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# Strategies for Managing the Habitat of the Tapanuli Orangutan (Pongo tapanuliensis) in Bulu Mario and Aek Batang Paya Villages, South Tapanuli

Hesty Triani[1], Ma'rifatin Zahrah[2], Alief Aththorick[3]

[1,2,3] Universitas Sumatra Utara, Medan, Indonesia.
Email: hestytriani1@gmail.com[1],tiezara64@gmail.com[2], aththorick@gmail.com[3]

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**ABSTRACT**
The Tapanuli orangutan (Pongo tapanuliensis) is a large ape endemic to Sumatra that is critically endangered, with a population of less than 800 individuals. The main pressures on the survival of this species are habitat degradation and increasing negative interactions with local communities around the Batang Toru Ecosystem. This study aims to analyse orangutan habitat management strategies in Bulu Mario and Aek Batang Paya villages, Sipirok sub-district, South Tapanuli regency, which are located in Other Use Areas (APL) and Production Forests. Research tools included cameras, GPS, ArcGIS 10.8, and Expert Choice for AHP data processing. Research materials included 50 cm resolution Pleiades Neo imagery (2023), Indonesian topographic maps, administrative maps, forest area function maps, literature, and questionnaires. Results showed that land cover was dominated by primary forest (43.2%) and secondary forest (40.5%). Thirty-six types of forage vegetation were identified at the tree level (80 individuals/ha) and 33 types at the pole level (239 individuals/ha), while nest trees consisted of 35 types at the tree level (70 individuals/ha) and 30 types at the pole level (243 individuals/ha). The socio-economic conditions of the community are still low, with the majority being farmers, so conflicts often arise due to orangutans eating crops, especially durians. SWOT-AHP analysis resulted in a management strategy that emphasises the development of community agricultural products, reduction of illegal logging, strengthening of multi-stakeholder collaboration, and development of conservation-based ecotourism. The main priority is set on the economic aspect, particularly increasing agricultural yields, as this factor is most decisive for the success of conservation. The implications of this study indicate that Tapanuli orangutan conservation efforts must be integrated with improving the welfare of local communities. Further research is needed to identify leading agricultural commodities and sustainable agroforestry systems, as well as to develop mechanisms for resolving human–animal conflicts, for example, through compensation systems, community-based ecotourism, or payments for environmental services.

**Keywords:** Management Strategy, Habitat, Tapanuli Orangutan, Pongo Tapanuliensis.

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## I. Introduction

Orangutans are the only great apes native to Asia and are fully protected due to their highly vulnerable status and threat of extinction. One of the orangutan species newly identified in 2017 is the Tapanuli orangutan (Pongo tapanuliensis). This species is categorised as critically endangered by the IUCN (2017), with an estimated population of only around 577–760 individuals (KLHK, 2019). The main habitat of Pongo tapanuliensis is the Batang Toru or Harangan Tapanuli Ecosystem, which covers an area of approximately 120,000 hectares and is divided into eastern and western blocks. Around 58.52% of this area is orangutan habitat. Habitat functions as a living space that provides food sources, breeding grounds, and natural protection. The western block is considered to have a greater carrying capacity because it has a buffer area in the form of community land planted with orangutan food sources, as well as a larger area than the eastern block. However, in-depth studies on the habitat conditions of Pongo tapanuliensis are still limited, especially in certain areas of strategic value.

The Batang Toru area currently faces a serious threat of habitat degradation, with an average forest cover loss of 2% per year due to logging activities. This pressure has the potential to increase and accelerate the decline of the orangutan population. In addition, population growth around the area is driving an increasing demand for land. The utilisation of natural resources remains exploitative and anthropocentric, with little attention paid to ecological sustainability. In fact, the primary rainforest in Batang Toru is not only important for the survival of orangutans, but also stores large amounts of carbon biomass that contributes to climate change mitigation. Land status in the Batang Toru ecosystem varies, ranging from protected forest areas, conservation areas, to other use areas (APL). APL has high potential to support orangutan life because it still provides food and nesting trees, but it is also prone to conversion for non-forestry purposes. One important APL area is Sipirok Subdistrict, South Tapanuli Regency, which includes the villages of Bulu Mario and Aek Batang Paya. This area serves as a link between the Sibualbuali Nature Reserve and the western block of the Batang Toru Protected Forest, and has a landscape that is still relatively supportive of orangutan life. Given these threats and potential, a study is needed to analyse habitat conditions, the availability of food vegetation and nesting trees, as well as socio-economic aspects of the community. The results of this study are expected to formulate a sustainable ecology- and socio-economy-based habitat management strategy to support the conservation of Pongo tapanuliensis in South Tapanuli.

## II. Literature Review and Hypothesis Development

### 2.1. Tapanuli Orangutan (Pongo tapanuliensis)

Orangutans are the only great apes native to Asia and are only found in Sumatra and Kalimantan. Taxonomically, there are three species of orangutan: Pongo abelii (Sumatra), Pongo pygmaeus (Kalimantan), and Pongo tapanuliensis (Tapanuli). The species P. tapanuliensis was only recognised in 2017 after analysis of skull morphology, dental structure, and genomic data revealed significant differences from its two relatives (Nater et al., 2017). With a population of fewer than 800 individuals in the wild, this orangutan is the rarest great ape in the world and is classified as critically endangered by the IUCN (2017).

### 2.2. Behaviour and Feeding Ecology

Tapanuli orangutans are arboreal and semi-solitary. They rely on a variety of natural food sources as well as crops cultivated by local communities. Some of the species they frequently utilise include durian (Durio zibethinus), petai (Parkia speciosa), jengkol (Archidendron pauciflorum), and aren (Arenga pinnata). Human-

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animal conflicts often arise, especially during the durian season, as an orangutan can consume 20–30 fruits per day directly from the tree. A case of conflict was recorded in Aek Batang Paya Village in 2019, where 43 farmers were affected by damage to 94 durian trees and 49 petai trees (Kuswanda, 2018; Kuswanda et al., 2021).

### 2.3. Orangutan Nests

Nest building is an important behaviour for orangutans to rest. Sumatran and Tapanuli orangutans usually build 1–2 nests per day on different trees. Nests are classified into five age types (A–E), ranging from new nests with green leaves to nests with only twigs remaining. Variations in nest position were also observed, including on side branches, main branches, between trees, or in the upper canopy (Prasetyo et al., 2021). This information is used as an indicator of daily activity and to estimate population density.

