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Identification of Factors and Variables in Orangutan Habitat Conservation in Central Tapanuli Using DPSIR Approach

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ABSTRACT

The habitat of the Tapanuli orangutan remains under threat from deforestation, fragmentation, development, and hunting, with only 11,787.7 hectares left. Conservation efforts have not been optimal due to the lack of a systematic approach and synergy among stakeholders. A long-term, data-driven management model integrating social, economic, ecological, and policy aspects is yet to be developed. This study aims to develop a scenario model for conserving the habitat of the Tapanuli orangutan in Central Tapanuli Regency. The method used in this research includes a literature review conducted over one year (November 2022–November 2023), secondary data collection, field surveys, and the DPSIR framework as an analysis tool. Four scenarios were analyzed: Business as Usual (BAU), land conversion threats, area strengthening policies, and habitat rehabilitation. The model was validated using historical data to ensure the accuracy of the results. The findings indicate that, although national and regional policies exist to protect the Tapanuli orangutan, their implementation is often hindered by weak law enforcement, corruption, and resistance from local communities. Thus, protecting the habitat of the Tapanuli orangutan requires a more holistic approach, including enhanced monitoring, forest restoration, community education, the development of sustainable alternative livelihoods, and multi-stakeholder collaboration. Continuous evaluation and strengthening of science-based policies are essential to ensuring the long-term effectiveness of conservation efforts.

Keywords: Deforestation, Environmental governance, Fragmentation, Habitat conservation, Stakeholder collaboration.

1. Introduction

The Tapanuli Tengah Regency is located in the North Sumatra Province, with an administrative area of 2,194.98 km² and consisting of 20 sub-districts (BPS Tapanuli Tengah Regency, 2022). Tapanuli Tengah has several land use zones, such as Other Use Areas (APL), Protected Forests (HL), Production Forests (HP), and Limited Production Forests (HPT).

The forest areas in Tapanuli Tengah possess a high biodiversity potential. Some parts of the regency fall under the Strategic Area of North Sumatra Province (KSP), the Batang Toru Ecosystem, in terms of environmental function and carrying capacity (Regional Regulation of North Sumatra No. 2 of 2017). The forest areas in Tapanuli are important as habitats for high biodiversity, including the Tapanuli Orangutan (Wich et al., 2019), 67 species of mammals, 287 species of birds, 110 species of herpetofauna, and 688 species of plants (Samsuri et al., 2014). The local communities surrounding the Tapanuli forest are highly dependent on its sustainability, as they utilize its resources for food, water, and protection from environmental disasters.

The habitat of the Tapanuli Orangutan ("*Pongo tapanuliensis*") is one of the most important and unique ecosystems in the world, as it is only found in the Batang Toru ecosystem in North Sumatra (Nater et al., 2017). The Tapanuli Orangutan is the rarest orangutan species, with a population estimated to be less than 800 individuals. The critical status assigned by the International Union for Conservation of Nature (IUCN) reflects the very high threat to their population's sustainability. Their habitat is under serious threat due to human activities, such as land conversion for agriculture, infrastructure development, natural resource exploitation, and illegal hunting and trade. Therefore, research to identify the factors affecting the sustainability of the Tapanuli Orangutan's habitat is urgently needed (Nowak et al., 2017).

The urgency of this research is based on the ecological role of the Tapanuli Orangutan as an "umbrella species" that maintains the balance of tropical forest ecosystems. The loss of the Tapanuli Orangutan would not only result in the loss of biodiversity but would also lead to the degradation of the broader ecosystem, as orangutans play a crucial role in seed dispersal, which is vital for forest regeneration. Compared to orangutans in other locations, such as the Bornean Orangutan ("Pongo pygmaeus") and Sumatran Orangutan ("*Pongo abelii*"), the Tapanuli Orangutan holds greater significance due to its unique genetic traits. Genetic studies show that the Tapanuli Orangutan has been isolated for over 10,000 years, making their conservation essential to maintaining genetic diversity among primates in Southeast Asia.

