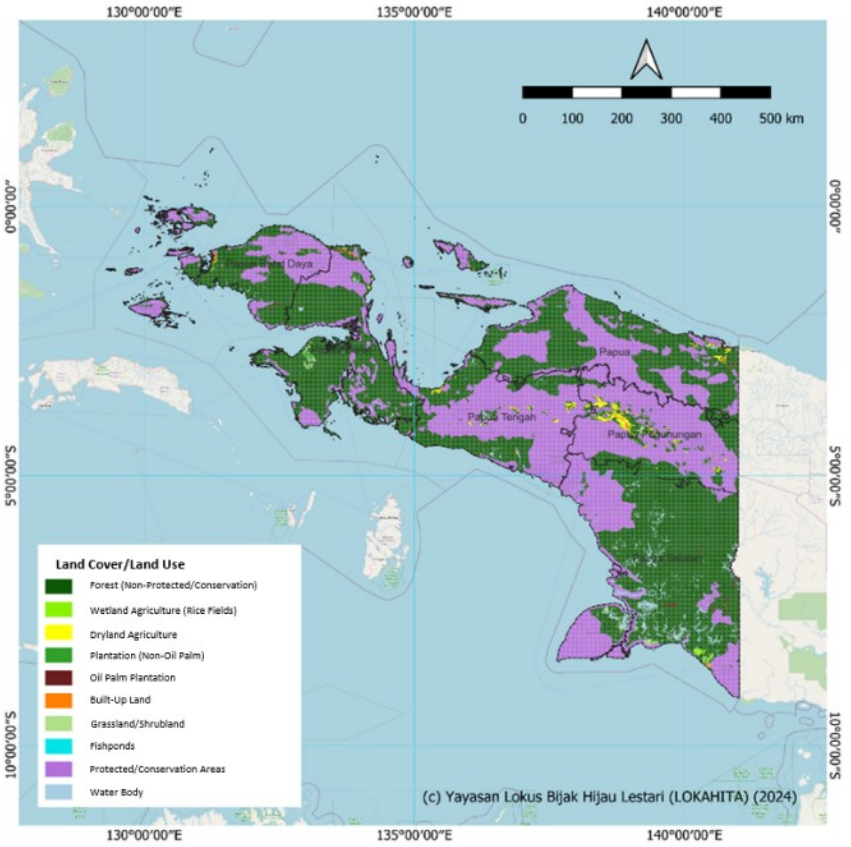



*Figure 4.44 Distribution map of existing PPL in Papua Island in 2022 (Source: analysis results, 2024)*

*Table 4.34 Area of existing PPL types on the island of Papua in 2022*

| PL Types | Area (ha) | Area (%) |
|---|---|---|
| Forest (non-Protected/Conservation) | 20.848.719,86 | 50,57% |
| Wetland Agriculture (Rice Fields) | 57.308,33 | 0,14% |
| Dryland Agriculture | 596.486,39 | 1,45% |
| Plantations (non-Palm Oil) | 41.509,62 | 0,10% |
| Oil Palm Plantation | 290.659,14 | 0,71% |
| Built-up areas | 141.176,00 | 0,34% |
| Grassland/Scrubland | 494.763,88 | 1,20% |
| Pond | 767,69 | 0,00% |
| Protected/Conservation Area | 17.997.456,14 | 43,65% |
| Water Body | 758.431,73 | 1,84% |
| **PAPUA ISLAND** | **41.227.278,78** | **100,00%** |

Source: analysis results, 2024

According to the D3TLH, the existing oil palm plantations on the island of Papua (290,659.14 ha) are insufficient to meet the island's land needs (685,846.17 ha). As a result, additional land from other types of PPL must be allocated as oil palm plantations in Papua Island, given

the land deficit. Table 4.35 shows a comparison of the needed area and the existing PPL in 2022 on the island of Papua.