### 2.4. Habitat of the Tapanuli Orangutan

The habitat of P. tapanuliensis is spread across semi-connected forest blocks with different statuses: protected forests, conservation areas, production forests, and other use areas (APL). Its main habitat includes the Batang Toru Protected Forest and three nature reserves, namely Dolok Sipirop, Dolok Sibualbuali, and Lubuk Raya (Prasetyo et al., 2021). The total area of the Batang Toru ecosystem is approximately 120,000 ha, divided into eastern and western blocks. Research shows that Batang Toru has a high diversity of trees, providing food and potential nesting trees, making it an important habitat for orangutans (Nasution et al., 2018; Meijaard et al., 2021). In addition to its ecological value, this area also supports the livelihoods of local communities as a source of clean water, food, and ecosystem support.

### 2.5. Threats to the Habitat

The Batang Toru ecosystem faces serious pressure from deforestation and land use change. Forest cover loss is estimated at an average of 2% per year due to illegal logging. Agricultural expansion, infrastructure development, and uncontrolled agroforestry practices exacerbate habitat conditions. In addition, illegal hunting and wildlife trade add to the risks to small populations. Conflicts with communities over the use of cultivated plants highlight the tension between ecological needs and local economic needs (Kuswanda et al., 2021).

## III. Research Method

This research was conducted from November 2023 to June 2024 in the villages of Bulu Mario and Aek Batang Paya, Sipirok District, South Tapanuli Regency, North Sumatra. The status of the location is 80% Other Use Area (APL) and 20% Production Forest Area (HP) based on the function of Area SK.579. The tools used in this study were a camera, Global Positioning System (GPS), ArcGIS 10.8 software, and Expert Choice software used for AHP data processing. The materials used in this study were 50 cm resolution Pleiades Neo imagery from 2023, Indonesian topographic maps, South Tapanuli Regency administrative maps, SK.579 Forest Area Function maps, literature, and questionnaires as interview materials for respondents.

### 3.1. Land cover conditions of the Tapanuli orangutan (Pongo tapanuliensis) habitat

a. Satellite image analysis.

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Pleiades Neo image data with a resolution of 50 cm recorded on 16 May and 19 June 2023 were used to identify land cover in the study area. Pleiades 1A and Pleiades 1B are twin satellites, each with one camera with one panchromatic band and four multispectral bands. The high-resolution Pleiades sensor produces images in panchromatic mode with a resolution of 70 cm, which are resampled to 50 cm at ground level. In multispectral mode, the camera captures images with a resolution of 2.8 m, which are resampled to 2 m. Combining the two types of products produces colour images with a resolution of 50 cm. The details of the Pleiades sensor bands are as follows: Blue, 0.430 – 0.550 µm, 2 m resolution; Green, 0.500 – 0.620 µm, 2 m resolution; Red, 0.590–0.710 µm, resolution 2 m; NIR IR, 0.740–0.940 µm (middle IR), resolution 2 m; PAN, 0.470–0.820 µm, resolution 50 cm. The creation of land cover classification maps with visual interpretation was carried out based on the recognition of spatial characteristics of objects using interpretation elements, namely colour/hue, shape, size, pattern, shadow, and texture. Visual land cover classification was carried out by delineating each land cover class in a computer layer using ArcGIS 10 software at a scale of 1:50,000. Land cover class detection was carried out by delineating the outer boundaries of groups with the same colour and separating them from others. The next step was to identify and analyse classes using spatial information in accordance with the habitat information requirements of P. tapanulieneis, namely primary forest, secondary forest, and mixed plantations.

b. Vegetation analysis

Vegetation analysis was used to determine whether the research location was generally a habitat that provided food sources and nesting sites for orangutans. Data collection on vegetation and potential food and nesting plant species was carried out through sampling vegetation analysis. Plots were placed purposively in locations where orangutans and nests were frequently found. In this study, this was done using a grid with a transect length of 600 m and a distance of 20 m between plots. Plots measuring 10 x 10 metres were made for poles and 20 x 20 metres for trees. In each pole and tree plot, the plant species and stem diameter of each plant found in each observation area were recorded. The presence of P. tapanulieneis nests was also recorded in each plot, and the number of nests found, their position, and class were identified.

c. Socio-economic conditions of the community

To determine the socio-economic conditions of the community, interviews and direct descriptive observations will be conducted at the research location. Questionnaires will be distributed to the community members of the Bulu Mario and Aek Batang Paya villages in the Sipirok sub-district of South Tapanuli Regency. Respondents were selected using the purposive sampling method, which only included respondents who met the criteria of being members of the community whose livelihood came from land managed using a mixed plantation system. A total of 140 respondents were sampled (76 respondents from Bulu Mario Village and 64 respondents from Aek Batang Paya Village) based on the Slovin formula (Noor, 2012).

$$n = \frac{N}{1 + N\,e^2}$$

Where:

n = Number of samples
N = Population size
e = error rate or critical value (10%)

3.2. Habitat management strategy for the Tapanuli orangutan (Pongo tapanuliensis)

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To analyse the habitat management strategy for P. tapanulieneis Using SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was carried out using the following procedure:

a. Agreement on definitions/perceptions among informants. The sources were from the North Sumatra Natural Resources Conservation Agency (BKSDA), the North Sumatra Provincial Forestry Service, the Padang Sidimpuan Region X Forest Management Unit, the South Tapanuli Regency Environment Agency, the Bulu Mario and Aek Batang Paya Village Administrations, Sipirok Subdistrict, researchers, and conservation institutions managing the area. The criteria for informants to be selected for this study are: knowledge of the depth of information related to the issue being studied, acceptance by various groups in every policy-making process, and knowledge of the issues being studied. In-depth interviews (in-depth interview) were also conducted with the aim of obtaining more detailed information.
b. The information for each SWOT variable was collected using a questionnaire (to inventory various views/opinions on the content of each SWOT aspect).
c. Creating internal and external factors in the Internal Strategic Factors Analysis Summary (IFAS) and External Strategic Factors Analysis Summary (EFAS) matrices.
d. Creating a SWOT diagram by comparing strengths and weaknesses (horizontal lines) with opportunities and threats (vertical lines).

