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FORUM PETANI KELAPA SAWIT BERKELANJUTAN INDONESIA

PERKUMPULAN MITRA HARAPAN
PMH - KALBAR

STUDY AND IDENTIFICATION OF BIODIVERSITY VALUES IN THE SACRED FORESTS

PERKUMPULAN PETANI MITRA HARAPAN (PPMH) MANISMATA, KETAPANG, WEST KALIMANTAN

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FOREWORD

We give thanks to God Almighty for all His grace and blessings, which have enabled the successful completion of this Study and Identification of Biodiversity Values in the Sacred Forests[1] of the Mitra Harapan Farmers' Association (PPMH) in Manismata, Ketapang, West Kalimantan. This study was conducted to assess the state of biodiversity, habitat quality, ecosystem services, carbon stocks, and High Conservation Value (HCV) areas, and to formulate recommendations for landscape management and restoration in the Brupis, Air Dekakah, and Tamtam Sacred Forests in Manismata Subdistrict, Ketapang Regency, West Kalimantan Province. The results of this study serves as a scientific basis for supporting sustainable landscape management, biodiversity conservation, climate change mitigation, and strengthening of community-based land management.

This study was conducted by the Perkumpulan Petani Mitra Harapan[2] (PPMH) with support from the Forum Petani Kelapa Sawit Berkelanjutan Indonesia[3] (FORTASBI) as a supporting institution that provided institutional training, technical assistance, and research fundings. This collaboration reflects a shared commitment to supporting the sustainable management of smallholder palm oil landscapes through the conservation of the Sacred Forest and the protection of biodiversity.

We express our appreciation and gratitude to FORTASBI for the trust, guidance, and financial support provided, as well as to PPMH Manismata, the owners and managers of the Sacred Forest, the local government, indigenous leaders, the local community, and all parties who have contributed to the implementation of this study. We recognize that this report still has its limitations, hence constructive criticism and suggestions are welcome for future improvements. It is our sincere hope that this report will serve as a useful scientific reference and guide for stakeholders in achieving sustainable landscape management, biodiversity conservation, and improved community well-being.

Bogor, June 29th 2026

Research Team

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[1] Sacred Forests or in Indonesian, "Hutan Larangan", are customary, privately owned forest, most times by Indigenous groups. In this report, both Brupis and Tamtam forest are privately owned, while Air Dekakah is managed by local governments.
[2] the Manismata Mitra Harapan Farmers Association
[3] Indonesian Forum for Sustainable Oil Palm Farmers

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CHAPTER I. INTRODUCTION

1.1 Background

The three PPMH Manismata Sacred Forest areas—Brupis Forest (48 ha), Air Dekakah Forest (20 ha), and Tamtam Forest (23 ha)—are patches of natural ecosystems that plays a significant role in the landscape of smallholder oil palm cultivation in Manismata Subdistrict, Ketapang Regency, West Kalimantan. Although located outside state forest areas and classified as Other Land Use Areas (APL), these three areas serve vital ecological functions as natural habitats, environmental buffers, and providers of ecosystem services for surrounding communities. The presence of these remaining small forests in the midst of palm plantation landscape is crucial as they act as biodiversity protection while maintaining ecological balance at the landscape level.

The Brupis Forest, Air Dekakah Forest, and Tamtam Forest does not only hold ecological value but also social, cultural, and economic value for the community. The Air Dekakah Forest, for instance, functions as a water source protection area that supports the village community's water needs year-round, including during the dry season. Meanwhile, the Brupis Forest is known to harbor rare tree species such as Ipuh (Antiaris toxicaria), which holds significant value in the traditional knowledge of the Dayak people. These conditions indicate that all three areas have the potential to harbor high biodiversity value as well as provide essential ecosystem services for the sustainability of the landscape and the livelihoods of local communities.

Within the context of smallholder oil palm landscapes, the presence of natural forest patches is increasingly important as they serve as wildlife habitats, ecological corridors, protection areas for key species, and supports hydrological functions and microclimates. Unfortunately, amid pressures from land-use changes, plantation expansion, and the growing threat of habitat fragmentation, these three Sacred Forests face the risk of degradation and conversion. This is especially true because these areas lie outside formal forest zones and are not subject to regulatory conservation obligations, meaning their sustainability depends heavily on community commitment and multi-stakeholder support.

FORTASBI, as an organization for sustainable oil palm farmers, has promoted the protection and restoration of areas of conservation value as part of its commitment to sustainability principles, including certification standards such as RSPO and ISPO. The initiative to protect restricted forest areas by PPMH is a concrete example of how smallholder farmers play a role in preserving biodiversity and ecological functions at the site level. As the approach to sustainable landscape management evolves, these practices are also becoming part of the transformation toward the paradigm of Regenerative Agriculture—a production system that does not only focus on increasing yields, but also restoring ecosystem health, improving soil quality, strengthening hydrological functions, preserving biodiversity, increaings carbon stocks, and enhanings the socioeconomic resilience of communities. However, effective conservation efforts requires a strong scientific foundation, including information on flora and fauna composition, habitat structure, biodiversity value, key species, and the ecosystem services provided by these areas.

To date, scientific information regarding the state of biodiversity, habitat quality, the value of ecosystem services, and the level of conservation significance in these three areas has not been systematically documented. The lack of a baseline data poses a challenge in formulating management strategies, monitoring ecosystem changes, and developing targeted restoration interventions. Therefore, a comprehensive study is needed that not only inventories biodiversity but also assesses ecological functions, identifies threats, and generates data-driven management and restoration recommendations.

This study is expected to produce a credible biodiversity baseline to serve as a foundation for area protection, strengthening community-based conservation management, and planning the rehabilitation of open areas within the Manismata PPMH landscape. Additionally, the study's findings are expected to provide a technical basis for supporting collaborative plans with partners such as Cargill in landscape restoration efforts, while also serving as a model for farmer-led conservation that can be replicated in other regions. Thus, this study not only contributes to documenting biodiversity values but also supports a broader agenda related to landscape conservation, the sustainability of smallholder oil palm farming, the implementation of Regenerative Agriculture principles, and the strengthening of farmers' roles in safeguarding natural resources.

1.2 Study Objectives

1.2.1 General Objective

To conduct a comprehensive study of the state of biodiversity, ecological functions, and the value of ecosystem services in the PPMH Manismata Sacred Forest area as a scientific foundation to support effective, data-driven, and sustainable conservation management. This study aims to provide a comprehensive understanding of the composition and condition of biodiversity, habitat quality, the ecological role of the area in maintaining landscape balance, as well as the various ecosystem services it provides, such as water regulation, habitat availability, and ecosystem buffer. In addition, this study aims to identify the area's conservation value and the various threats that could potentially trigger degradation or land-use conversion, thereby enabling the formulation of appropriate recommendations for the management, protection, and restoration of the area. Thus, this study is expected to serve as a strategic foundation for preventing the conversion of forests into oil palm plantations, strengthening farmer-led conservation practices, and supporting sustainable landscape management in the Manismata PPMH area.

1.2.2 Specific Objectives

1. Identifying the composition of flora and fauna species;
2. Assessing vegetation structure and habitat quality;
3. Measuring biodiversity indices and ecosystem services;
4. Identifying important species (protected, endemic, threatened);
5. Developing recommendations for landscape conservation and restoration.

1.3 Study Location

- Brupis Forest
- Air Dekakah Forest
- Tamtam Forest

1.4 Research Framework

Figure 1. Conceptual Framework

The biodiversity study in the PPMH Manismata Sacred Forest was conducted using an integrated approach (*Integrated Biodiversity Assessment*) that combines field ecology, spatial landscape analysis, conservation value assessment, and community participation. This approach is designed to provide a comprehensive understanding of biodiversity conditions, habitat quality, ecological functions, and the role of the Sacred Forest area in supporting the longevity of the smallholder oil palm landscape. The integration of these various approaches allows the study to focus not only on species inventory but also on assessing the relationships between biodiversity, habitat conditions, ecosystem services, and the risks faced by the area.

The field ecology approach is done through surveys of flora, fauna, and habitats to collect primary data on species composition, vegetation structure, natural regeneration, and the presence of key species. This data serves as the basis for calculating biodiversity index, assessing habitat conditions, and identifying species with high conservation value. At the same time, spatial analysis is conducted using GIS technology and remote sensing to understand habitat configuration, fragmentation levels, ecological connectivity, vegetation distribution, and carbon stock distribution at the landscape level. This analysis is important to understand the position and function of the three Sacred Forests within the broader landscape context.

Furthermore, conservation value assessments were conducted by integrating information on key species, high-value habitats, ecosystem services, and threat levels present in each area. This approach aims to determine the ecological significance of the areas and establish priorities for protection and restoration. In addition to biophysical aspects, the study also incorporates local community knowledge through interviews, focus group discussions (FGDs), and documentation of the area's management history. Information from the community serves as a vital data source to complement field survey results, particularly regarding the presence of key species, changes in habitat conditions, and the socio-cultural functions of the Sacred Forests.

All the data received is then analyzed to produce information on biodiversity levels, habitat quality, ecosystem services, carbon stocks, the conservation value of the areas, and potential threats to ecosystem sustainability. The results of this analysis serve as the basis for the development of maps of important habitats, species distribution maps, habitat quality maps, threat maps, and the identification of priority areas for landscape rehabilitation and restoration.