*Table 4.35 Area of needs and existing PPL on Papua Island in 2022*

| | Type of Land Cover/Use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantations (non-Palm Oil) | Oil Palm Plantation | Built-Up Areas | Grassland/ Shrubland | Pond |
| **Land demands (ha)** | 1.006.180,05 | 32.290,40 | 710.656,13 | 16.910,24 | 685.846,17 | 7.824,82 | 1.006.180,05 | 32.290,40 |
| **Existing PPL Areas (ha)** | 20.848.719,86 | 57.308,33 | 596.486,39 | 41.509,62 | 290.659,14 | 141.176,00 | 20.848.719,86 | 57.308,33 |
| **Status** | Surplus | Surplus | Deficit | Surplus | Deficit | Surplus | Surplus | Deficit |

Source: analysis results, 2024

## b. Land Physical Suitability and Constraint Variables

According to land suitability modelling, an area of 29,213.43 ha can be allocated for oil palm plantations. Forests (non-protected/conservation) account for 13,783.50 ha (47.18%) of the land that can be allocated for oil palm plantations, followed by Dryland Agriculture (7,086.11 ha (24.26%) and Built-up Land (4,843.25 ha). Table 4.36 and Figure 4.44 show the detailed results of the land suitability model on Papua Island.

*Table 4.36 Allocation of the area for each type of PPL based on the land physical suitability model in Papua Island in 2022*

| | | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 20.784.029,09 | 5.331,84 | 25.247,71 | 682,96 | 13.783,50 | 2.907,62 | 16.737,14 | |
| | 2 | 22.376,42 | 26.497,07 | 3.666,73 | | 1.196,51 | 3.148,51 | 423,09 | |
| | 3 | 355.261,10 | 4.005,90 | 223.323,16 | | 7.086,11 | 5.284,11 | 1.526,02 | |
| | 4 | 19.308,89 | | 427,16 | 17.418,77 | 1.024,90 | 85,38 | 3.244,52 | |
| | 5 | 195.723,18 | | 3.160,04 | 341,49 | 89.129,01 | 427,22 | 1.878,20 | |
| | 6 | 71.452,27 | 6.529,39 | 23.631,83 | 85,38 | 4.843,25 | 33.780,89 | 852,99 | |
| | 7 | 384.267,35 | 2.081,32 | 4.264,84 | 2.134,54 | 1.193,78 | 1.519,96 | 99.302,09 | |
| | 8 | 85,39 | | 512,35 | | 85,39 | 84,56 | | |

Source: analysis results, 2024

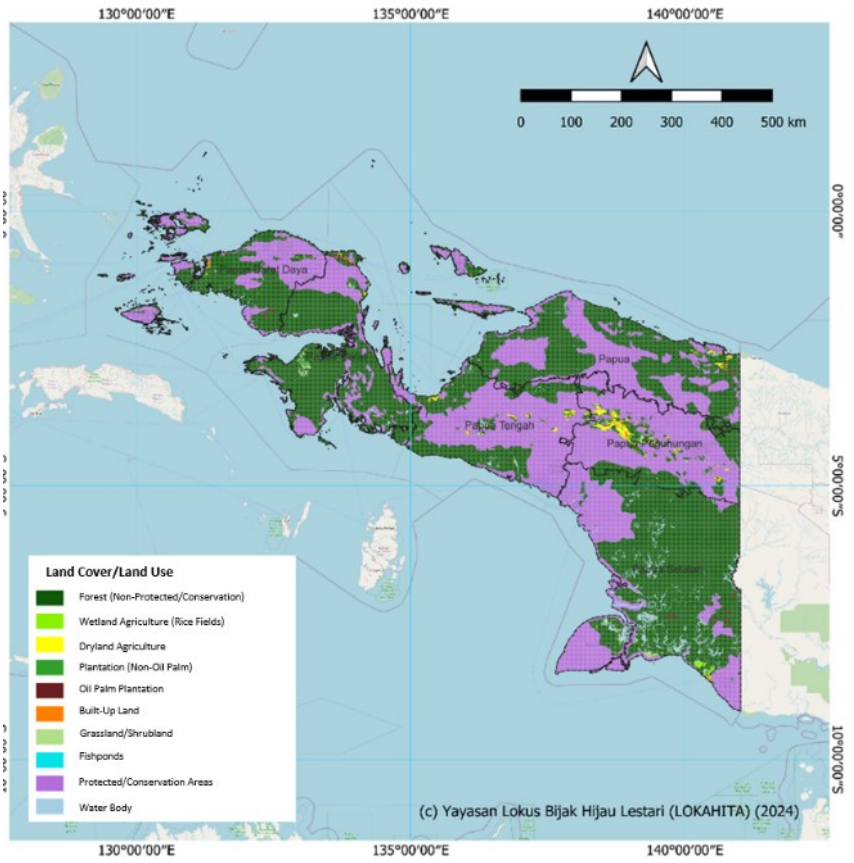



*Figure 4.45 Map of land physical suitability in Papua Island*
*(Source: analysis results, 2024)*

Although there is a large area of land that can be converted into oil palm plantations based on its physical suitability, such changes must also take into account important ecosystems to avoid a decline in environmental functions in the area. As a result, the land suitability model is refined to account for the constraint cariables, ensuring that oil palm plantations are not allocated in important ecosystems that must be protected. Figure 4.46 depicts the distribution of constraint variables on the island of Papua, and the Appendix contains distribution maps for each constraint variable.