3.3. Priorities for managing the habitat of the Tapanuli orangutan (Pongo tapanuliensis)

The priority of orangutan habitat management (Pongo tapanuliensis) is based on the results of the SWOT analysis. The stages of using the AHP method that will be carried out in this study are as follows:

a. Compiling a hierarchy in the AHP hierarchy structure chart. The AHP structure chart is presented in Figure.
b. Creating a pairwise comparison matrix between criteria
c. Determining the priority weights of the criteria by calculating the eigenvector
d. Measuring logical consistency by testing the Consistency Index (CI) and Ratio Consistency (RC) of the criteria
e. Creating a pairwise comparison matrix and priority weights (eigenvector) between alternatives in relation to criteria, and measuring their logical consistency
f. Establishing global priorities
g. Return to the hierarchical structure diagram and write the calculation results in the boxes for each criterion and alternative.
h. Making a decision

**Table 1. Sample Criteria (N = 256)**

| Measurement | N | % |
|---|---|---|
| Gender | | |
| Man | 128 | 50 |
| Female | 128 | 50 |
| Age (years-old) | | |
| 30 – 35 | 30 | 11.7 |
| 36 – 40 | 112 | 43.8 |

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| Measurement | N | % |
|---|---|---|
| 41 – 45 | 53 | 20.7 |
| > 45 | 61 | 23.8 |
| Academic Grade | | |
| Asisstant Professor | 172 | 67.1 |
| Associate Professor | 82 | 32 |
| Professor | 2 | 0.7 |
| Length of Work (years) | | |
| 3 – 5 | 16 | 6.25 |
| 5 – 8 | 60 | 23.4 |
| > 8 | 180 | 70.3 |

## IV. Results and Discussion

### 4.1. Image Interpretation

Based on the interpretation of the 50 cm resolution Pleiades Neo image, land cover at the study site consists of six classes: primary forest, secondary forest, settlements, mixed plantations, rice fields, and shrubs. The differences in land cover can be seen from the colours and patterns in the images, such as light to dark green vegetation, dark green dense forest, brown settlements, and patterned rice fields. The appearance of land cover objects is shown in Figure 1.

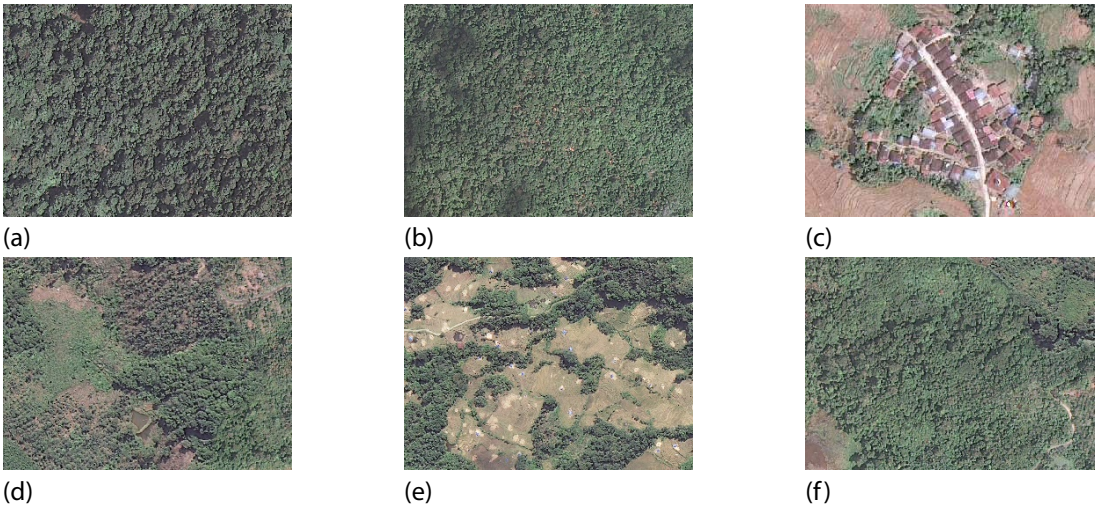


**Figure 1. Examples of land cover types: a) primary forest, b) secondary forest, c) settlements, d) mixed plantations, e) rice fields, and f) scrubland**

### 4.2. Land Cover Classification

The results of land cover classification of Pleiades Neo imagery with a resolution of 50 cm are shown in Figure 2, with primary forest in the west and east, rice fields and settlements in the north, mixed plantations and scrub in the west and south, and secondary forest in the centre.

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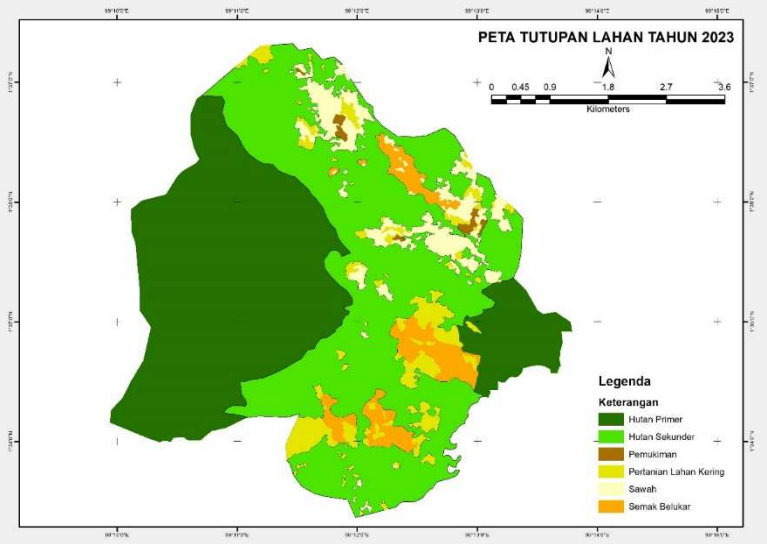


**Figure 2. Land cover classification map for 2023 using Pleiades Neo imagery with a resolution of 50 cm**

The percentage of land cover based on Pleiades Neo imagery is shown in Table 1, with primary forest (43.2%) and secondary forest (40.5%) as the dominant types. Classes other than forest were not analysed because they are not Orangutan habitats.

**Table 1. Results of the 2023 Pleiades image classification**

| No | Land cover type | Area (Ha) | |
|---|---|---|---|
| 1 | Primary forest | 1351.77 | 43.2 |
| 2 | Secondary Forest | 1267.49 | 40.5 |
| 3 | Settlements | 13.72 | 0.4 |
| 4 | Mixed Plantations | 175.25 | 5.6 |
| 5 | Rice fields | 181.49 | 5.8 |
| 6 | Scrubland | 149.8 | 4.5 |
| Total | | 3131.39 | 100 |

Based on Table 1, primary and secondary forests dominate land cover, but this does not necessarily make them the preferred habitat of Tapanuli orangutans due to other factors such as food trees, temperature, and humidity (Schaik et al., 1995). High temperatures and light levels due to dense canopy cover can increase daily temperatures, making orangutans less active (Rushayati & Arief, 1997; Sinaga, 1992).

### 4.3. Vegetation Conditions

Of the 150 observation plots, 60 tree species and 54 understory species were found, and analysed based on land cover type and location.

### 4.4. Primary forest

The vegetation of the primary forest was classified as good with 36 tree species and 39 understory species, but there were differences in composition between the upstream, middle, and downstream areas.