Ultimately, this study is expected to yield management recommendations grounded in scientific data and local knowledge, encompassing strategies for the protection of the area, rehabilitation of degraded habitats, strengthening of community-based conservation, development of a long-term biodiversity monitoring system, and landscape restoration planning that considers biodiversity and carbon aspects. Thus, the Brupis, Air Dekakah, and Tamtam Sacred Forests can continue to function as critical habitats, providers of ecosystem services, and models for sustainable, farmer-led conservation management within the Manismata landscape.

CHAPTER II. OVERVIEW OF THE STUDY AREA

2.1 Location and Accessibility

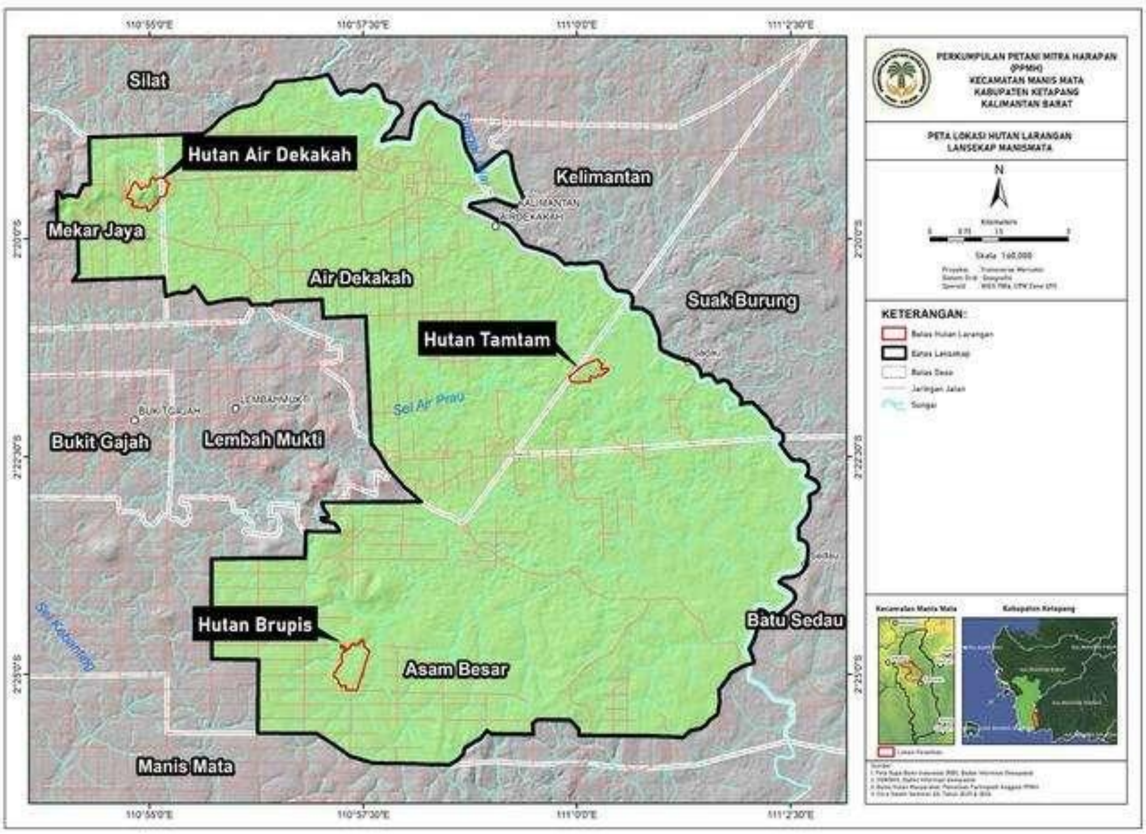

Figure 2. Research Location

The three Sacred Forests that serve as the study sites—Air Dekakah Forest, Tamtam Forest, and Brupis Forest—are located in Manismata Subdistrict, Ketapang Regency, West Kalimantan Province. Access to the sites can be reached via Ketapang City, the regency capital, or via Pangkalan Bun City in Central Kalimantan Province. From Pontianak, the journey to the study sites is typically undertaken by flying to Ketapang, followed by a road trip to Manismata Subdistrict lasting approximately 4–6 hours. A more efficient alternative is via Pangkalan Bun, as it is geographically closer to Manismata Subdistrict, with a road travel time of about 3–4 hours. From the center of Manismata Subdistrict, access to the Air Dekakah Forest, Tamtam Forest, and Brupis Forest continues via village roads, plantation roads, and footpaths, with conditions varying depending on the season. Overall, access via Pangkalan Bun is faster and more economical for field research activities than via Pontianak or Ketapang.

- Air Dekakah Forest (Northern Section)
  It borders directly on or is closest to: Mekar Jaya Village (to the west) and the Air Dekakah area (to the south/southeast). The northern part is also adjacent to the Silat area.
- Tamtam Forest (Central Section)
  Directly borders or is closest to: the Air Dekakah area (to the west/northwest), Kelimantan Village (to the north), and Suak Burung Village (to the east).
- Brupis Forest (Southern Section)
  Directly borders or is closest to: Asam Besar Village (to the east/southeast) and the Manismata area (to the south)

2.2 Biophysical Conditions

- Topography

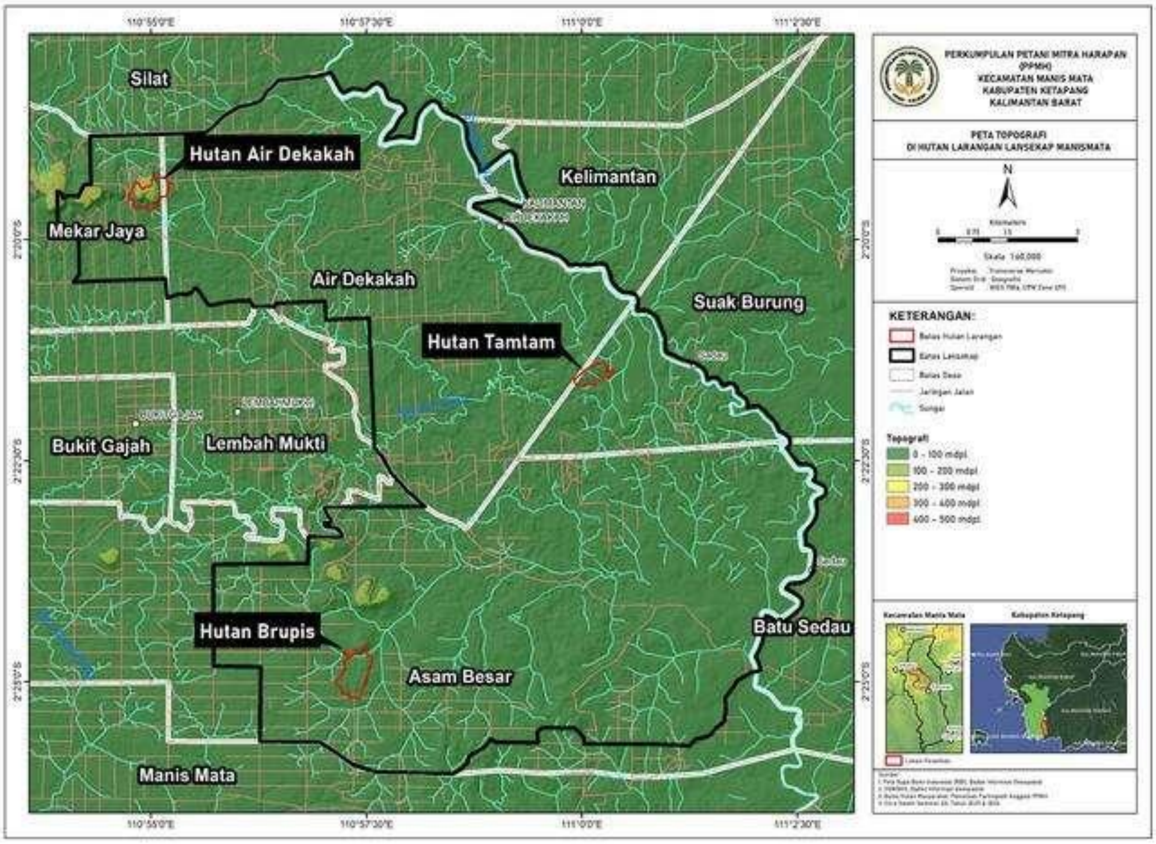

Figure 3. Topographic Map

Based on the topographic map, the three Sacred Forest sites in the Manismata Landscape—namely, the Air Dekakah Forest, the Tamtam Forest, and the Brupis Forest—are generally located in lowland areas with a dominant elevation of 0–100 meters above sea level. However, the Air Dekakah Forest shows greater elevation variation, with some areas falling within the 100–200 m above sea level elevation class, which corresponds to hilly terrain. The relatively flat to gently sloping topography indicates that the study area has low relief with a well-developed river network. These conditions support the area’s ecological function as a water catchment and storage area, as well as fostering the growth of lowland tropical forest vegetation. In general, elevation differences between locations are relatively small, so the biophysical characteristics of the three areas tend to be similar in terms of topography, although the Air Dekakah Forest exhibits greater elevation variation compared to the other two locations.