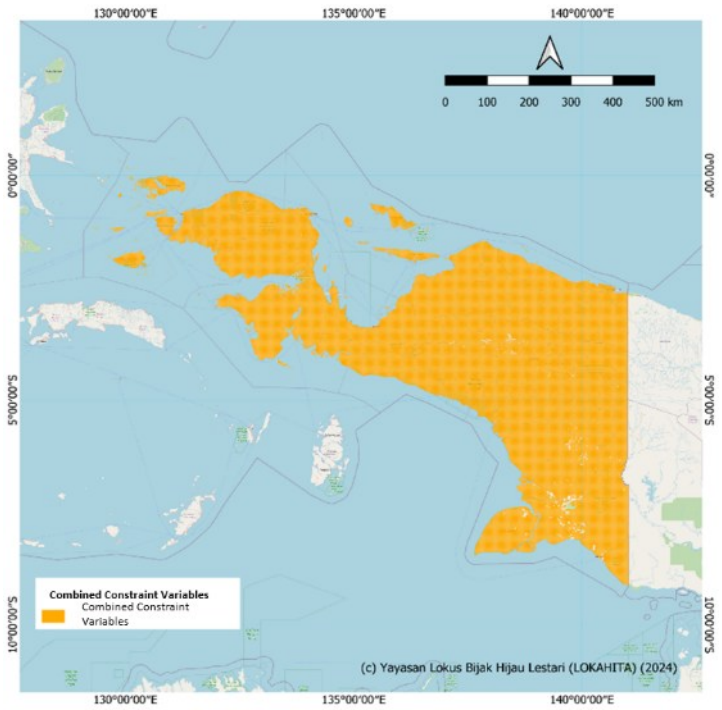



*Figure 4.46 Combined map of constraint variable distribution on Papua Island in 2022*
*(Source: analysis results, 2024)*

There are 12 constraint variables found on the island of Papua, with 38,778,142.20 ha (94.06% of the area of Papua Island) classified as High Conservation Value (HCV), 34,514,185.02 ha (83.72% of the area of Papua Island) classified as primary and secondary forest cover, and 23,833,166.00 ha (57.81% of the area of Papua Island) classified as the home range of protected wildlife, covering more than half of the island. In total, there are 40,911,387.39 ha of constraint variables. Table 4.37 displays the area of each constraint variable found on the island of Papua.

*Table 4.37 Area of Constraint Variables on the Island of Papua in 2022*

| No | Constraint Variable | Area (ha) | Area in relation to Papua Island's total area (%) |
|---|---|---|---|
| 1 | Environmental supporting capacity (DDLH) of water providers based on water district (WD) | - | 0,00% |
| 2 | Peat Hydrological Unit (KHG) | 6.584.127,42 | 15,97% |
| 3 | Karst | 4.773.694,63 | 11,58% |
| 4 | Mangrove | 1.644.379,05 | 3,99% |
| 5 | Conservation areas and protected forests. | 18.203.730,05 | 44,15% |
| 6 | Cover of primary and secondary forest land | 34.514.185,02 | 83,72% |

| No | Constraint Variable | Area (ha) | Area in relation to Papua Island's total area (%) |
|---|---|---|---|
| 7 | Spring | - | 0,00% |
| 8 | Slope above 30% | 1.514.719,21 | 3,67% |
| 9 | Critical Land | 851.063,11 | 2,06% |
| 10 | Protected wildlife | 23.833.166,00 | 57,81% |
| 11 | Indigenous community | 11.716.514,22 | 28,42% |
| 12 | Key Biodiversity Areas (KBA) | 3.770.329,89 | 9,15% |
| 13 | High environmental services (ES) (water regulation, habitat and biodiversity support, carbon regulation) | 38.778.142,20 | 94,06% |
| 14 | Built-up areas | 129.476,66 | 0,31% |

Source: analysis results, 2024

To ensure that ecosystem functions continue, areas with constraint variables should not be converted into oil palm plantations. If the physical land suitability results indicate oil palm plantations but they are located in an area with constraint variables, the allocation to oil palm plantations cannot be carried out, so the allocation remains in accordance with the existing PPL and no new oil palm plantations are created. However, if the existing land use plan (PPL) already includes oil palm plantations, and the land suitability results also show oil palm plantations, but they are located in an area with constraint variables, the oil palm plantation cannot be developed further. Figure 4.47 depicts an example of land allocation on Papua Island that has been returned to the existing PPL because it falls within the constraint variable.