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**Table 2. Primary forest vegetation conditions**

| Primary Forest Location | Number Tree Species | Highest INP Species | H' | E |
|---|---|---|---|---|
| Tree | | | | |
| Upper | 33 | Castanopsis javanica (24.08%) Syzygium elliptilimbum (24.04%) Styrax benzoin (22.33%) | 3.30 | 0.94 |
| Central | 14 | Syzygium elliptilimbum (40.26%) Castanopsis javanica (38.17%) Persea declinata (28.62%) | 2.52 | 0.96 |
| Downstream | 4 | Shorea leprosula (86.00%) Styrax benzoin (84.64%) Macaranga rhizinoides (74.01%) | 1.37 | 0.99 |
| Pole | | | | |
| Upper | 28 | Syzygium elliptilimbum (27.19%) Styrax benzoin (25.65%) Litsea sp.2 (19.81%) | 3.12 | 0.94 |
| Middle | 20 | Syzygium elliptilimbum (44.48%) Macaranga rhizinoides (38.53%) Mallotus paniculatus (31.29%) | 3.04 | 1.02 |
| Downstream | 9 | Styrax benzoin (120.13%) Macaranga rhizinoides (47.45%) Mallotus sp. (28.82%) | 1.86 | 0.85 |

Differences in primary forest area affect the number of vegetation types, with the upstream area (1,000–1,250 m above sea level) being the most diverse compared to the middle and downstream areas. Dominant species in all areas include Castanopsis javanica, Syzygium elliptilimbum, and Styrax benzoin. Diversity in the upstream area is high, while in the middle and downstream areas it is moderate. Tree species evenness is relatively uniform (E 0.85–1.02), supporting the stability of the Tapanuli Orangutan habitat.

4.5. Secondary forest

Secondary forests have 45 tree species and 41 pole species, more than primary forests due to logging. Many pioneer species, such as Macaranga sp., are found, which will be replaced by climax species as natural regeneration occurs.

**Table 3. Vegetation conditions in the secondary forest**

| Secondary Forest Location | Number of Tree Species | Highest INP species | H' | E |
|---|---|---|---|---|
| Tree | | | | |
| Middle 01 | 29 | Syzygium elliptilimbum (37.95%) Liquidambar excelsa (33.04%) Castanopsis javanica (21.62%) | 3.02 | 0.90 |
| Central 02 | 25 | Ficus padana (32.96%) Styrax benzoin (32.16%) Artocarpus sp. (24.48%) | 2.98 | 0.92 |
| Central 03 | 6 | Stryrax benzoin (86.27%) Palaquium rostratum | 1.64 | 0.92 |

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| | | | | |
|---|---|---|---|---|
| | | (70.78%)<br>Persea declinata (55.31%) | | |
| Downstream | 15 | Durio zibethinus (40.02%)<br>Hevea brasiliensis (34.29%)<br>Macaranga lowii (28.70%) | 2.6 | 0.96 |
| Pole | | | | |
| Centre 01 | 17 | Knema mandarahan (26.12%)<br>Syzygium sp.1 (25.73%)<br>Aglaia argentea (24.11%) | 2.78 | 0.98 |
| Central 02 | 29 | Syzygium elliptilimbum (31.94%)<br>Syzygium pauper (29.92%)<br>Macaranga rhizinoides (26.59%) | 3.11 | 0.92 |
| Central 03 | 15 | Mallotus paniculatus (31.42%)<br>Syzygium pauper (28.33%)<br>Syzygium elliptilimbum (27.08%) | 2.61 | 0.96 |
| Downstream | 13 | Hevea brasiliensis (45.26%)<br>Persea declinata (40.77%)<br>Macaranga lowii (32.02%) | 2.44 | 0.95 |

The secondary forests in central areas 01 and 02 have the most tree species, influenced by older succession. The dominant species are Styrax benzoin (tree) and Syzygium elliptilimbum (pole). High diversity is found in central areas 01 and 02, while high species evenness (E close to 1) indicates a uniform plant community without dominant species.

### 4.6. Mixed plantations

The mixed plantation area is dominated by traditional plantations of rubber, cinnamon, and durian, and is not intensively cultivated. Seven tree species and ten shrub species were found.

**Table 4. Results of tree-level vegetation analysis in mixed plantation areas**

| No | Local Name | Species | Family | KR(%) | FR(%) | DR(%) | INP (%) |
|---|---|---|---|---|---|---|---|
| 1 | Frankincense | Styrax benzoin | Styracaceae | 28.00 | 28.00 | 20.40 | 76.40 |
| 2 | Halban | Vitex pinnata | Malvaceae | 16.00 | 16.00 | 33.84 | 65.84 |
| 3 | Sapot | Macaranga rhizinoides | Euphorbiaceae | 24.00 | 24.00 | 14.58 | 62.58 |
| 4 | Tulason | Sweetgum | Altingiaceae | 8.00 | 8.00 | 15.92 | 31.92 |
| 5 | Pirdot | Saurauia pendula | Actinidiaceae | 12.00 | 12.00 | 7.80 | 31.80 |
| 6 | Jengkol | Archidendron pauciflorum | Fabaceae | 8.00 | 8.00 | 5.71 | 21.71 |
| 7 | Spear fig | Macaranga heynei | Euphorbiaceae | 4.00 | 4.00 | 1.74 | 9.74 |

**Table 5. Results of vegetation analysis at the pole level in mixed plantations**

| No | Local Name | Species | Family | KR(%) | FR(%) | DR(%) | INP (%) |
|---|---|---|---|---|---|---|---|
| 1 | Sapot | Macaranga rhizinoides | Euphorbiaceae | 19.05 | 19.05 | 22.53 | 60.63 |
| 2 | Rubber | Hevea brasiliensis | Euphorbiaceae | 19.05 | 19.05 | 16.70 | 54.79 |

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| No | Local Name | Species | Family | KR(%) | FR(%) | DR(%) | INP (%) |
|---|---|---|---|---|---|---|---|
| 3 | Frankincense | Stryrax benzoin | Stryracaceae | 14.29 | 14.29 | 12.22 | 40.79 |
| 4 | Goat randu | Alstonia sp. | Apocynaceae | 9.52 | 9.52 | 9.75 | 28.79 |
| 5 | Spear sapot | Macaranga heynei | Euphorbiaceae | 9.52 | 9.52 | 9.37 | 28.42 |
| 6 | Sitarak | Macaranga lowii | Euphorbiaceae | 9.52 | 9.52 | 5.87 | 24.92 |
| 7 | Jengkol | Archidendron pauciflorum | Fabaceae | 4.76 | 4.76 | 6.32 | 15.85 |
| 8 | Breadfruit | Mangifera sp. | Anacardiaceae | 4.76 | 4.76 | 5.95 | 15.47 |
| 9 | Ubar | Syzygium sp.1 | Myrtaceae | 4.76 | 4.76 | 5.95 | 15.47 |
| 10 | Pirdot | Saurauia pendula | Actinidiaceae | 4.76 | 4.76 | 5.35 | 14.87 |

Mixed plantations are dominated by Styrax benzoin (trees) and Macaranga rhizinoides and Hevea brasiliensis (poles), with moderate diversity (H': trees 1.77; poles 2.17) and high evenness (E > 0.9). Styrax benzoin and Syzygium elliptilimbum are dominant in all areas due to their wide distribution and good adaptation, and play an important role as nesting trees for Tapanuli orangutans.