Tapanuli Tengah Regency is a key area in conservation efforts because it encompasses most of the remaining habitat. Unfortunately, pressures on the habitat due to land use changes and ongoing development continue to increase, leading to conflicts between economic interests and environmental conservation. A systematic approach is therefore required to develop effective conservation strategies. The DPSIR Framework (Driving Forces, Pressures, State, Impacts, Responses) is a relevant analytical method to identify the factors and variables contributing to the preservation of the Tapanuli Orangutan's habitat. This framework enables researchers to understand the cause-and-effect relationships between human activities, environmental changes, and potential mitigation efforts (Samsuri et al., 2014). Habitat loss and hunting are major factors affecting the sustainability of the Tapanuli Orangutan population in Batang Toru. Industrialization and urbanization have significantly accelerated land use and land cover changes, leading to the loss of ecological balance (Wu et al., 2021). *To systematically analyze the complex interactions between human activities, environmental changes, and conservation efforts, this study applies the DPSIR framework*

This study aims to assess models and scenarios for the future sustainability of the Tapanuli Orangutan's habitat, considering the factors that threaten the habitat in Tapanuli Tengah Regency. The Tapanuli Orangutan's habitat in Tapanuli Tengah covers 11,787.7 hectares (Utami Atmoko SS, Traylor-Holzer K, Rifqi M.A, et al. 2017.). *This study aims to identify key factors influencing the sustainability of the Tapanuli Orangutan's habitat and develop conservation scenarios using the DPSIR framework, integrating social, economic, ecological, and policy considerations."*(Wich et al., 2019).

Intervention by the government and NGOs is necessary to mitigate the damage to the Tapanuli orangutan's habitat. These efforts may include conservation actions to help increase the Tapanuli Orangutan population, such as planting to increase the number of food plants (restoration), patrols to monitor populations, and reducing human activities in the forest (Kuswanda et al., 2021).

A model can be useful for environmental management by synthesizing relevant and up-to-date aspects and understanding how environmental management processes impact components and processes (Schuwirth et al., 2019). Furthermore, to examine long-term management, it is important to analyze the changes with and without government and NGO interventions to reduce deforestation rates over the next 40 years. The impact of these interventions can be examined using system dynamics modeling. The relationship between physical, social, and economic factors influences the dynamic system (Wang and Bao, 2021). Therefore, scenario development is crucial to illustrate the sustainability of the Tapanuli Orangutan and its habitat in Tapanuli Tengah Regency. The development of these scenarios will explore the impact of government and NGO interventions in Tapanuli Orangutan conservation programs and their habitats in terms of social, economic, ecological, and policy factors.

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2. Method

This research was carried out for one year from November 2022 to November 2023. The research locus was in the Tapanuli Orangutan Habitat which is part of the administrative area of Central Tapanuli Regency. A map of the research area can be seen in Figure 1.