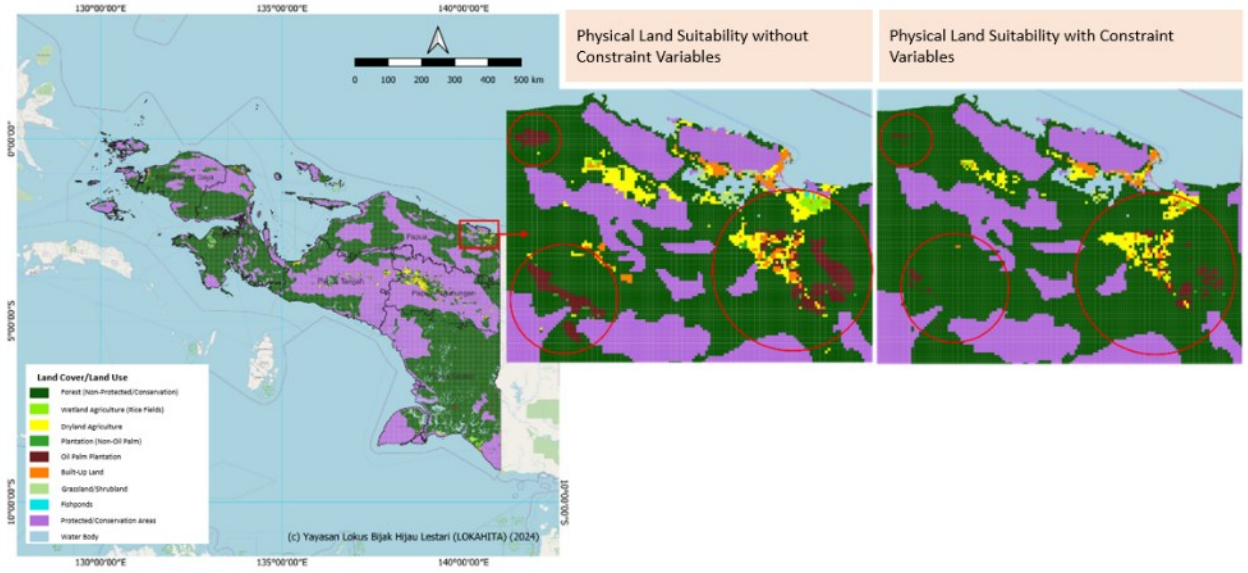



*Figure 4.47 Example of allocation locations returned to existing PPL because they are in areas with Constraint Variables in Papua Island.*
*(Source: analysis results, 2024)*

The addition of constraint variables to the analysis reduced the allocation of oil palm plantation land from other types of PPL to 177.89 ha. Forests (non-Protected/Conservation) account for 92.0 ha (52.11%) of the PPL that can be allocated to oil palm, while Grasslands/Shrublands account for 85.19 ha (47.89%). Figure 4.48 and Table 4.38 show the distribution map and allocation of each type of PPL on the island of Papua based on the land suitability model, which has already taken into account the constraint variables.