### 4.7. Tapanuli Orangutan (Pongo tapanuliensis) Food Vegetation

The results of the study show that land cover locations provide a food source for orangutans, with several food plant species identified as shown in Table 6.

**Table 6. Land Cover Locations Provide a Food Source for Orangutans**

| Land Cover Type | Orangutan Food Vegetation | |
|---|---|---|
| | Trees | Pole |
| Primary Forest | 27 | 24 |
| Secondary forest | 28 | 27 |
| Mixed Plantation | 6 | 6 |
| Forage vegetation density (ind./ha) | 80 | 239 |

Based on Table 6, primary and secondary forests have abundant orangutan food vegetation such as Durio zibethinus, Ficus fistulosa, and Syzygium elliptilimbum. Food density reaches 80 trees/ha and 239 poles/ha. This vegetation also serves as a nest and supports forest regeneration, as orangutans help spread seeds through their faeces (Russon, 2010).

### 4.8. Characteristics of Tapanuli Orangutan (Pongo tapanuliensis) Nests

Nesting trees are trees where orangutans build nests, typically 1–2 nests per day. Nest locations are influenced by the feeding season, such as durian. A survey by the Sumatra Rainforest Institute (2023) recorded a nest density of 8.9/km$^2$ and an orangutan population of 0.21 individuals/km$^2$ (approximately 6 individuals in 31.3 km$^2$). This study found 29 nests in 15 tree species (Table 7).

**Table 7. Three species of nests**

| No | Species | Nest findings | Percentage |
|---|---|---|---|
| 1 | Archidendron pauciflorum | 1 | 3.45 |
| 2 | Castanopsis javanica | 1 | 3.45 |
| 3 | Durio zibethinus | 1 | 3.45 |

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| | | | |
|---|---|---|---|
| 4 | Knema mandarahan | 1 | 3.45 |
| 5 | Sweetgum | 1 | 3.45 |
| 6 | Litsea sp.1 | 2 | 6.90 |
| 7 | Macaranga heynei | 1 | 3.45 |
| 8 | Macaranga rhizinoides | 1 | 3.45 |
| 9 | Mallotus paniculatus | 2 | 6.90 |
| 10 | Payena lucida | 1 | 3.45 |
| 11 | Persea declinata | 2 | 6.90 |
| 12 | Saurauia pendula | 1 | 3.45 |
| 13 | Styrax benzoin | 9 | 31.03 |
| 14 | Syzygium elliptilimbum | 4 | 13.79 |
| 15 | Syzygium sp.1 | 1 | 3.45 |
| Total | | 29 | 100 |

Based on Table 7, the most commonly used trees for orangutan nests are Styrax benzoin (31.03%) and Syzygium elliptilimbum (13.79%). Orangutans rarely use food trees as nests, except in open habitats to conserve energy. Styrax benzoin was chosen because its wood is strong and durable, in line with previous studies. Syzygium elliptilimbum is widely used because it is dominant in the location, even though its wood is less strong. The nest age classes are shown in Table 8.

**Table 8. Nest Ege Classes**

| Nest age class | Number of nests | Percentage |
|---|---|---|
| A | 2 | 6.90 |
| B | 3 | 10.34 |
| C | 4 | 13.79 |
| D | 10 | 34.48 |
| E | 10 | 34.48 |
| Total | 29 | 100.00 |

Most nests were found in classes D and E (34.48% each), while new nests (class A) accounted for only 6.90%. The large number of old nests indicates that orangutans have long since left the location, possibly due to food availability and the fruit season. Nest durability varies depending on nest quality, weather, and tree conditions. Orangutan movement is also influenced by the fruit season, so nests tend to be found near food trees. The percentage of nest positions is presented in Table 9.

**Table 9. Percentage Of Nest Positions**

| Nest position | Number of nests | Percentage |
|---|---|---|
| 1 | 8 | 27.59 |
| 2 | 8 | 27.59 |
| 3 | 1 | 3.45 |
| 4 | 12 | 41.38 |
| Total | 29 | 100.00 |

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Most nests were found at the end of branches (41.38%), with nest height influenced by tree height and food plant type. Orangutans tend to choose higher nests for safety from predators, even though the top of the tree is more fragile. Nest height also follows canopy height and food tree availability.

**Table 10. Nest trees of the Tapanuli orangutan (Pongo tapanuliensis)**

| Land Cover Type | Nesting trees | |
|---|---|---|
| | Tree | Pole |
| Primary forest | 24 | 24 |
| Secondary forest | 27 | 24 |
| Mixed Plantation | 5 | 7 |
| Tree density (ind./ha) | 70 | 243 |

Based on Table 10, primary and secondary forests have 24–27 tree species, including Styrax benzoin and Syzygium elliptilimbum, while mixed plantations have far fewer. Tree density reaches 70 trees/ha and 243 poles/ha, indicating high habitat potential for Tapanuli orangutans.

4.9. Socio-economic conditions of the community

The characteristics of the research respondents consisted of 140 people who were members of the communities of Bulu Mario and Aek Batang Batang Paya villages, Sipirok Subdistrict, South Tapanuli Regency. The characteristics of the research respondents, including gender, age, education, ethnicity and religion, are shown in Table 11.

**Table 11. Characteristics of respondents**

| Respondent Characteristics | Category | Village | |
|---|---|---|---|
| | | Bulu Mario | Aek Batang Paya |
| Gender | Male | 62.7 | 84.4% |
| | Female | 28.9 | 15.6 |
| Age | 20-30 | 3.6 | 3.1% |
| | 31-40 | 21.7 | 9.4% |
| | 41-50 | 16.9 | 20.3% |
| | 50–60 | 27.7 | 35.9 |
| | >60 | 21.7% | 31.3 |
| Education | Primary | - | 42.2% |
| | Secondary | 31.3% | 40.6% |
| | Senior High School | 18.1 | 17.2 |
| | D1 | 1.2 | - |
| | D4 | 1.2 | - |
| | Bachelor's Degree | 1.2% | - |
| Ethnic group | Batak | 100 | 100% |
| Religion | Islam | 90.4% | 100% |
| | Christian | 1.2% | - |

The majority of respondents were male, aged 50–60 years old, with a dominant education level of junior high school in Bulu Mario Village and primary-junior high school in Aek Batang Paya. All respondents were Batak ethnic group, with the majority being Muslim. Low education levels influenced community

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behaviour, thus requiring education and training to enhance their role in preserving orangutan habitats. The majority of respondents work as farmers on family-owned land (Table 12).