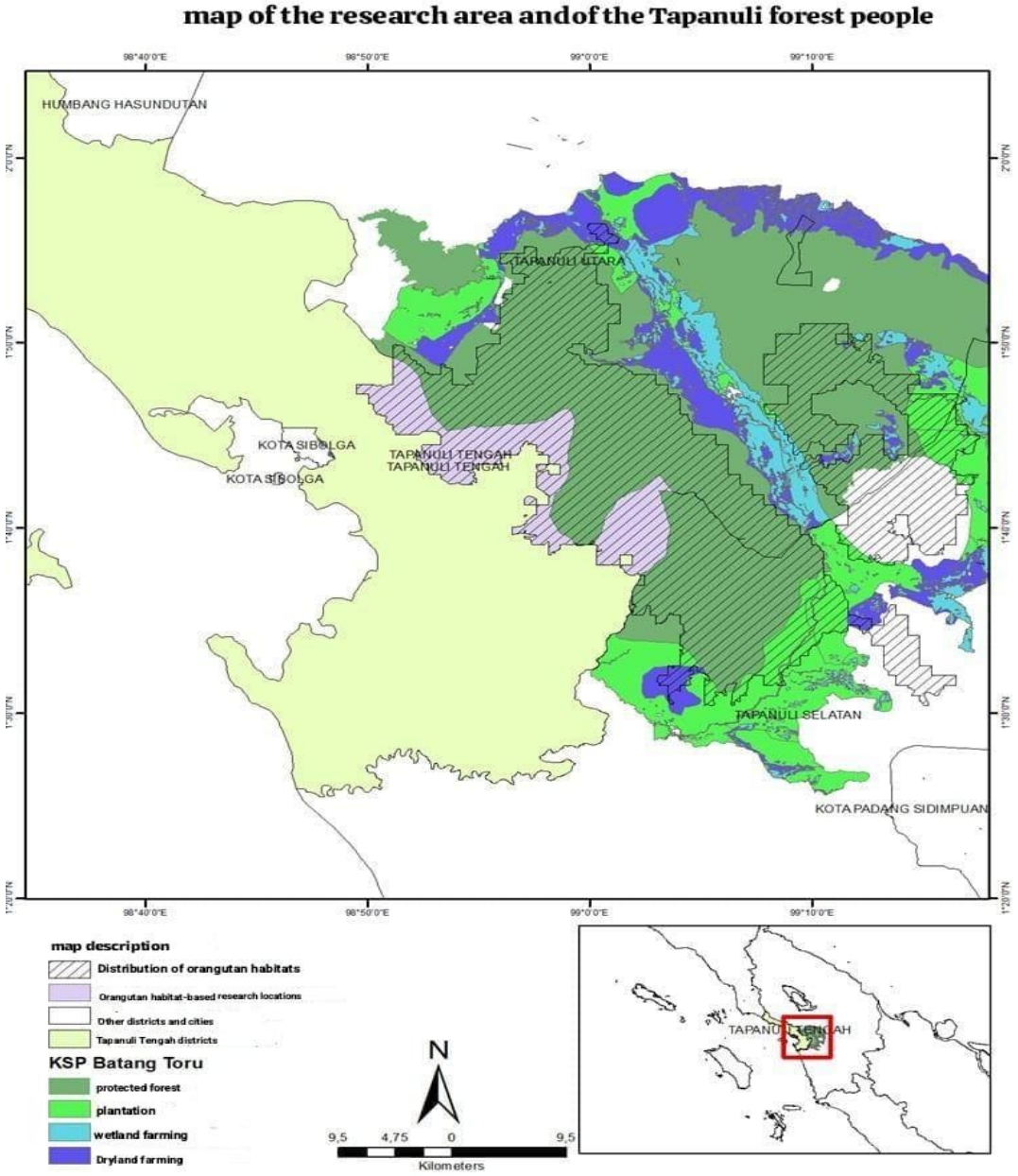

Figure 1. Map of research locations (Research data processing, 2024)

This research design uses a combination of literature study methods, primary data collection by means of field surveys, interviews, analytical observations of land cover changes, and secondary data using satellite imagery. Next, the data collected is processed by creating a dynamic system framework. Next, create scenarios that might occur with and without intervention, after which the scenarios are tested. The framework creation and scenario testing were carried out using Vensim software. In this research, there are two approaches used based on research (Xingqing et al. 2022), namely framework description, disgregation and model formalization. The approach used to determine the sustainability factors of the Tapanuli Orangutan habitat uses the DPSIR model (*Drive force, Pressure, State, Impact, Responses*). The DPSIR conceptual model was first developed by the European Environment Agency (EEA) to assist in describing the relationship between the consequences and causes of environmental problems (Smeets and Weterings, 1999). Through the DPSIR model, there will be a close connection between one event and another in looking at the sustainability of the Tapanuli Orangutan habitat. *The DPSIR model enables an integrated analysis of interconnected events affecting the sustainability of the Tapanuli Orangutan habitat* (Wang and Fu. 2023). DPSIR model analysis was carried out to determine

the causes, impacts, and responses made to the problem of land cover changes that occurred. Considering the importance of data and information regarding changes in land use over ten years, it is very necessary. This research aims to analyze land use changes based on the Driving Force, Pressure, State, Impact, and Response (DPSIR) model.