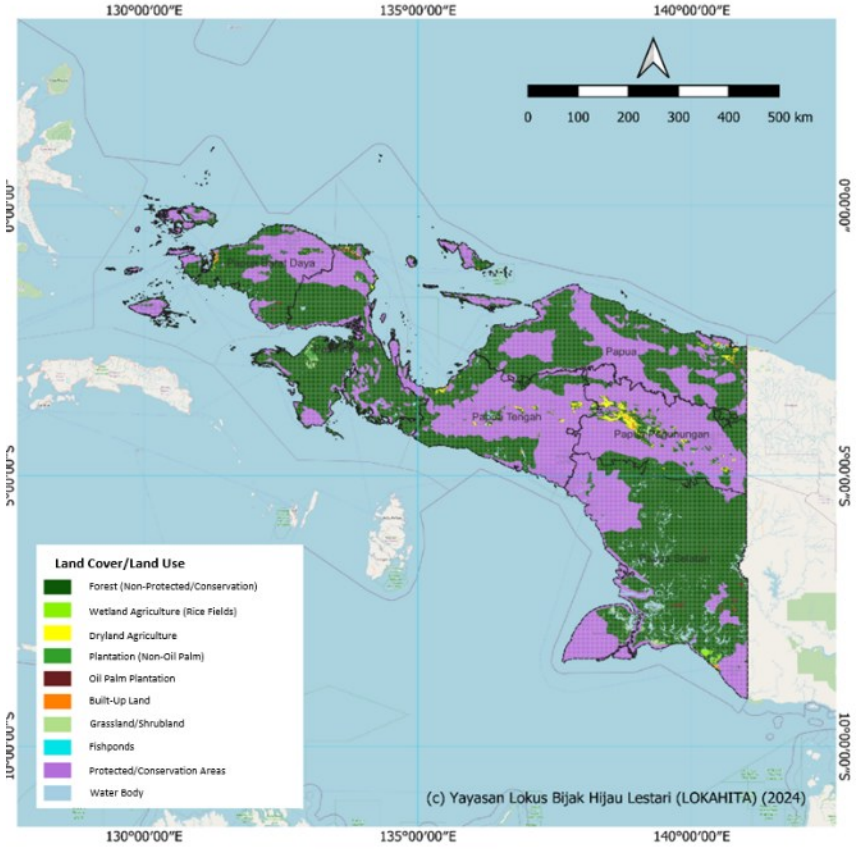



*Figure 4.48 Map of the physical land suitability model results on Papua Island using Constraint Variables (Source: analysis results, 2024)*

*Table 4.38 Allocation of the area for each type of PPL based on the land physical suitability model considering constraint variables on the Island of Papua in 2022*

| | | Area of Physical Land Suitability Considering Constraint Variables (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forest (non-Protected/ Conservation) | Wetland Agriculture (Rice Fields) | Dryland Agriculture | Plantation (Non-Oil Palm) | Oil Palm Plantation | Built-Up Land | Grassland/ Shrubland | Fishponds |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Existing PPL Area (ha) | 1 | 20.797.719,89 | 5.331,84 | 25.247,71 | 682,96 | 92,70 | 2.907,62 | 16.737,14 | |
| | 2 | 22.376,42 | 27.693,58 | 3.666,73 | | | 3.148,51 | 423,09 | |
| | 3 | 355.261,10 | 4.005,90 | 230.409,27 | | | 5.284,11 | 1.526,02 | |
| | 4 | 19.308,89 | | 427,16 | 18.443,67 | | 85,38 | 3.244,52 | |
| | 5 | 195.723,18 | | 3.160,04 | 341,49 | 89.129,01 | 427,22 | 1.878,20 | |
| | 6 | 71.452,27 | 6.529,39 | 23.631,83 | 85,38 | | 38.624,14 | 852,99 | |
| | 7 | 384.267,35 | 2.081,32 | 4.264,84 | 2.134,54 | 85,19 | 1.519,96 | 100.410,67 | |

Source: analysis results, 2024

According to the analysis results of the land physical suitability model with the previous constraint variables, there are existing oil palm plantations in 2022 within an area with constraint variables covering 75,308.04 ha (Figure 4.49). There is a risk of environmental disruption in this area because land has been converted into oil palm plantations. Monitoring and prevention efforts are required on converted land to ensure that further development and expansion of oil palm plantations does not occur in areas with constraint variables, thereby preventing environmental damage.


*Figure 4.49 Map indicating the boundaries of existing oil palm plantation development (Source: analysis results, 2024)*

### c. Upper Limit Value of Oil Palm Plantations on Papua Island

According to the D3TLH perspective, oil palm plantations cover 290,837.03 ha of Papua Island, accounting for 0.71% of the total area. Figure 4.50 depicts the proportion of oil palm plantations (PPL) on Papua Island, taking into account land physical suitability and limiting variables, whereas Table 4.39 shows the area and proportion of land allocation, existing PPL, and the difference.