**Table 12. Livelihood and land ownership**

| Respondent Characteristics | Category | Village | |
|---|---|---|---|
| | | Bulu Mario | Aek Batang Paya |
| Occupation | Farmer<br>Labourer<br>Teacher<br>Private sector employee | 96.1<br>2.6<br>1.3<br>- | 95.3<br>3.1<br>-<br>1.6 |
| Land ownership | <1 Ha<br>1-2 hectares<br>>2 ha | 50.0<br>34.2<br>15.8 | 23.4<br>57.8<br>18.8 |

Based on Table 12, the majority of the communities in Bulu Mario and Aek Batang Paya work as farmers due to low education levels and inherited land. They generally own 1–2 hectares in Bulu Mario and <1 hectare in Aek Batang Paya. Land clearing is carried out gradually, threatening biodiversity as primary and secondary forests are converted into agricultural land. The community has various types of land, predominantly mixed plantations (coffee, cocoa, areca, durian). The main income comes from seasonal commodities, but is often disrupted by orangutans during the harvest season, especially durian, because the plantations are close to the forest (Figure 3).

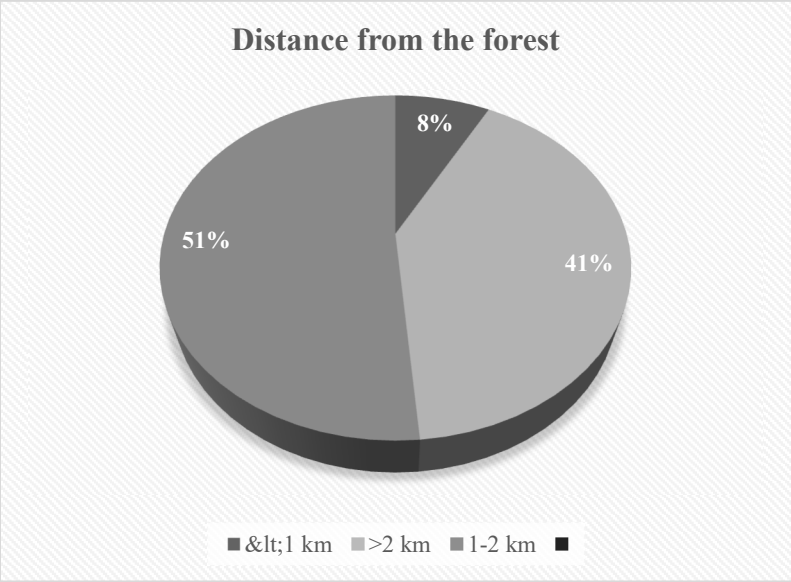


**Figure 3. Distance to forest**

The majority of respondents have land 1–2 km from the forest (47%), with orangutan conflicts often occurring in surrounding villages such as Aek Nabara and Sitandiang. Orangutans often damage durian, petai, coffee and palm sap crops. The community usually drives them away using traditional methods, even though they are aware that orangutans are protected. The proximity of the gardens to the forest is the main cause of conflict.

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4.10. Strategy for Managing the Habitat of the Tapanuli Orangutan (Pongo tapanuliensis).

The Internal Strategic Factor Analysis Summary (IFAS) for the management of the Tapanuli orang utan (Pongo tapanuliensis) habitat in the villages of Bulu Mario and Aek Batang Paya, Sipirok District, South Tapanuli Regency, is presented in Tables 13 and 14.

**Table 13. Internal Strategic Factors Analysis Summary (IFAS)**

| No | Internal Factors (IFAS) | Weight | Rating | Score |
|---|---|---|---|---|
| Strength (S) | | | | |
| 1 | The Tapanuli orangutan (Pongo tapanuliensis) is an endemic wild animal with aesthetic value/appeal. | 0.16 | 4 | 0.6 |
| 2 | Natural potential supporting the habitat of the Tapanuli orangutan (Pongo tapanuliensis) | 0.17 | 4 | 0.68 |
| 3 | The existence of customary institutions that strongly uphold customs related to the harmony of relationships between living beings | 0.14 | 3 | 0.47 |
| 4 | Natural potential for the development of conservation-based ecotourism for the Tapanuli orangutan (Pongo tapanuliensis) | 0.16 | 3 | 0.47 |
| Subtotal | | 0.64 | | 2.22 |
| Weaknesses (W) | | | | |
| 1 | Low community economic status | 0.14 | 3 | 0.47 |
| 2 | The community is ineffective in land management | 0.11 | 2 | 0.22 |
| 3 | Lack of community concern for the safety of Tapanuli orangutans (Pongo tapanuliensis) | 0.11 | 2 | 0.26 |
| Subtotal | | 0.36 | | 0.95 |
| Total | | 1.00 | | 3.17 |

**Table 14. External Strategic Factors Analysis Summary (ElFAS)**

| No | External Factors (EFAS) | Weight | Rating | Score Value |
|---|---|---|---|---|
| Opportunity (O) | | | | |
| 1 | Attracting investor interest for economic development | 0.17 | 3 | 0.59 |
| 2 | Business development to support ecotourism | 0.17 | 3 | 0.56 |
| 3 | Community capacity building | 0.18 | 4 | 0.65 |
| 4 | Proposed regulations for expanding wildlife protection areas | 0.12 | 2 | 0.3 |
| Subtotal | | 0.65 | | 2.10 |
| Threats (T) | | | | |
| 1 | Potential damage to vegetation due to legal and illegal logging activities | 0.12 | 2 | 0.28 |
| 2 | The community considers orangutans to be pests that cause economic losses | 0.13 | 3 | 0.34 |
| 3 | Negative interactions between humans and Tapanuli orangutans (Pongo tapanuliensis) | 0.11 | 2 | 0.22 |
| Subtotal | | 0.35 | | 0.83 |
| Total | | 1.00 | | 2.93 |

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The criterion values for each factor are obtained from:

a. Weight, obtained by dividing the average value of a factor by the total number of factors (IFAS/EFAS).
b. Rating, based on the level of importance of internal and external factors, is given a numerical value from 1 to 4, where 4 = Very good response, 3 = Above-average response, 2 = Average response, and 1 = Below-average response.
c. Score, obtained by multiplying the weight and rating of each factor.
d. The graph's cut-off point is based on the calculation of X and Y values. The X value is obtained from the total strength score minus the total weakness score, while the Y value is obtained from the total opportunity score minus the total threat score.