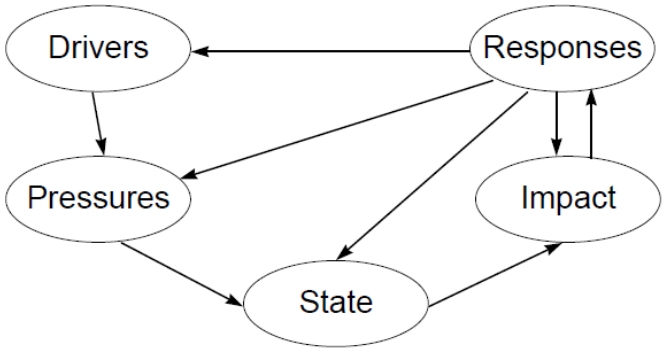

Figure 2. DPSIR Framework (Source: EEA-Smeets and Weterings. 1999)

By using this approach, it is hoped that this research can provide a better understanding of the factors that influence the sustainability of the Tapanuli orangutan and provide guidance for managing and preserving their habitat. The DPSIR (Driving Forces, Pressures, State, Impact, Responses) approach is used to analyze the causal relationship between human activities and the sustainability of the Tapanuli orangutan habitat. The first stage is Driving Forces, which encompasses key factors such as population growth, economic development, or other human activities that drive environmental changes. Next, Pressures emerge as the direct consequences of these driving forces, such as deforestation, pollution, or habitat fragmentation, that threaten the survival of orangutans. These pressures then influence the State, which refers to the condition of ecosystems or the environment experiencing degradation, such as the loss of biodiversity or the decline in the Tapanuli orangutan population. Changes in the state result in Impact, which includes further consequences such as ecosystem damage, the risk of species extinction, or human- wildlife conflicts. To address these impacts, Responses are implemented in the form of actions such as conservation policies, habitat restoration programs, or collaborations between governments and NGOs. Through this approach, the study can provide a comprehensive understanding of the factors affecting the sustainability of the Tapanuli orangutan and offer guidance in managing and preserving its habitat.

3. Disscussion

3.1. Factors and Variables for the Sustainability of the Tapanuli Orangutan and Their Habitat

The sustainability of the Tapanuli orangutan is very dependent on the quality and sustainability of habitat; habitat conversion and forest fragmentation are driving the decline in the Tapanuli orangutan population. (Wich et al. 2022). Factors influencing habitat conversion and forest fragmentation include plantations, illegal logging, and fires (Voigt et al. 2022). Furthermore, around orangutan habitat areas where many humans live, small orangutan populations were found (Wich et al. 2016).

Wang and Fu (2023) stated that the DPSIR conceptual model (*Driving force*) is a socio-economic process, where economic activity will produce pressure (*Pressure*) into the environment and cause changes (*State*) to natural resources, for example, global warming, loss of biodiversity, and forest area, which will have an impact (*Impact*) on ecology and the environment. Next, an assessment will be carried out (*Response*) as a preventive measure in reducing environmental quality, in this case the Tapanuli orangutan habitat. Interrelated factors such as driving: *Driving forces* (D) towards *states* (S)/the result of pressure, then impacts (I) on the ecosystem, carrying capacity, and security for the Tapanuli Orangutan then lead to political and regulatory responses (R).