- Geology and Soil

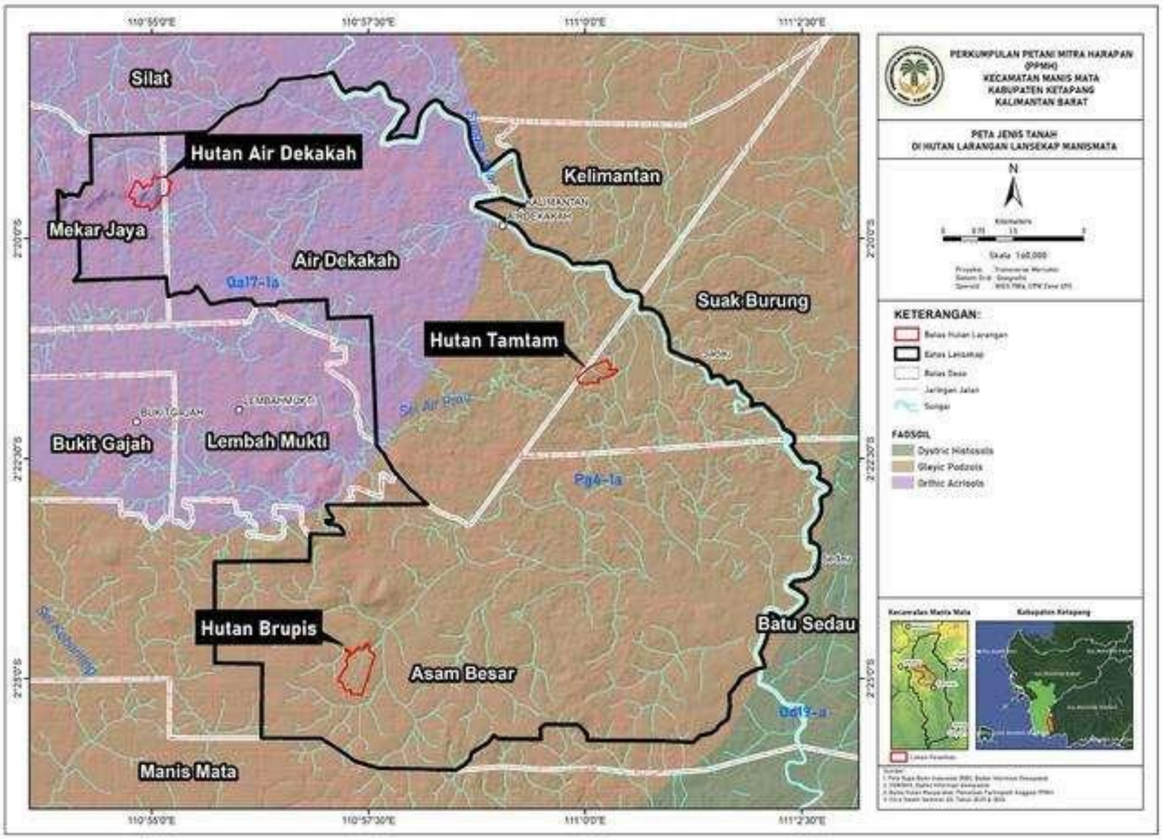

Figure 4. Soil Map

Soil types in the study area are dominated by **Orthic Acrisols (Qa)** and **Gleyic Podzols (Pg)**. Orthic Acrisols are old soils that have undergone advanced weathering; they have high acidity, low base saturation, and relatively low natural fertility due to the intensive leaching of nutrients in the wet tropical environment. Meanwhile, Gleyic Podzols are characterized by highly acidic soil conditions, poor drainage to the point of waterlogging, and a process of podzolization that leads to the accumulation of organic matter, iron, and aluminum in the lower soil horizons. Both soil types generally have limited natural fertility but are still capable of supporting forest vegetation growth as long as land cover and hydrological conditions are maintained. In the context of carbon management, the presence of vegetation on Acrisols and Podzols plays a crucial role in maintaining biomass carbon and soil carbon stocks. Specifically for Gleyic Podzols, soil conditions ranging from moist to water-saturated can increase soil carbon accumulation due to slower decomposition rates; thus, changes in land cover or disturbances to the water regime have the potential to cause significant carbon releases into the atmosphere.

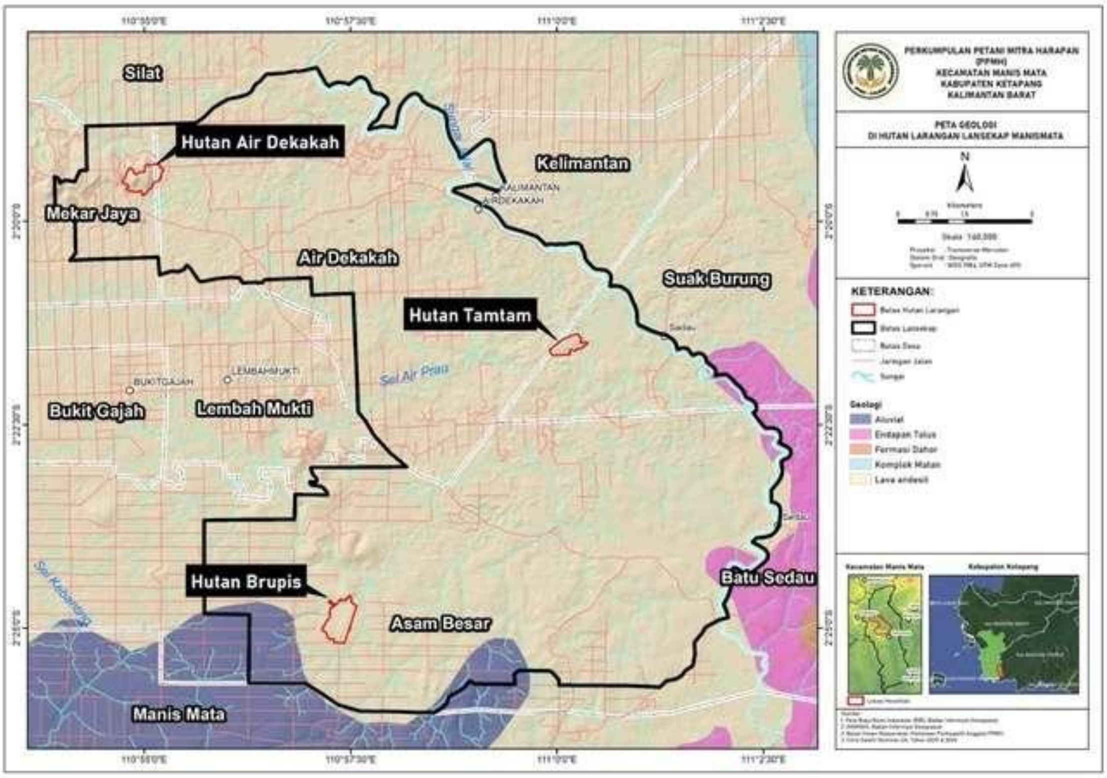

Figure 5. Geological Map

The geology of the study area is dominated by **andesitic lava**, an extrusive volcanic igneous rock formed by the solidification of intermediate-composition magma at the Earth's surface. These rocks generally have a massive to porphyritic texture, with the main mineral constituents being plagioclase, pyroxene, hornblende, and small amounts of quartz. The weathering of andesite rocks produces soils that generally have a medium to fine texture, relatively good mineral content, and a fairly high water-holding capacity compared to more acidic volcanic rocks.

In the context of ecosystem restoration, the presence of andesite parent rock provides conditions that are relatively conducive to vegetation growth. The weathering of andesite can produce soils with moderate to high fertility, thereby providing the nutrients needed for both natural regeneration and planting activities. Additionally, the physical properties of soils formed from andesite generally exhibit good water infiltration and retention capacities, which support root system development and enhance vegetation resilience during periods of drought.

Geological conditions characterized by andesitic lava also play a role in maintaining landscape stability and the area's hydrological functions. In areas still covered by forest, rainwater infiltration occurs more effectively, thereby reducing surface runoff and the risk of erosion. Therefore, restoration efforts in areas with andesitic lava geology have the potential to provide significant ecological benefits, including increasing vegetation cover, improving water management functions, reducing the rate of land degradation, and enhancing carbon storage capacity through the accumulation of biomass and soil organic matter.

- Climate

  Manismata Subdistrict, Ketapang Regency, West Kalimantan Province, has a wet tropical climate influenced by equatorial climate characteristics. Based on climatological data for Ketapang Regency recorded at the Rahadi Oesman Ketapang Meteorological Station, the annual average air temperature ranges from 27.6–27.8°C with relative humidity around 82–83%. Rainfall is relatively high and distributed almost evenly throughout the year, with average monthly rainfall ranging from 220–368 mm and the number of rainy days at about 11–22 days per month. These conditions indicate that the region does not have a distinct dry season and maintains a sufficient water supply year-round.