Based on the above weighting results, a SWOT analysis graph is obtained, which provides information on the appropriate strategic planning to be carried out in the management of the Tapanuli Orangutan (Pongo tapanuliensis) habitat in Bulu Mario and Aek Batang Paya Villages, Sipirok District, South Tapanuli Regency, as presented in Figure 4.

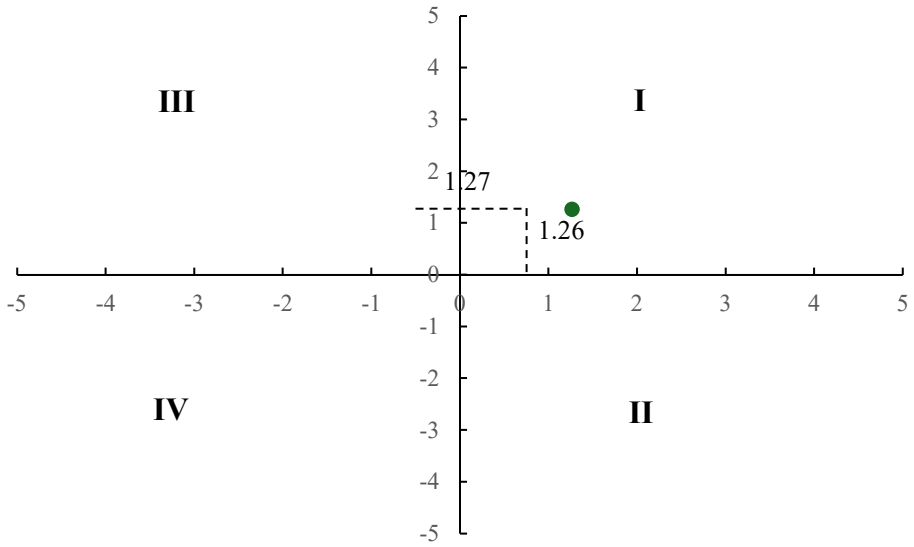


**Figure 4. SWOT analysis graph of orangutan habitat management strategy**

Based on Figure 4, the intersection point is in Quadrant I (1.26; 1.27), indicating a strategic position with dominant strengths and opportunities. The recommended strategy is a progressive strategy, which is to utilise strengths and opportunities to support the management of the Tapanuli orangutan habitat while improving the community's economy. Based on the evaluation of internal and external factors, a SWOT matrix was developed to determine the Tapanuli orangutan habitat management strategy in Bulu Mario and Aek Batang Paya villages. The SWOT analysis identified strengths, weaknesses, opportunities, and threats, as well as future habitat management opportunities. The complete strategy is presented in Table 15.

**Table 15. SWOT Matrix**

| SWOT MATRIX | Internal Factor Evaluation (IFE) | |
|---|---|---|
| | Strengths (S)<br>1. Tapanuli orangutan (Pongo tapanuliensis) is an | Weaknesses (W)<br>1. Low community economic status. |

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| | | | |
|---|---|---|---|
| | | endemic wild animal with aesthetic value/appeal<br>2. Natural potential that supports the habitat of the Tapanuli orangutan (Pongo tapanuliensis)<br>3. The existence of customary institutions that strongly uphold customs related to the harmony of relationships between living creatures<br>4. Natural potential for the development of ecotourism based on the conservation of the Tapanuli orangutan (Pongo tapanuliensis) | 2. The community is ineffective in land management<br>3. Lack of community awareness regarding the safety of Tapanuli orangutans (Pongo tapanuliensis) |
| External Factor Evaluation (EFE) | Opportunities (O)<br><br>1. Attracting investor interest for economic development<br>2. Business development to support ecotourism<br>3. Increasing community capacity<br>4. Proposed regulations for expanding wildlife protection areas | Strategy (SO)<br><br>1. Development of ecotourism<br>2. Strengthening village institutions | Strategy (WO)<br><br>1. Development of community agricultural products<br>2. Undertaking efforts to enhance community capacity through education and training. |
| | Threats (T)<br><br>1. Potential damage to vegetation due to legal and illegal logging activities<br>2. The community considers orangutans to be pests that cause economic losses<br>3. Negative interactions between | Strategies (ST)<br><br>1. Reducing large-scale logging activities.<br>2. Restore vegetation in fragmented habitats.<br>3. Protect wildlife. | Strategy (WT)<br><br>1. Collaborative efforts between government, private sector, and academia to raise awareness about addressing negative interactions between humans and orangutans.<br>2. Conducting outreach on the importance of preserving forests for the sustainability of future generations. |

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| | | | |
|---|---|---|---|
| | humans and Tapanuli orangutans (Pongo tapanuliensis) | | |

4.11. Priority Factors for Tapanuli Orangutan (Pongo tapanuliensis) Habitat Management

The results of the Analytic Hierarchy Process (AHP) data analysis on the priority management of the Tapanuli orangutan (Pongo tapanuliensis) habitat, with the assistance of the Expert Choice software application, are presented in Table 16.

**Table 16. Weights in the criteria structure for priority management of the Tapanuli orangutan (Pongo tapanuliensis) habitat**

| No | Criteria | Criterion Value | Rank |
|---|---|---|---|
| 1 | Economic Aspect | 453 | 1 |
| 2 | Social aspects | 263 | 3 |
| 3 | Ecological aspects | 284 | 2 |

Based on Table 16, the main priority for managing the Tapanuli orangutan habitat is the economic aspect (value 453), followed by the ecological (284) and social (263) aspects. The economic aspect plays an important role in the development of orangutan corridors and strengthening human resources, while the social aspect provides support through community empowerment and dissemination of orangutan protection regulations.

The social aspect is weak due to a lack of supervision by relevant institutions, resulting in suboptimal implementation of laws. As a result, community participation and understanding of Tapanuli orangutan protection remain low. Sub-criteria assessments can be seen in Table 17.

**Table 17. Sub-criteria weights for Tapanuli orangutan (Pongo Tapanuliensis) habitat management priorities**

| No | Sub-criteria | Sub-criterion score | Rank |
|---|---|---|---|
| 1 | Agricultural development | 759 | 1 |
| 2 | Education and training | 572 | 2 |
| 3 | Reducing the rate of deforestation | 494 | 3 |
| 4 | Strengthening village social institutions | 428 | 4 |
| 5 | Revegetation | 289 | 5 |
| 6 | Ecotourism development | 241 | 6 |

The priority for managing the Tapanuli orangutan habitat places agricultural development first (759), followed by education and training (579), and deforestation reduction (494). Animal protection ranks seventh (217). Conflicts often arise because orangutans consume community agricultural products such as durian and petai. Community education and training are considered important to reduce conflicts by understanding orangutan behaviour. To increase agricultural yields while preserving orangutan habitats, agroforestry systems are an ideal solution because they combine economically valuable commodities with environmental conservation. It is necessary to select the right commodities that benefit the community and support habitat sustainability. Efforts to reduce deforestation must be supported by institutional strengthening, regular monitoring, and revegetation. Community-based ecotourism can also be developed as an alternative source

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of income, through orangutan observation, education, and planting of food trees. This development is in line with the integrated economic, ecological, and social strategies presented in Table 18.