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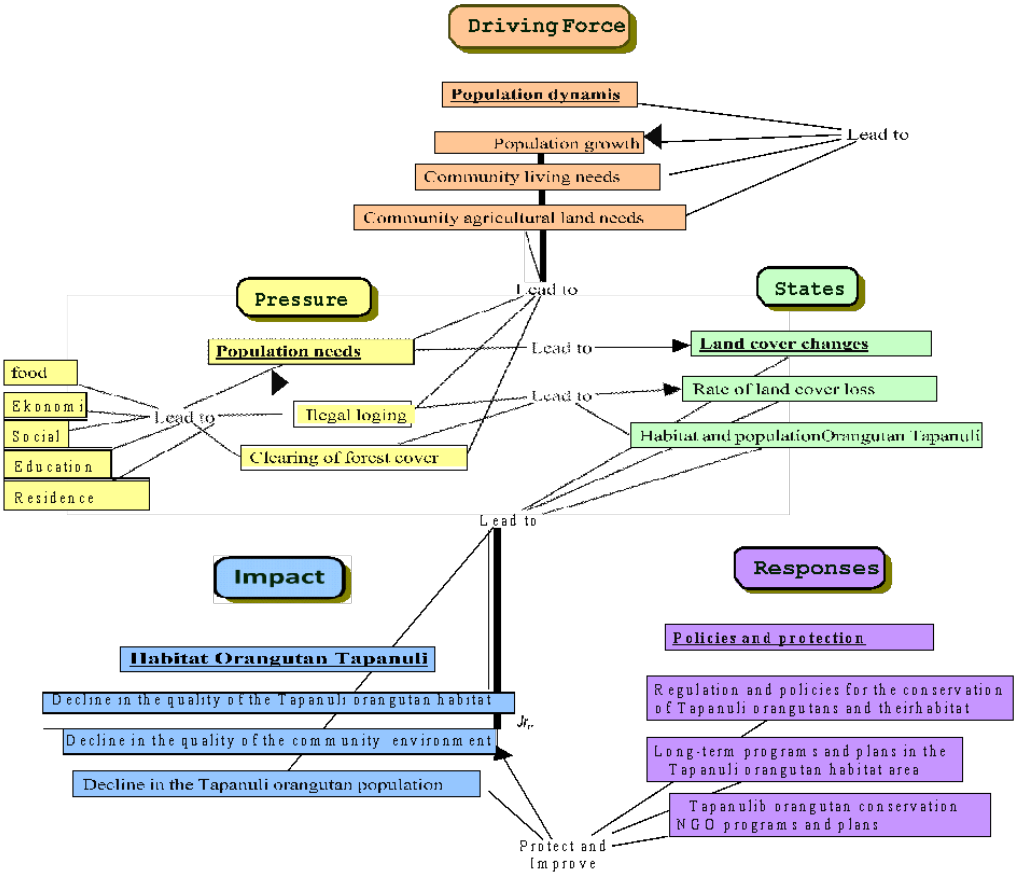

Figure 3. Tapanuli Orangutan Conservation Framework

Tapanuli Orangutan sustainability factors and variables and habitat will be divided into several categories according to the DPSIR conceptual model, namely population dynamics, population needs, land cover changes, Tapanuli Orangutan habitat, and policies and protection. The following is a description of the results as factors and variables of this research.

3.2. Population Dynamics and Population Needs

People living around forests use natural resources to meet their needs. These resources are to meet food, water, land, and economic needs. The land resources needed by society as agricultural land continue to increase along with the increase in population. The increase in population affects the number of changes in forest cover in the forest as habitat for the Tapanuli orangutan. The total population in the research area subdistrict in 2021 is 102,033 people (BPS Central Tapanuli Regency, 2022), who have direct access to forest areas. The community also has a garden adjacent to the Tapanuli orangutan habitat forest area. Population dynamics in six sub-districts bordering the Tapanuli orangutan habitat are an important factor in changes in forest cover. The increase in population is triggering the need for land for agriculture, increasing pressure on the Tapanuli orangutan's habitat.

In 2020 a survey was conducted on the environment and community around the Batang Toru Ecosystem. There are 10 villages in Central Tapanuli Regency bordering the Tapanuli orangutan habitat that were surveyed, namely Tapian Nauli, Sait Kalangan, Lubuk Ampolu, Pagaran Honas, Aek Bontar, Toga Basir, Sialogo, Hutagurgur, Sibio-bio, and Muara Sibuntuon, with the total number of people living there. interviewed 628 people. The average family members per house is 4.57 people per house. The highest age range is 12-18 years; the productive age range is 19-50 years, around 38%. The ratio of men to women is 51.3%: 59.7%. The highest level of education was elementary school at 22.45% and no school at 21.99%. The tribe that occupies the highest is the Nias tribe, almost 80%, and a small part of the Batak tribe. As many as 62.36% of people have land, and some do not have land.