  The humid climate and high rainfall support the development of lowland tropical rainforest ecosystems, which are the defining feature of the Manismata Landscape. The relatively stable water availability throughout the year plays a crucial role in maintaining the area's hydrological functions, supporting the natural regeneration of vegetation, and enhancing the success of forest restoration efforts. Furthermore, these climatic conditions also support biomass accumulation and carbon storage—both in vegetation and in the soil—thereby making a significant contribution to climate change mitigation.

● Hydrology

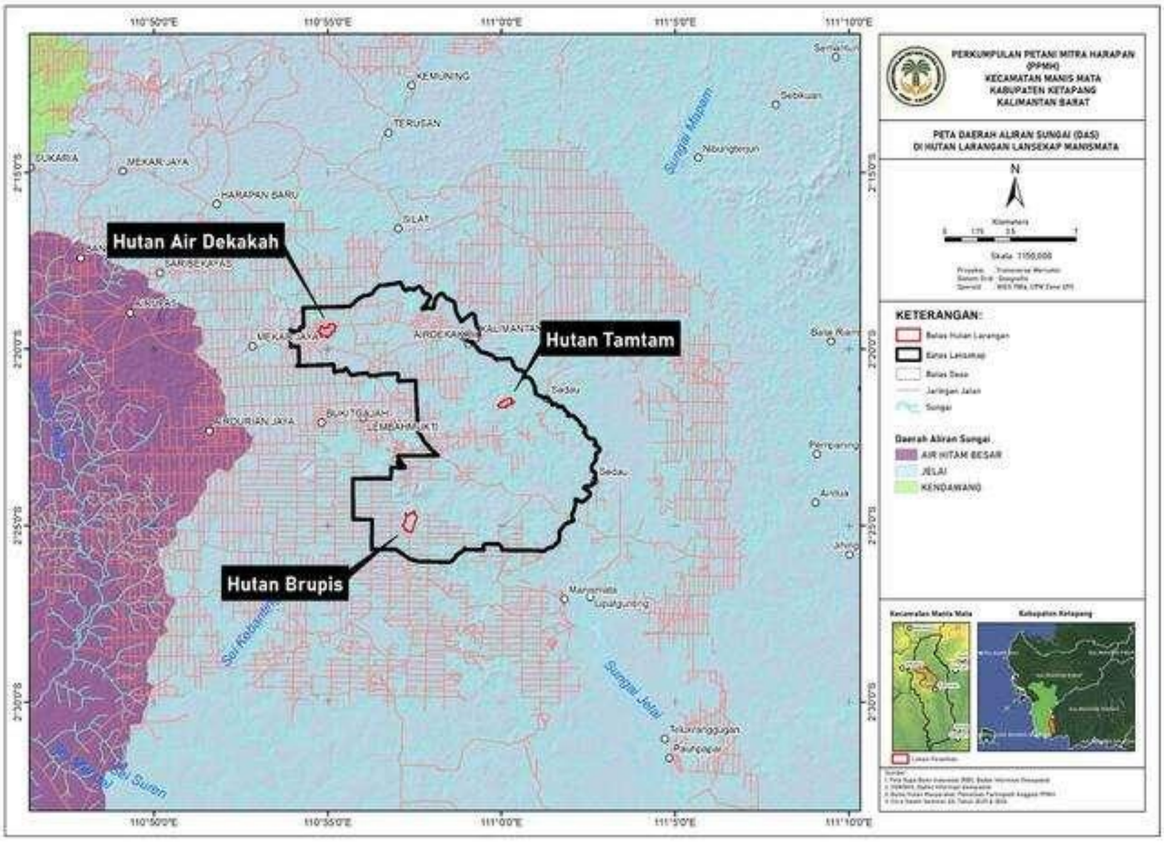

Figure 6. Hydrological Map

The Manismata subdistrict has hydrological conditions influenced by a wet tropical climate, lowland topography, and a well-developed river network within the Jelai–Kendawangan River Basin. Most of the area lies at an elevation of less than 100 meters above sea level, so surface runoff is concentrated toward the main rivers and tributaries, which function as natural drainage systems. High rainfall throughout the year supports the availability of water resources and maintains the area’s function as a water recharge and storage zone. Forest cover in the Manismata landscape plays a crucial role in regulating the water cycle by increasing infiltration, reducing surface runoff, and controlling erosion. Therefore, efforts to protect and restore forests in this area are not only vital for biodiversity and carbon conservation but also for maintaining the stability of hydrological functions and ensuring water availability for communities in downstream areas.

2.3 Landscape Land Cover

In general, the Manismata landscape is dominated by oil palm plantations (50%), but it still retains significant natural vegetation cover in the form of secondary forests, old-growth thickets, and shrubs, which collectively account for approximately 44% of the landscape's total area. The presence of these remaining forest blocks is a crucial component in maintaining habitat connectivity, biodiversity, hydrological functions, and conservation potential within the landscape. The dominance of oil palm plantations indicates a high intensity of land use for economic activities, making sustainable landscape management essential to balance production and conservation functions.

Table 1. Landscape Land Cover Area

NO	TUTUPAN LAHAN	LUAS (HA)	PERSEN (%)
1	Belukar Tua	1,013	8%
2	Hutan Sekunder	2,917	23%
3	Hutan Tanaman	1	0%
4	Kolam/Badan Air	4	0%
5	Perkebunan Sawit	6,469	50%
6	Permukiman dan Tempat Kegiatan	154	1%
7	Rawa	252	2%
8	Semak	1,670	13%
9	Sungai	147	1%
10	Tanah Terbuka	244	2%
	TOTAL	12,871	100%

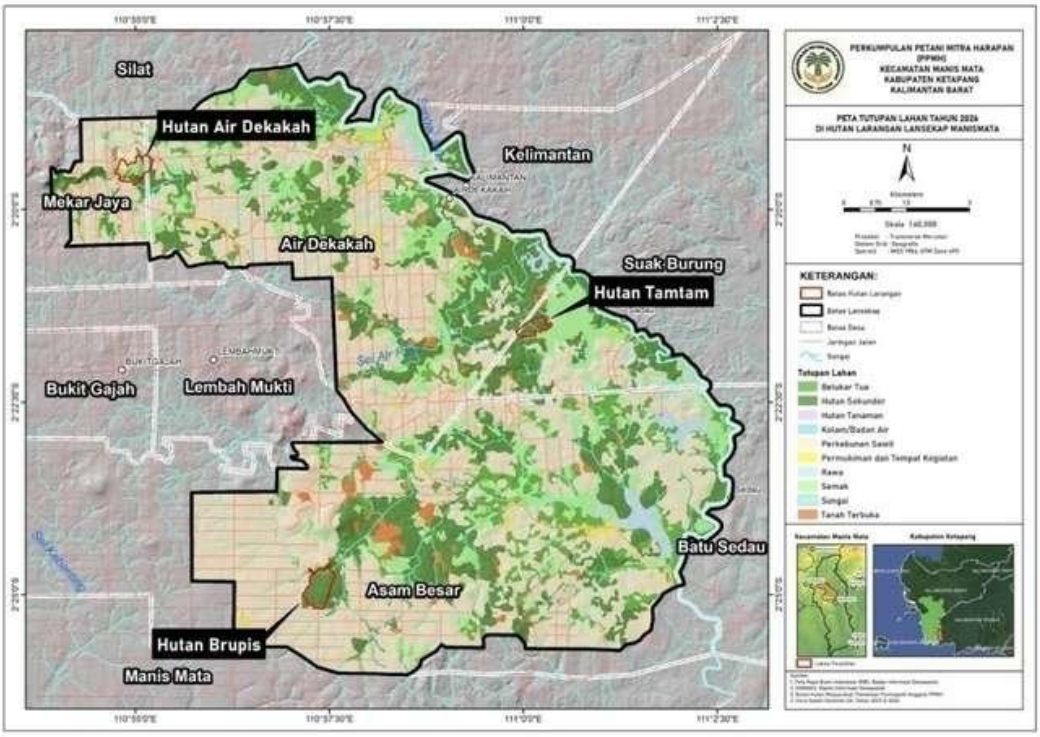

Figure 7. Landscape Land Cover in 2026

2.4 Social Conditions and Area Management

2.4.1 History of the Larangan Forest

- Brupis Sacred Forest

The Brupis Sacred Forest is privately owned by Mr. Samsul. The local community utilizes the forest's resources for the following purposes: gathering medicinal plants that are becoming increasingly difficult to find elsewhere; harvesting materials for industry, such as rubber sap; collecting firewood; enjoying fresh air; and providing a refuge for the remaining birds and other wildlife.

The history of the Brupis Forest dates back to when it was first explored and cleared by my mother's grandparents, who came from the village of Asam Besar. Their purpose in clearing the forest was to farm and hunt wildlife, as the Brupis Forest was home to an abundance of edible animals. In addition, many people from all over came to search for agarwood, as the Brupis Forest is home to many agarwood trees. My grandparents and their family returned to Asam Besar, and the land they had cleared was taken over by their son-in-law (Mr. Samsul and his wife). In 1992, Mamaa passed away, and for many years afterward, my father single-handedly protected the forest from fires and encroachment by irresponsible people who used various methods—such as setting fires or clearing land without permission. After my father passed away, Mr. Samsul's family and his two brothers took over the task of protecting the Brupis Forest.