**Table 18. Weighting in the alternative structure f priority management of the Tapanuli Orangutan (Pongo Tapanuliensis) habitat**

| No | Alternative | Alternative Value | Rank |
|---|---|---|---|
| 1 | Economic growth | 390 | 1 |
| 2 | Natural resource conservation | 333 | 2 |
| 3 | Harmony | 277 | 3 |

Based on Table 18 above, it can be seen that the alternatives for the Tapanuli orangutan habitat management strategy consist of three priorities. The first priority is economic improvement with an alternative value of 390, the second priority is natural resource conservation with an alternative value of 333, while the third priority is harmony with an alternative value of 277.

### 4.12. Discussion

The results of satellite image classification show that primary forest (43.2%) and secondary forest (40.5%) dominate the land cover in the study area. This dominance indicates the potential availability of core habitat for the Tapanuli orangutan. However, forest area alone does not guarantee habitat suitability; other factors such as the availability of food trees, nesting trees, canopy structure, temperature, and humidity also play a role. These findings are consistent with the literature, which states that the activities of great apes are greatly influenced by microclimate conditions and the distribution of food sources. Vegetation analysis shows that primary forests have high diversity, dominated by Castanopsis javanica, Syzygium elliptilimbum, and Styrax benzoin. Secondary forests are actually richer in species due to natural regeneration after logging, characterised by the abundance of pioneer species such as Macaranga sp. Mixed plantations, although moderately diverse, serve an important function as buffer zones and connecting corridors when managed using orangutan-friendly agroforestry systems. Thus, the landscape mosaic consisting of primary forest, secondary forest, and mixed plantations plays a complementary role in maintaining habitat sustainability.

Orangutan nest preferences reinforce this: Styrax benzoin (31.03%) and Syzygium elliptilimbum (13.79%) are the dominant nesting trees because their branching and wood strength support stability. The majority of nests were found in classes D–E, indicating that orangutan presence is seasonal and correlates with periods of food availability (e.g. durian and petai). The fact that nests are more commonly found in the upper canopy suggests that orangutans use this strategy to avoid predators, although it makes them vulnerable to weather factors. These indications show that secondary forests and mixed plantations continue to serve as functional habitats, especially when food availability is limited. The socio-economic aspects of the community show a direct link to the dynamics of orangutan conflict. The majority of respondents were farmers with mixed plantations located 1–2 km from the forest. This pattern explains the frequent conflicts during the fruit season, especially durian, which is a favourite food of orangutans. The relatively low level of education among the community limits their knowledge of conservation, so that their response tends to be traditional expulsion. This condition has implications for the AHP results, in which economic aspects emerge as the top priority in habitat management strategies, followed by ecological and social aspects. In other words, the success of conservation is largely determined by economic incentives and community empowerment, not solely by ecological regulations.

The SWOT analysis places the research location in Quadrant I, which is a condition with dominant strengths and opportunities. This indicates the need for a progressive strategy that utilises ecological potential

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as well as economic opportunities. The SWOT and AHP matrices emphasise that a realistic strategy includes the development of community agricultural products, education and training, and an emphasis on deforestation. Sub-criteria such as strengthening village institutions, revegetation, and community-based ecotourism reinforce the sustainability of long-term strategies. These priorities are consistent with field data: communities will be more cooperative in conservation if their economic needs are met and conflicts with orangutans are reduced. Theoretically, this study confirms the importance of a "landscape mosaic" approach to orangutan conservation, whereby fragmented habitats can still be utilised if connectivity and food availability are maintained. In practical terms, the research results provide direction for habitat management through (i) non-conflictive agroforestry in mixed plantations, (ii) protection of key food and nesting trees on forest edges, (iii) inter-agency conflict management SOPs, and (iv) community-based ecotourism as an alternative source of income. The resulting policy implications are the integration of orangutan corridors into spatial planning, the provision of incentives for non-conflicting seedlings, a scheme to compensate for crop losses, and collaborative monitoring by the community and government.

The original contribution of this study lies in the integration of four layers of evidence—interpretation of very high-resolution imagery, inventory of food vegetation and nest trees, nest analysis, and socio-economic data—into a strategy prioritisation framework (SWOT → AHP) in the context of Other Use Areas (APL) and the western Batang Toru Production Forest. This comprehensive approach is relatively rare in studies of Tapanuli orangutans. A comparison with the literature shows that while other studies emphasise ecological aspects, this study highlights economic aspects as the most decisive factor, in line with the local reality of forest edges. However, this study has limitations, including the absence of image classification accuracy tests, orangutan population estimates that were not calculated directly, and AHP results that are sensitive to stakeholder perceptions. Nevertheless, the recommendations formulated remain relevant and applicable to support Tapanuli orangutan conservation.

## V. Conclusion

This study shows that land cover in Bulu Mario and Aek Batang Paya villages is dominated by primary forest (43.2%) and secondary forest (40.5%), which are important bases for the survival of Tapanuli orangutans (Pongo tapanuliensis). Vegetation analysis revealed the availability of food trees (80 ind./ha in the tree stratum and 239 ind./ha in the pole stratum) and nest trees (70 ind./ha and 243 ind./ha), confirming the significant carrying capacity of the habitat. The socio-economic conditions of the community remain low with dependence on mixed gardens, so negative interactions with orangutans, especially during the fruit season, often occur. Based on the SWOT–AHP results, the most relevant management strategy is to utilise ecological strengths and economic opportunities to overcome social weaknesses and threats of conflict. The main priority lies in the economic aspect, particularly the development of community agricultural products, which can also reduce conflicts with orangutans. Other supporting strategies include the development of conservation-based ecotourism, the reduction of illegal logging, and the strengthening of multi-stakeholder collaboration in the socialisation of orangutan protection. The main implication of this study is that the conservation of Tapanuli orangutans cannot be separated from the welfare of local communities. Thus, the integration of economic, ecological and social approaches is key to sustainability. Further research needs to explore high-potential agroforestry commodities and mechanisms for resolving human-animal conflicts, for example through compensation systems, payments for environmental services, or community-based ecotourism.

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