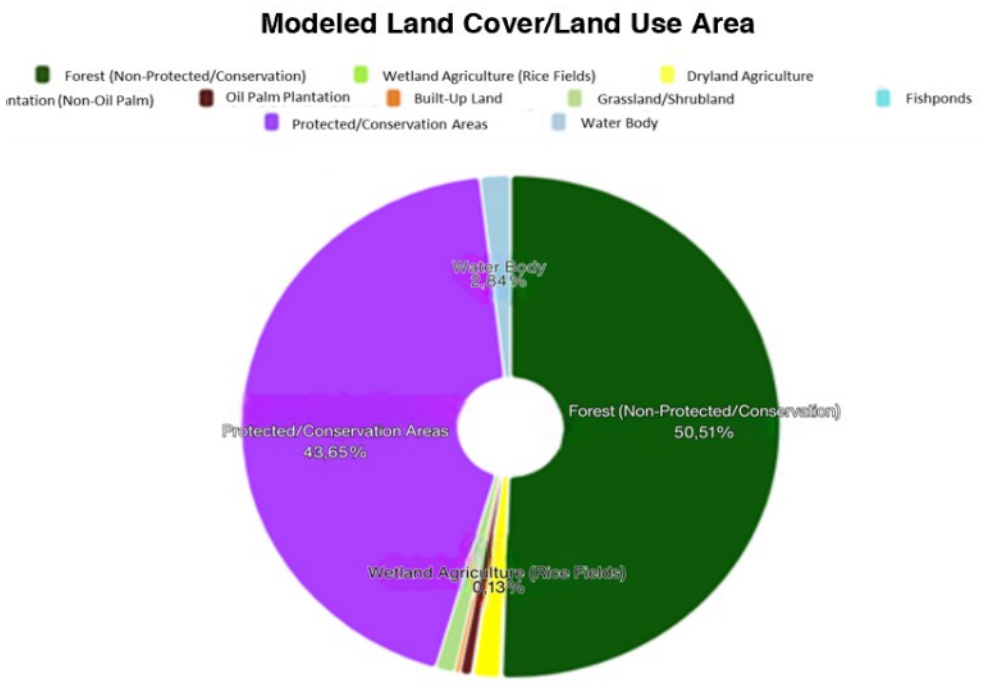



*Figure 4.50 Proportion of PPL area from land suitability modeling considering Constraint Variables on the Island of Papua in 2022*
*(Source: analysis results, 2024)*

*Table 4.39 Area and Proportion of Land Allocation, Existing PPL, and Their Difference in Papua Island*

| PL Types | Allocation | PL 2022 | Difference | Allocation | PL 2022 | Difference |
|---|---|---|---|---|---|---|
| | (ha) | | | (%) | | |
| Forest (non-Protected/Conservation) | 20.823.379,45 | 20.848.719,86 | 25.340,41 | 50,51% | 50,57% | 0,06% |
| Wetland Agriculture (Rice Fields) | 53.641,60 | 57.308,33 | 3.666,73 | 0,13% | 0,14% | 0,01% |
| Dryland Agriculture | 653.724,68 | 596.486,39 | -57.238,28 | 1,59% | 1,45% | -0,14% |
| Plantations (non-Palm Oil) | 41.082,46 | 41.509,62 | 427,16 | 0,10% | 0,10% | 0,00% |
| Oil Palm Plantation | **290.837,03** | 290.659,14 | -177,89 | 0,71% | 0,71% | 0,00% |
| Built-up areas | 117.544,16 | 141.176,00 | 23.631,83 | 0,29% | 0,34% | 0,06% |
| Grassland/Scrubland | 490.413,84 | 494.763,88 | 4.350,03 | 1,19% | 1,20% | 0,01% |
| Pond | 767,69 | 767,69 | 0,00 | 0,00% | 0,00% | 0,00% |
| Protected/Conservation Area | 17.997.456,14 | 17.997.456,14 | 0,00 | 43,65% | 43,65% | 0,00% |
| Water Body | 758.431,73 | 758.431,73 | 0,00 | 1,84% | 1,84% | 0,00% |
| **PAPUA ISLAND** | **41.227.278,78** | **41.227.278,78** | **0,00** | **100,00%** | **100,00%** | **0,00%** |

Source: analysis results, 2024

# Chapter 5 Conclusion and Recommendations

## 5.1 Conclusion

The upper limit (cap) of oil palm plantation coverage based on the D3TLH perspective in Indonesia is 18,148,602.96 hectares or 18.15 million hectares. According to the analysis of each island, Sumatra and Kalimantan have more oil palm plantation areas than they need. Meanwhile, the islands of Java, Sulawesi, Papua, the Bali Nusa Tenggara Archipelago, and the Maluku Archipelago are in greater need of oil palm plantation land than there is available. However, this deficit condition cannot be used to justify the establishment of new palm oil plantation lands, because the demand can be met by distributing production results from surplus areas. Furthermore, many deficit areas have ecological and spatial constraints, such as conservation areas, protected forests, and ecologically significant regions, making palm oil plantation expansion impossible.