- Kesepayangan Sacred Forest (Air Dekakah)

The Kesepayangan/Air Dekakah Sacred Forest is owned by the Air Dekakah Village Government, as evidenced by Certificate No. 00016. Within the Kesepayangan forest area, there is a spring that flows year-round. This clean spring water serves as a source of drinking water for the residents of Air Dekakah village.

A brief history of this forest: it has been managed and utilized by the people of Air Dekakah village for generations. The forest is located on a hill where the forest has been well-preserved through generations to this day. The Kesepayangan Forest covers an area of 22 hectares and is home to the best source of clean water in Air Dekakah Village.

- Tamtam Sacred Forest

The Tamtam Hamlet Sacred Forest is a customary forest area located within the Manismata Landscape, Ketapang Regency, West Kalimantan. This area has been owned and managed for generations by Abraham Minsul and his descendants— —who to this day continue to preserve the forest in accordance with the mandate of their ancestors. Its status as a customary Sacred Forest reflects the family's commitment to preserving the area's sustainability based on cultural values, customs, and local wisdom passed down from generation to generation. Through management grounded in the principles of protection and wise utilization, the Tantam Village Sacred Forest serves not only as a source of livelihood for the owner's family but also functions as a conservation area of significant ecological, historical, and cultural value to the surrounding community.

The Tantam Sacred Forest is utilized in a limited and sustainable manner by the owner's family without altering its primary function as a forest area. Some of the benefits derived from this area include:

- Rubber plantations as a source of livelihood for families.
- Durian trees and various types of wild fruits such as mentawa, pekawai, and other local fruits.
- Traditional medicinal plants used for the health needs of the local community.
- Ketatai plants, which are traditionally used as a hunting poison and hold historical significance as a means of defense for the community during the colonial era.

These uses are carried out while maintaining the area's sustainability and without causing forest damage.

The Larangan Forest of Tantam Village is an area of great historical and cultural significance to the landowning family and the local community. This area has existed since the Dutch colonial era and was originally cleared by an ancestral figure named Datok Benyawai.

At that time, Datok Benyawai built a farm hut and settled with his family in the area. In addition to clearing land to meet their basic needs, he also planted various types of fruit trees such as durian, mentawa, pekawai, and other local plants. Over time, the area developed into a forest rich in fruit trees and various wild plants growing naturally.

Before his death, Datok Benyawai instructed his children and grandchildren to preserve this area and pass it on to future generations. His message emphasized that the forest must not be converted into oil palm plantations or used for any other land-use purposes that could harm the area's sustainability.

To this day, this ancestral message is still upheld by his descendants, including Abraham Minsul, the current owner and guardian of the area. The family's commitment to preserving their ancestral legacy ensures that the Tantam Sacred

Forest remains a forest area of significant ecological, economic, cultural, and historical value to the local community.

The Tantam Sacred Forest holds several important values, including:

1. **Ecological Value** – It serves as a habitat for various species of local flora and fauna and helps maintain environmental balance.
2. **Economic Value** – It provides non-timber forest products such as rubber, fruits, and medicinal plants that are utilized sustainably.
3. **Cultural Value** – It is an ancestral heritage preserved from generation to generation based on local customs and traditional knowledge.
4. **Historical Value** – It serves as evidence of the existence of settlements and community activities dating back to the Dutch colonial era.
5. **Educational and Conservation Value** – Serves as an example of community- and family-based conservation practices that have successfully maintained forest cover amid the expansion of oil palm plantations in the Manismata Landscape.

2.4.2 Profile of PPMH Manismata

The Perkumpulan Petani Mitra Harapan (PPMH) is an independent oil palm farmers' organization comprising farmers from Ketapang Regency, West Kalimantan Province. This organization serves as a platform for farmers to strengthen their institutional capacity, enhance human resource capabilities, and promote the adoption of sustainable oil palm plantation practices. PPMH currently represents 698 farmers, organized into 5 member groups, managing a total of 3,303.02 hectares of land spread across several subdistricts in Ketapang Regency.

PPMH was established and legally incorporated through Notarial Deed No. 5 dated July 18, 2023, and has been a member of the Roundtable on Sustainable Palm Oil (RSPO) since January 31, 2023, with membership number 1-0433-23-000-00. In the same year, PPMH successfully obtained RSPO certification, demonstrating the organization's commitment to managing oil palm plantations in a manner that sustainably addresses environmental, social, and economic aspects.

Vision

To empower palm oil smallholders to become independent, prosperous, and sustainable in managing their plantations.

Mission

1. To strengthen the capacity and resources of oil palm farmers through education and training in plantation management.

2. To build strong farmer institutions to ensure access to production inputs, financing, and markets.
3. Promoting sustainable oil palm management through governance that is fair, transparent, accountable, and farmer-centered.

Commitment to Environmental Sustainability

In addition to focusing on improving farmers' productivity and well-being, PPMH is also active in conservation and environmental protection efforts. The organization has developed various initiatives for reforestation, the rehabilitation of degraded areas, and the protection of High Conservation Value (HCV) areas. One such effort is the establishment and management of the Sacred Forest conservation area in the Manismata and Air Upas regions, serving as a habitat for wildlife and an ecosystem buffer zone. The total area of the managed conservation area spans approximately 100 hectares.

In 2024, PPMH received the RSPO Premium for the sale of RSPO-certified Fresh Fruit Bunches (FFB) through the physical trade scheme. This achievement serves as evidence of the success of independent smallholder farmers in applying sustainability principles while simultaneously improving the well-being of their members.

Role in the Manismata Landscape

In the Manismata Landscape, PPMH serves as a farmers' organization that not only promotes sustainable oil palm farming practices but also acts as a initiator for community-based conservation. Through the management of Sacred Forests, reforestation activities, wildlife habitat protection, and the strengthening of farmers' institutions, PPMH strives to create a balance between community economic development and the conservation of natural resources. This organization serves as an example of how independent oil palm farmers can contribute to climate change mitigation, deforestation prevention, and sustainable landscape management in Ketapang Regency.

Table 2. Perkumpulan Petani Mitra Harapan (PPMH) Organization

Uraian		Keterangan
Nama Organisasi	:	Perkumpulan Petani Mitra Harapan (PPMH)
Lokasi	:	Kecamatan Manis Mata dan sekitarnya, Kabupaten Ketapang, Kalimantan Barat
Tahun Berdiri	:	2021 (kelembagaan disahkan tahun 2023)
Jumlah Anggota	:	698 petani
Jumlah Kelompok	:	5 kelompok anggota
Luas Kelola	:	3.303,02 ha
Sertifikasi	:	RSPO (2023)
Kemitraan	:	Cargill dan anggota FORTASBI
Fokus Program	:	Sawit berkelanjutan, penguatan petani, konservasi hutan, penghijauan, perlindungan satwa liar
Kawasan Konservasi	:	±100 ha Hutan Larangan dan kawasan bernilai konservasi tinggi (HCV)

2.4.3 Community Management System

The management of the Manismata Sacred Forest Landscape is carried out collaboratively by the local community through local institutions facilitated by the Perkumpulan Petani Mitra Harapan (PPMH). This management system integrates traditional values, local wisdom, and the principles of sustainable natural resource management to preserve the Sacred Forest as an area that serves ecological, social, and economic functions for the community.

In practice, the community has established an organizational structure tasked with coordinating area protection activities, field assistance, internal oversight, membership management, as well as safety and emergency response. Through this system, the community plays an active role in patrolling the area, monitoring forest conditions, resolving land-use conflicts, and disseminating management regulations to members and the surrounding community.

The management of Sacred Forests is also supported by customary rules that restrict land clearing, tree cutting, and the use of certain natural resources in the area. These rules aim to preserve hydrological functions, protect biodiversity, and sustain the natural resources that support the community’s livelihood. In addition, communities have also developed various more sustainable economic activities, such as managing community gardens and strengthening independent farmers’ organizations, as efforts to reduce pressure on forest areas.

Nevertheless, the community management system still faces various challenges, including the increasing expansion of oil palm plantations, changes in land ownership, and a declining interest among the younger generation in community-based forest management. Therefore, strengthening local institutions, building community capacity, and developing conservation-based economic incentives are critical factors in supporting the sustainability of the Larangan Manismata Forest Landscape management.

2.4.4 Socioeconomic Dynamics and Landscape Management Challenges

The socioeconomic conditions of communities in the Larangan Manismata Forest Landscape have undergone significant changes in recent decades alongside the expansion of oil palm plantations. Most of the land currently managed as oil palm plantations has shifted from local communities to migrants or external parties. This shift in land tenure has driven the expansion of plantations and the clearing of forested areas, ultimately contributing to a reduction in natural forest cover within the landscape.

Although the plantation sector contributes to the region's economic activity, the benefits reaped by local communities have not fully matched the changes that have occurred. In many cases, local communities serve only as laborers or have limited involvement in the plantation's economic chain. This situation has the potential to widen the social and economic gap between local communities and outsiders, who have greater access to land resources and business capital.