3.3. Population Land Needs

The results of the environmental and community survey (HEPI, 2020) show that people who do not have land will work on other people's land. However, if they don't have additional income, some will clear forests to make way for plantations. Apart from that, there is an opinion that to increase garden yields, they will open up wider gardens so that the results will be even greater. However, it is not followed by the implementation of good agriculture, so it is not optimal. Furthermore, there are several reasons why people enter the forest, namely taking forest products, farming, clearing land, hunting, and cutting wood. Some people state that the forest is not threatened, and some state that it is important to protect the Batang Toru forest. The biggest reason is because it is a source of water and provides plant seeds.

As many as 27% of people said that there was still illegal logging in the Batang Toru forest area. With 26% of people stating that their family had experienced illegal logging. Around 5% stated that their families were still active in illegal logging; the reason was to meet daily needs, medical treatment, and educational costs. Additional value, firstly, 79% of the community thought that the Batang Toru Forest was good, and 91% of the community thought that the Batang Toru Forest had benefits for the public. The highest benefits obtained by the community are clean water sources (50%), fruit sources (10.28%), and seed sources (7.48%). The most abundant agricultural resources are rubber at 71.01% and rice fields at 9.7%. The average income of 39% of people is IDR. 1,501,000 to 2,000,000; 29% is IDR 2,001,000 to 2,500,000; and 12% is IDR 1,001,000 to 1,500,000. The average monthly income of the community is Rp. 989,765.

Data from BPS Central Tapanuli (2022) shows that the area of rubber plantations in 2020 in the sub-district in the Batang Toru forest area was 14,543 ha, comparable to the results of the social survey data above. In 2021, there will be a large decrease in the area of rubber plantations to 9,420 ha. The results of field observations showed that existing rubber plantations in the sub-district were turning into oil palm plantations. According to BPS Central Tapanuli data (2022), in 2020, the area of oil palm plantations in the sub-district in the Batang Toru forest area was 884 ha, but in 2021, there was an increase in the area of oil palm plantations by 5,552 ha. The pattern of changes in plantation commodities will have an impact on changes in land cover and microclimate in the area. In addition, the expansion of oil palm plantations has had an impact on changes in air temperature, flooding, loss of biodiversity, and environmental services (Amalia et al. 2019).

3.4. Land Cover Changes

The conversion of forest areas into plantations and illegal logging are factors in the sustainability of the Tapanuli orangutan's habitat. Habitat loss will greatly affect the sustainability of the Tapanuli orangutan in the future. This research uses the *Global Forest Watch* (GFW) to collect data related to forest cover loss, threat points, and plantation areas. The trend of land cover loss in the research area from 2001 to 2023 can be seen in Figure 9. In the research area from 2001 to 2022, 370 ha of tree cover has been lost (GFW 2023). Field observations confirm that many areas near orangutan habitats have been cleared for crops such as cassava, rice, bananas, and chilies. Furthermore, there has been a significant shift from rubber to oil palm plantations. In 2020, rubber plantations covered 14,543 hectares in the Batang Toru forest area, but by 2021, this had declined to 9,420 hectares. In contrast, oil palm plantations expanded from 884 hectares in 2020 to 5,552 hectares in 2021 (BPS Central Tapanuli, 2022). Such land-use changes contribute to shifts in microclimates, increased air temperatures, biodiversity loss, and heightened flood risks (Amalia et al., 2019).