The results of the research are not expected to worsen the current situation regarding the upper limit (cap) of oil palm plantation areas on each island/archipelago, because there are existing oil palm plantations that can no longer be developed due to their location in areas with limiting variables, namely:

- On Sumatra, existing oil palm plantations with limiting variables cover 5.97 million hectares in Aceh, North Sumatra, Riau, Jambi, South Sumatra, Bengkulu, Lampung, and the Bangka Belitung Islands. This region is dominated by peatlands, conservation areas, protected forests, and habitats for protected wildlife like the Sumatran tiger, making palm oil expansion extremely hazardous to the environment and biodiversity.
- On the island of Java, there are 2.12 thousand hectares of existing oil palm plantations in Banten and West Java, particularly in Lebak, Pandeglang, and several points to the west and south of West Java. This area has a slope of more than 30%, conservation zones, and indigenous territories, making palm oil development impossible.
- On the island of Kalimantan, there are 5.30 million hectares of existing oil palm plantations spread across almost all provinces, especially West Kalimantan, Central Kalimantan, and South Kalimantan. This region contains peatlands, conservation areas, Key Biodiversity Areas (KBA), and orangutan habitats, as well as several areas prone to flooding and landslides, so palm oil expansion is not recommended.
- On the island of Sulawesi, existing oil palm plantations with constraint variables reach 201.71 thousand hectares, especially in West Sulawesi, South Sulawesi, and Central Sulawesi. This region has slopes greater than 30%, conservation areas, and

high environmental services, so strict management is needed to prevent environmental degradation.

- In the Maluku Islands, there are 11,260 hectares of existing oil palm plantations on Seram Island, mainly in the western and eastern parts. This area includes protected forests, customary lands, and KBA, making it highly vulnerable to the conversion of land for oil palm plantations.
- On the island of Papua, existing palm oil plantations cover 75.30 thousand hectares, mainly in Southwest Papua and West Papua. This region is dominated by primary forests, conservation areas, KBAs, and bird-of-paradise habitats, making palm oil expansion highly risky to the ecosystem and indigenous people's rights.

If the area of oil palm plantations exceeds the upper limit (cap), the environmental consequences can be severe. Expansion in Sumatra and Kalimantan risks hastening peatland degradation, increasing carbon emissions, exacerbating climate change, and increasing the frequency of forest fires. Land conversion in conservation areas and protected forests endangers biodiversity, including protected species like orangutans, Sumatran tigers, and birds of paradise. Furthermore, the reduction of water catchment areas raises the risk of flooding and drought, particularly in Sumatra, Kalimantan, and Sulawesi. Uncontrolled expansion in indigenous regions like Kalimantan, Maluku, and Papua can also lead to land conflicts with local communities, exacerbating social and economic inequalities.

This research emphasises that determining oil palm plantation caps using D3TLH should be the foundation for developing palm oil management policies in Indonesia. Policies that should be promoted include limiting palm oil expansion in areas with low carrying capacity, increasing productivity without expanding land, and improving environmental and social governance. Palm oil plantations can be managed sustainably by taking into account the limits of environmental carrying capacity and support capacity, without sacrificing ecosystem preservation or community welfare.

## 5.2 Recommendations

This research has many limitations, both in terms of data and the methodology used. Therefore, in the next research, there are several aspects that can be developed, such as:

a. The use of more diverse scenarios to provide more representative results, whereas in this study only one scenario was used: 100% fulfilment of needs.
b. The use of more representative training data, such as a oil palm plantation suitability model using training data with ideal land suitability, as opposed to the oil palm

plantation suitability model used in this study, which uses training data derived from the physical conditions of existing palm oil plantations, which may not be ideal.

c. Physical parameters are added for land suitability modelling, as well as constraint variables, to better match the ideal oil palm plantation conditions.
d. Further research using system dynamics to investigate the potential development of oil palm plantations and their future consequences.

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