In addition to pressures from land-use changes, the sustainability of biodiversity in the Larangan Manismata Forest Landscape also faces challenges from wildlife hunting activities still practiced by some members of the community. Hunting practices—whether for consumption or other purposes—have the potential to deplete wildlife populations and disrupt ecosystem balance. Therefore, conservation efforts in this landscape must integrate habitat protection with the economic empowerment of local communities, the development of sustainable livelihoods, and increased awareness of the importance of wildlife conservation and the ecological functions of the Sacred Forest as part of the local community's natural and cultural heritage.

2.5 Context of the Smallholder Oil Palm Landscape

The Brupis (48 ha), Air Dekakah (20 ha), and Tamtam (23 ha) Sacred Forests are located within a landscape dominated by smallholder oil palm plantations operated by members of the Manismata PPMH in Manismata Subdistrict, Ketapang Regency. This landscape is a mosaic of land uses consisting of oil palm plantations, settlements, road networks, water bodies, and remnants of natural forest scattered in the form of habitat patches.

Amid the dominance of cultivated areas, these three Sacred Forests play a vital role as biodiversity habitats, ecological corridors, and environmental buffers. These areas serve as refuges for various species of flora and fauna, while also supporting ecological functions such as water source protection, water regulation, erosion control, carbon sequestration, and microclimate regulation.

The presence of natural forest patches within the smallholder oil palm landscape also supports the implementation of sustainable plantation principles aligned with RSPO and ISPO standards. However, these areas face various pressures—such as habitat fragmentation, land-use conversion, human disturbance, and declining habitat quality—that threaten the sustainability of their ecological functions.

Therefore, the PPMH Manismata Sacred Forest holds strategic value as a community-based conservation area that contributes to the preservation of biodiversity, ecosystem services, and the sustainability of smallholder oil palm landscapes in the Manismata region.

CHAPTER III. METHODOLOGY

3.1 Study Approach

The biodiversity study of the Manismata PPMH Sacred Forest was conducted using an integrated approach that combines field ecology, spatial landscape analysis, conservation value assessment, and a participatory community approach. This approach aims to gain a comprehensive understanding of the state of biodiversity, ecological functions, conservation values, and the potential for sustainable landscape management and restoration.

1. Field Ecology Approach

   The field ecology approach was carried out through inventory and primary data collection to identify the state of biodiversity within the Sacred Forest area. Activities included field surveys, direct observations, and sampling at the study sites. The data collected encompassed flora and fauna composition, vegetation structure, habitat conditions, and indications of the presence of keystone species and protected species. In addition, field documentation methods, wildlife track monitoring, and the installation of camera traps were used to support the identification of faunal diversity. The results of this approach were used to describe the actual ecological conditions and the level of biodiversity in the study area.

2. Spatial Landscape Approach

   The spatial approach was conducted using Geographic Information Systems (GIS) and remote sensing to analyze landscape characteristics at the regional level. The analysis includes the identification of land cover, habitat configuration, the level of forest fragmentation, ecological connectivity, and the distribution of areas of significant ecological value. Additionally, vegetation cover analysis and estimates of potential carbon stocks are conducted based on available spatial data. The results of the analysis are used to identify priority habitats, ecological corridors, and areas requiring rehabilitation or restoration.

3. Conservation Value Approach

   The conservation value approach aims to assess the importance of an area in terms of biodiversity, ecosystem functions, and ecosystem services. The assessment is conducted by identifying key species, habitats of high conservation value, water source buffer zones, and areas that play a critical role in carbon sequestration and climate change mitigation. In addition, threats and pressures on ecosystems—such as land conversion, wildlife poaching, wildfires, and habitat fragmentation—are identified. The results of the assessment are used to determine priorities for the protection, management, and restoration of the area.

4. Participatory Approach

A participatory approach was utilized to integrate local knowledge and community experiences into the assessment process. Data collection was conducted through semi-structured interviews, focus group discussions (FGDs), participatory mapping, and consultations with community leaders and area managers. The information gathered includes the history of Sacred Forest management, the use of natural resources, the presence of species considered important by the community, and community perceptions of the area's conditions and threats. This approach aims to ensure that the study's results are not only based on scientific data but also take into account the social, cultural, and institutional aspects that influence the sustainability of the area's management.

5. Integration of Study Results

The results of these four approaches were then integrated to produce biodiversity-based landscape management and restoration recommendations. The integration of ecological, spatial, conservation, and social data was used to determine priority protection areas, habitat corridors, rehabilitation sites, species conservation strategies, and opportunities for developing sustainable management schemes that support biodiversity conservation and improve community well-being.

3.2 Secondary Data Collection

Secondary data used in the preparatory phase included relevant biophysical, spatial, and biodiversity reference data, such as:

A. Spatial Data and Base Maps

- Maps of study area boundaries (3 Sacred Forests)
- Village administrative and territorial boundary maps
- Topographic and contour/elevation maps
- Maps of river networks, hydrology, and springs
- Slope maps
- Soil type and geology map
- Current and historical land cover maps
- Medium and high-resolution satellite imagery for interpreting existing conditions
- Land use maps of the area surrounding the study area

- Accessibility and road network maps

B. Spatial Planning Data and Area Status

- Map of forest areas and land-use categories (if adjacent or nearby)
- Map of Other Land Use Areas (APL)
- RTRW/RDTR maps and land-use designations for the study area
- Indicative map of high conservation value areas (if available)
- Data on permits or land tenure status (if relevant)
- Information on community-based rehabilitation areas or local protected areas

C. Geophysical and Landscape Ecology Data

- Climate data (rainfall, temperature, seasons)
- Biophysical data and habitat characteristics
- Information on landscape fragmentation and connectivity
- Data on riparian conditions and water sources
- Available information on environmental pressures/threats
- Other geophysical data relevant to ecosystem characterization

D. Biodiversity Data and Conservation References

- List of potential flora and fauna in the study area
- Data on the distribution of key species (if available)
- Information on species conservation status based on:
- IUCN Red List
- CITES Appendices
- Species Protection Regulations (Ministry of Environment and Forestry/Ministry of Environment and Forestry Decree)
- Previous literature/studies related to the biodiversity of West Kalimantan or similar landscapes
- Local community knowledge regarding important species and the ecological functions of the area

3.3 Vegetation (Flora) Survey

A flora vegetation survey was conducted to identify plant species composition, vegetation structure, regeneration levels, and vegetation habitat characteristics at the three study sites. This survey aimed to obtain baseline data on the condition of plant communities and their ecological roles as habitat components, while also serving as a basis for analyzing biodiversity and ecosystem quality. The approach used was a vegetation inventory employing a line transect system, with each transect measuring 1,000 m in length. A total of 10 plots ( ) were sampled, each measuring 20 m × 20 m and spaced 100 meters apart (Figure 8).

Vegetation analysis was conducted using a combination of:

Method:

- Vegetation transect (*line transect*)
- Plot sampling
- Field observations and plant species identification
- Documentation of species and vegetation habitat conditions

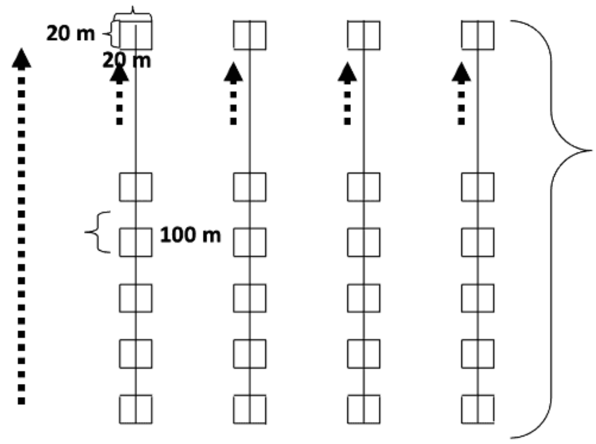

Figure 8. Vegetation Survey Transect and Plot Design

Observed Parameters

The vegetation parameters measured include:

- Species composition
- Density
- Frequency
- Dominance
- Diameter at breast height (DBH)
- Tree height
- Canopy cover (if relevant)
- Vegetation regeneration:
    - Seedling
    - Sapling
    - Pole
    - Tree

Based on field measurements and data collection, the species importance value (NPJ) is used to analyze differences in species composition among various forests. To determine the NPJ, Cottam & Curtis (1956) described and compared tree taxa (family, genus, species) across different plot configurations and various research sites. The species importance value (NPJ) is calculated as by summing the relative density (Kr), relative dominance (Dr), and relative frequency (Fr) (NPJ

= Kr + Dr + Fr), where the parameters supporting the calculation must be known to obtain the NPJ value.