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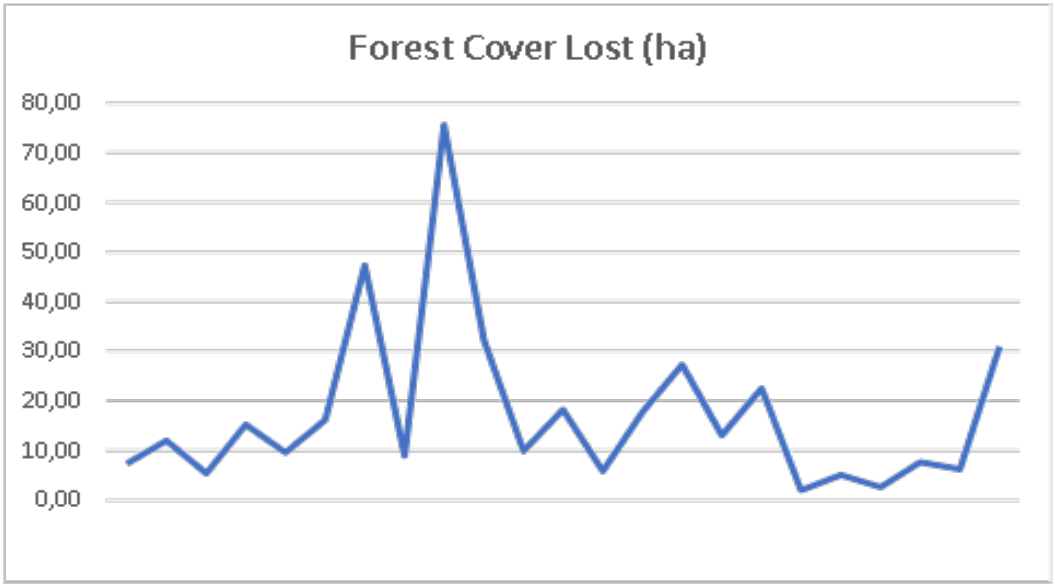

Figure 4. Trend of Land Cover Loss in the Research Area
Data source: Processed GFW Data (2023)

3.5. Habitat Orangutan Tapanuli

The Tapanuli orangutan is only found in the Batang Toru ecosystem. The Tapanuli Orangutan habitat area is 97,811.8 ha (PHVA 2016), while the Tapanuli Orangutan habitat area in Central Tapanuli is 11,787.7 ha. Currently, the orangutan habitat is under a lot of pressure. Based on Global Forest Watch Alert data for the 2023 period, there are 31 deforestation warning points in the study area. This warning point is a sign that there is a possibility of damage to the forest area in the area. There was a forest clearing found in an area close to the Tapanuli orangutan habitat, which can be seen in Figure 5. The clearing point is close to the Tapanuli Orangutan habitat. From the results of the visit to this point, it was found that the forest had been converted into plantations of cassava, land rice, bananas, and chilies

Figure 5. Forest Clearing Around the Tapanuli Orangutan Habitat

3.6. Policies and Protection

The Batang Toru ecosystem is currently of global concern because it is the habitat of the rarest great ape in the world, namely the Tapanuli orangutan. Several policies and regulations have been implemented to protect the Tapanuli orangutan and its habitat. One of the main policies is Law Number 5 of 1990 concerning the Conservation of Biological Natural Resources and Ecosystems, which provides the legal basis for the

protection of biodiversity, including the Tapanuli Orangutan and its habitat. This law regulates the conservation, management, and utilization of biological natural resources with sustainability principles. Apart from that, Government Regulation Number 7 of 1999 concerning the Preservation of Wild Plant and Animal Species also regulates the protection and preservation of wild plant and animal species, including the Tapanuli Orangutan. These regulations limit hunting, maintaining habitat, and enforcing laws against activities that harm wildlife (Prasetyo et al. 2021). Law Number 32 of 2009 concerning Environmental Protection and Management emphasizes the importance of protecting the environment as a whole, including the natural habitat of the Tapanuli Orangutan. Through this law, regulations are made regarding environmental impact assessment, reclamation, and the obligation to maintain environmental sustainability. Furthermore, Minister of Environment and Forestry Regulation Number P.20/MENLHK/Setjen/Kum.1/4/2018 concerning Implementation of Supervision and Law Enforcement in the Environment and Forestry Sector regulates supervision and law enforcement in the environmental sector, including law enforcement against violations related to the protection of the Tapanuli Orangutan and its habitat (KLHK. 2018).