Plot Size (Indicative)

The stratified sample plot design used indicatively is as follows:

Vegetation Level	Plot Size
Trees	20 m x 20 m
Poles	10 m x 10 m
Stakes	5 m x 5 m
Seedling	2 m x 2 m

Illustration of Plot Design

```
+------------------------------------------------+
|                20 x 20 m                       |
|               Plot Pohon                      |
|                                                |
|        +-------------------------+             |
|        |       10 x 10 m         |             |
|        |       Plot Tiang        |             |
|        |                         |             |
|        |   +---------------+     |             |
|        |   |    5 x 5 m    |     |             |
|        |   | Plot Pancang  |     |             |
|        |   |   +--------+  |     |             |
|        |   |   |2 x 2 m |  |     |             |
|        |   |   | Semai  |  |     |             |
|        |   |   +--------+  |     |             |
|        |   +---------------+     |             |
|        +-------------------------+             |
+------------------------------------------------+
```

Figure 9. Vegetation Survey Plot Design

The inventory data was analyzed to generate information regarding:

- Importance Value Index (INP)
  To determine the dominance and ecological role of each species.
- Species Richness
  Describes the number of species found.
- Stand Structure
  Based on the distribution of diameter, height, and growth classes.
- Vegetation Stratification
  To examine the vertical structure of the stand (lower, middle, and upper canopy layers).
- Regeneration Analysis
  To assess the condition of natural recovery and the sustainability of plant communities.

The results of this vegetation analysis will provide information on flora composition, dominant species, habitat conditions, and ecosystem integrity—

which serve as the basis for assessing biodiversity value and making conservation management recommendations.

3.4 Wildlife (Fauna) Survey

Observations of the presence and diversity of mammal species in the study areas—specifically in the three Sacred Forest zones—were conducted along pre-planned transects and at other locations where information on mammal presence was expected to be obtained. Mammals are generally more difficult to observe than birds, and there are many different methods for observing and studying them. The best approach depends on the mammal species and its preferred habitat; most mammal species are found in lowland rainforests, while fewer species are found in kerangas forests or swamp forests. Many mammal species are able to adapt to changes in habitat (generalist species) and are often easily spotted in secondary forests or even plantations. Wildlife surveys are conducted to identify the presence, composition, and characteristics of wildlife communities that utilize the three Sacred Forest areas as habitats, corridors, or foraging areas.

The fauna inventory also aims to assess habitat quality through the presence of indicator species, keystone species, and animals with significant conservation status. Given the distinct characteristics of different fauna groups, the survey approach employs a combination of several methods tailored to each taxonomic group to increase detection rates and data representativeness.

3.4.1 Mammals/Primates

Inventories of mammals and large wildlife were conducted to document species presence, habitat use patterns, and indications of the area's importance as a wildlife habitat. The approach combined direct and indirect observations, as well as verification based on local knowledge.

Methods:

- Animal Tracks and Signs
  Identification of footprints, droppings, feeding traces, nests, scratch marks, or other signs of presence.
- Direct Encounter Survey
  Direct observations through transect surveys or field patrols.
- Local Interviews

Semi-structured interviews with local communities to obtain information on wildlife presence, encounter frequency, and key species.

As part of the wildlife biodiversity survey focusing on mammals in three Sacred Forest areas, two observation methods were used: indirect observation (footprints, droppings, scratch marks, sounds, calls, etc.) and direct field observation. These observation methods were combined with nighttime observations by patrolling forest trails using flashlights.

Indirect observations of terrestrial mammals were also made by looking for signs indicating their presence at the observation sites, including footprints sought on sandy soils, muddy soils, riverbanks, and other bodies of water. Other signs include scratch marks, bite marks on tree trunks and fruit, burrow holes, and feces.

Observed Parameters:

- Presence/existence of the species
- Encounter frequency
- Relative abundance (indicative)
- Signs of animal activity
- Species conservation status
- Ecological role and keystone species

3.4.2 Birds

Birds are used as one of the indicator groups for biodiversity and habitat quality because they are sensitive to changes in ecosystem conditions. The methods used for bird observation are the “point count” method and the 20-species method. The “point count” method aims to determine the population and distribution of birds around the observation site. The transect route is divided into several points spaced 100 meters apart, and each observation point is monitored for 20 minutes. Observations take place from morning until afternoon, from 6:00 AM to 1:00 PM WITA. In addition to these methods, bird data collection is also conducted outside of observation hours, including for certain nocturnal bird species identified by their calls.

Method:

- Point Count

  Bird observations at specific points with standardized observation radii and durations.
- Line Transect Observation

  Observations along a transect route to record species that are seen or heard.

Parameters:

- Species richness
- Relative abundance
- Encounter frequency
- Ecological guilds (frugivores, insectivores, granivores, predators, etc.)
- Indicator species and protected species

3.4.3 Herpetofauna

Herpetofauna surveys are conducted opportunistically or in a targeted manner when there are indications of potential habitats such as riparian areas, moist forest floors, thick litter, or water sources.

- Visual Encounter Survey (VES)
  Systematic direct observation of potential microhabitats.
- Time-Constrained Search
  Search for species within a specific time period using standardized sampling methods.

Observed Parameters:

- Species presence
- Species richness
- Microhabitats used
- Habitat indicator species
- Conservation status (if relevant)

This survey is particularly important for detecting amphibian and reptile groups that are sensitive to changes in environmental conditions.

3.5 Community Social Studies

A community social study was conducted to gather information on socioeconomic conditions, the community's level of dependence on forest resources, perceptions regarding the existence of Sacred Forests, and the level of community participation in area management and conservation activities. This study aims to understand the relationship between the community and the forest as a basis for developing sustainable landscape management strategies.

3.5.1 Collection of Secondary Data

Secondary data were obtained from various sources, including publications by the Central Statistics Agency (BPS) of Ketapang Regency, the BPS of Manismata Subdistrict, village documents, area management reports, and relevant literature. The data collected included population size, livelihood composition, education levels, socioeconomic conditions, land use, and developments in the plantation sector within the study area.

Secondary data was used to provide an overview of the socioeconomic conditions of communities surrounding the Air Dekakah Sacred Forest, Tamtam Forest, and Brupis Forest, as well as to serve as a basis for comparison with the results of the field survey.

3.5.2 Primary Data Collection

Primary data were collected through semi-structured interviews, questionnaire surveys, and discussions with communities living near the Sacred Forest area. Respondents were selected using purposive sampling—specifically, community members considered to have knowledge and experience related to the management of the area, including members of farmers' groups, community leaders, officials of the Perkumpulan Petani Mitra Harapan (PPMH), and community members who utilize forest resources.
The questionnaire was designed to gather information on:

1. Respondent characteristics, including age, gender, educational level, primary occupation, and length of residence in the village.
2. Community knowledge about the Sacred Forest, including understanding of the area's ecological functions and benefits.
3. Utilization of forest resources, such as the use of non-timber forest products (NTFPs) including honey, rattan, medicinal plants, and other forest products.
4. Perceptions of ecosystem services, including the forest's role in maintaining water availability, regulating the microclimate, and supporting community livelihoods.
5. Threats to biodiversity, such as land clearing, wildlife poaching, illegal logging, forest fires, water pollution, and other human activities. Additionally, human-wildlife conflicts and mechanisms for addressing them were identified.
6. Area management and conservation, which includes community support for the protection of Sacred Forests, proposed conservation measures, and community willingness to participate in biodiversity monitoring and conservation activities.

3.5.3 Data Analysis

Data from the questionnaires and interviews were analyzed using both quantitative and qualitative descriptive approaches.

Quantitative analysis was conducted by calculating the frequency, percentage, and distribution of respondents' answers for each observed variable. The results of the analysis were presented in the form of tables, graphs, and diagrams to illustrate the community's socioeconomic characteristics, the level of forest resource utilization, perceptions of the forest's ecological functions, and the level of support for conservation efforts.

Meanwhile, data from interviews and discussions were analyzed qualitatively through data reduction, thematic grouping, and interpretation of information to understand the community's social dynamics, forms of local wisdom, area management systems, and the challenges faced in forest conservation and restoration efforts.

3.5.4 Study Outputs

The results of the community social study were used to:

- Identifying the socioeconomic conditions of communities surrounding the Sacred Forest area.
- Determining the extent of the community's dependence on forest resources.
- Analyze community perceptions of the area's ecological functions and conservation value.
- Identify threats to biodiversity from the community's perspective.
- Assessing the level of community support and participation in conservation and restoration activities.
- Developing recommendations for community-based conservation strategies that support the sustainability of the Air Dekakah Sacred Forest, Tamtam Forest, and Brupis Forest.

3.6 Habitat and Ecological Condition Assessment

Habitat and ecological condition assessments were conducted to evaluate the environmental quality of each Sacred Forest area and its capacity to support biodiversity. This analysis aims to understand the relationship between the biophysical conditions of the habitat and the presence of flora and fauna, while also identifying the levels of pressure and threats affecting ecosystem sustainability. The approach used is semi-quantitative, combining field observations, habitat parameter measurements, and spatial analysis.

The habitat parameters observed include:

- Canopy cover (percentage of canopy closure)
- Vegetation complexity (stratification and stand structure)
- Habitat connectivity (connections between forest patches)
- Riparian conditions and water sources
- Anthropogenic disturbances (human activities such as land clearing and encroachment)

- Landscape fragmentation

Habitat quality assessment:

Habitat quality assessment is conducted using an indicator-based scoring approach to classify habitat conditions (good, moderate, poor).