Relevant regional regulations, such as the Central Tapanuli Regency Regional Regulations on Nature and Ecosystem Conservation, also play an important role in local protection. This regulation includes zoning of conservation areas, restrictions on human activities in the Tapanuli Orangutan habitat, and concrete efforts to preserve the environment (Prasetyo et al. 2021). Policy evaluation shows that even though various regulations have been implemented, the protection of the Tapanuli orangutan is still faced with challenges. and shortcomings in its implementation. For example, law enforcement against illegal activities such as felling trees and forest encroachment is often less effective, especially in remote areas.

Research by Prasetyo et al. (2021) found that despite efforts to increase oversight and law enforcement, challenges such as corruption, lack of resources, and resistance from local communities hinder the effectiveness of these policies. The impact of this policy on the Tapanuli orangutan population still needs to be increased through increasing community participation and strengthening law enforcement capacity. The evaluation also shows that habitat protection still faces threats from land conversion for plantations and infrastructure development. Wich et al. (2019) underlined that habitat loss due to human activities is the biggest threat to the sustainability of the Tapanuli orangutan. Existing policies and regulations related to the protection of the Tapanuli orangutan and their habitat include a number of regulations and laws at both national and local levels. Each region usually has regional regulations that regulate nature and ecosystem conservation in its area. These regional regulations can include conservation area zoning, restrictions on human activities in the Tapanuli Orangutan habitat, and concrete efforts to preserve the environment. The implementation of these policies and regulations in the field is very important to protect the Tapanuli orangutan and its habitat from various threats. However, continuous evaluation is needed to ensure that this policy is effective in maintaining ecosystem sustainability and improving conditions that affect the sustainability of this rare species.

3.7. Proposed Recommendations

To effectively address deforestation and promote sustainable forest management, several key recommendations should be implemented**.** First Improved Supervision and Law Enforcement: Intensify supervision of illegal logging activities and enforce stricter laws against violators. Implementation of Forest Restoration Program: Continue and expand forest restoration programs by involving various stakeholders, including government, NGOs, and local communities, public Education and Awareness: Increase education programs and environmental awareness campaigns to local communities regarding the importance of forest conservation, alternative Economic Development: Encourage the development of sustainable alternative economies for local communities to reduce pressure on forest resources and reduce dependence on forest resources. Examples of alternatives include ecotourism, non-timber crop cultivation, and non-timber forest products, multi-stakeholder Cooperation: Encourage collaboration between various parties such as government, local communities, NGOs, the private sector, and academics in forest conservation efforts. And build an effective communication platform to facilitate cooperation and information sharing between stakeholders, strengthening Forest Protection Policy: Strengthen forest protection policies by implementing a science-based and inclusive approach that involves all stakeholders. Ensure that the policies implemented are supported by adequate budgets and competent human resources, sustainable Funding: Seek sustainable funding sources to support forest conservation and restoration programs, including through international funding schemes such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and environmental service payment programs. Develop innovative funding mechanisms such as green bonds and crowdfunding for environmental projects, and Regular Monitoring and Evaluation: Conduct regular monitoring and

evaluation of forest cover conditions and the effectiveness of implemented policies, and adjust strategies according to the findings.

4. Conclusion

The sustainability of Tapanuli orangutans is heavily influenced by habitat quality and the threats posed by land conversion and forest fragmentation. Factors such as plantations, illegal logging, and fires are the primary causes of habitat destruction, exacerbated by the increasing demand for land due to population dynamics in surrounding communities. The Tapanuli orangutan's habitat, concentrated in the Batang Toru ecosystem, continues to face significant pressures, including deforestation and the conversion of forests into oil palm plantations. Research indicates that although national and regional policies exist to protect the Tapanuli orangutan, the implementation of these policies is often hindered by weak law enforcement, corruption, and resistance from local communities. Therefore, protecting the Tapanuli orangutan's habitat requires a more holistic approach, including enhanced monitoring, forest restoration, community education, the development of sustainable alternative livelihoods, and multi-stakeholder collaboration. Continuous evaluation and the strengthening of science-based policies are crucial to ensuring the long-term effectiveness of conservation efforts.

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