- Habitat indicator scoring
- Threats to habitats

1. Habitat Indicator Scoring

   Each parameter is assigned a score:

   Table 3. Habitat Indicator Scoring

Parameter	Score 1 (Low)	Score 2 (Moderate)	Score 3 (High)
Canopy Cover	<40%	40-70%	>70%
Vegetation Complexity	Simple (1-2 strata)	Moderate (2-3 strata)	Complex (>3 strata)
Vegetation Density	Sparse	Moderate	Dense
Vegetation Regeneration	Minimal/None	Limited	Good (all strata present)
Habitat Connectivity	Isolated (disconnected patches) disconnected)	Partially connected	Well connected (clear corridors)
Landscape Fragmentation	High (small & scattered patches)	Moderate	Low (large, intact patches)
Riparian Conditions	Damaged/no vegetation	Partially disturbed	Good (intact riparian vegetation)
Water Source Availability	None / seasonal	Limited	Available year-round
Anthropogenic Disturbance	High (land clearing, intensive activities)	Moderate	Low/minimal
Encroachment Pressure	High	Moderate	None / very low
Presence of Keystone Species	Not found	There are indications	Clearly found
Presence of Protected Species	None	Potentially present	Identified
Soil Conditions	Degraded / high erosion	Partially stable	Stable / good
Microclimate	Hot / open	Moderate	Stable / naturally humid

The total score is used to determine habitat quality.

3.7 Analysis of Ecosystem Services

An analysis of ecosystem services was conducted to identify and assess the role of forest ecosystems in supporting the ecological, social, and economic functions of communities in a rapid and structured manner. The assessment covers four main categories: provisioning services (availability of water sources and potential for non-timber forest products), regulating services (hydrological protection, microclimate regulation, and indicative carbon storage potential), supporting services (biodiversity habitat functions and role in maintaining landscape balance), and cultural services (cultural/spiritual values and local community knowledge). The method used is a rapid ecosystem services assessment with a semi-quantitative scoring approach, which provides a quick overview of the importance and contribution of ecosystem services as a basis for area management and conservation.

3.8 Spatial Analysis and GIS

This analysis was conducted using GIS tools to integrate field survey data with spatial data such as satellite imagery, land cover, and other biophysical parameters. This approach allows for a more accurate identification of ecological patterns and relationships among landscape elements, including areas of high conservation value, levels of pressure, and opportunities for restoration. The results of the spatial analysis serve as the basis for determining management zones, prioritizing conservation interventions, and developing more targeted and effective landscape-based rehabilitation plans.

Spatial analysis includes:

1. Mapping of critical habitats
2. Distribution of key species
3. Vegetation cover analysis
4. Habitat fragmentation analysis
5. Landscape connectivity analysis
6. Delineation of priority rehabilitation areas

Map outputs:

- Map of important habitats
- Map of key species distribution
- Threats/Pressures Map
- Restoration Priority Area Map

3.9 Biodiversity Analysis

Biodiversity index analysis was conducted to quantitatively describe biodiversity conditions and compare community characteristics across study sites. This approach uses several key indices capable of representing levels of diversity, evenness, species richness, and similarity in community composition. In addition, an indicative assessment of biodiversity significance was conducted to determine the ecological importance of an area as a basis for conservation priorities.

The indices analyzed include:

I. Shannon-Wiener Diversity Index (H')
   Used to measure species diversity by considering the number of species and their relative abundance; the higher the H' value, the greater the diversity.
II. Evenness Index
   Describes the evenness of individual distribution among species within a community; a high value indicates an even distribution without the dominance of any particular species.
III. Richness Index
   Measures the total number of species found in a location, serving as an indicator of species richness.
IV. Similarity Index
   Used to compare the similarity of species composition among study sites, thereby revealing the degree of similarity or difference among communities.
V. Biodiversity Significance Value (indicative)
   A comprehensive assessment of the importance of an area based on several key criteria, namely:
   - Species richness
   - Presence of important species (protected, endemic, threatened)
   - Habitat quality
   - Ecological value of the area within the landscape

The results of this analysis will provide an overview of the level of biodiversity, the condition of the communities, and the ecological significance of each location, which will then serve as the basis for determining management and conservation priorities.

3.10 Identification of Key Species

The identification of important species is conducted to determine the types of flora and fauna that have high conservation value and play a strategic role in maintaining ecosystem functions within the study area. This process draws on field survey results combined with secondary data and conservation status references, resulting in a list of species relevant for management and protection efforts.
The classification of key species includes:

- Protected species
- Endemic species
- Threatened species (according to the IUCN)
- Species of high conservation value
- Species important to local culture

Next, a conservation priority analysis was conducted to determine the level of urgency for protecting each species. This assessment considered several key criteria, namely global and national conservation status, rarity, sensitivity to habitat change, and the pressures and threats faced in the field. Using this approach, species requiring special attention can be identified, whether in the form of habitat protection, threat reduction, or integration into area management plans.

The results of this identification not only provide a list of important species but also serve as the basis for determining conservation priorities, developing species-based management strategies, and supporting the assessment of biodiversity value and ecosystem sustainability within the Manismata PPMH landscape.

3.11 Threat Analysis

Threats to habitats were identified and classified, including:

- Land conversion to plantations
- Habitat fragmentation
- Encroachment and human activities
- Deterioration of water quality
- Pressure on wildlife

Figure 10. Threat Analysis

3.12 Carbon Stock Assessment

A carbon stock assessment was conducted to determine the amount of carbon stored in Sacred Forest areas and at the landscape level. The approach used consisted of two methods: field measurements for Sacred Forest areas and a land-cover-based approach for landscape-level carbon stock analysis.

Carbon Stocks in Sacred Forests

Carbon stock estimates for the Air Dekakah Sacred Forest, Brupis Sacred Forest, and Tantam Sacred Forest were derived from direct field measurements of vegetation biomass. Data collection was conducted using transect and sample plot methods, with plots placed representatively across each land cover type within the Sacred Forest areas.

In each plot, a tree inventory was conducted by measuring diameter at breast height (DBH) and identifying tree species. The diameter data were then used to calculate above-ground biomass (AGB) using allometric equations appropriate for tropical forest ecosystems. Below-ground biomass (BGB) was calculated using a *root-to-shoot ratio* conversion factor in accordance with IPCC guidelines.

Carbon stocks were calculated using the following equation:

Carbon (tC) = (AGB + BGB) × 0.47

where 0.47 is the biomass carbon fraction recommended by the IPCC and used in Indonesia's FREL.

The average carbon value per hectare obtained from each plot is then extrapolated based on the corresponding land cover area to estimate the total carbon stock in each Sacred Forest.

Landscape Carbon Stock

The landscape-level carbon stock assessment was conducted using *a land coverbased approach*. The analysis was performed by integrating the 2016 and 2026 land cover maps with biomass and carbon factors referenced from **Indonesia's Second Forest Reference Emission Level (Second FREL) for REDD+**, published by the Ministry of Environment and Forestry (KLHK).

Each land cover class was assigned an average biomass value based on the emission and absorption factors recommended in Indonesia's Second FREL document. These biomass values include both above-ground biomass (AGB) and below-ground biomass (BGB), allowing them to be used to calculate carbon stocks for each land cover class.

The carbon stock for each land cover class is calculated using the following equation:

Carbon Stock (tC) = Land Cover Area (ha) × Carbon Factor (tC/ha)

Next, the total landscape carbon stock is obtained by summing the carbon stocks of each land cover class.

For the purpose of analyzing changes in carbon stocks and greenhouse gas emissions, carbon values are converted to carbon dioxide equivalents (CO_2e) using the following conversion factor:

$$CO_2e = tC \times 44/12$$

or

$$CO_2e = tC \times 3.67$$

where the number 44/12 represents the ratio of the molecular weight of carbon dioxide to that of a carbon atom.

Analysis of Changes in Carbon Stocks and Emissions

Changes in carbon stocks are calculated by comparing the total landscape carbon stocks between 2016 and 2026. The difference in carbon stocks between the two periods is used to identify losses or increases in carbon stocks resulting from changes in land cover.

Carbon emissions are calculated based on the magnitude of the decrease in carbon stocks that occurs during the analysis period. If there is a decrease in carbon stocks, that difference is considered a carbon emission into the atmosphere. Conversely, an increase in carbon stocks indicates *carbon sequestration*.

The results of the analysis are used to evaluate the impact of land-use changes on carbon stocks and greenhouse gas emissions, as well as the role of Sacred Forest areas and other vegetation cover in supporting climate change mitigation in the Manismata Landscape.

CHAPTER IV. RESULTS AND DISCUSSION

4.1 Habitat and Ecosystem Conditions

4.1.1 Vegetation Cover

Current Conditions of Sacred Forest Cover

Based on the interpretation of 2026 Sentinel-2A satellite imagery and 2026 aerial photographs, the Brupis Sacred Forest, Air Dekakah Sacred Forest, and Tantam Sacred Forest are generally still dominated by secondary forest, that shows that their ecological functions and natural vegetation cover remain relatively well-preserved.

Table 4. Area of Sacred Forests in 2026

Tutupan Lahan	Hutan Larangan (Ha)			Grand Total
	Air Dekakah	Brupis	Tamtam	
Belukar Tua	2	0	0	2
Hutan Sekunder	12	46	21	78
Perkebunan Sawit	3	2		5
Semak	20		0	20
Tanah Terbuka	0		1	1
Grand Total	**37**	**48**	**22**	**107**

1. Brupis Sacred Forest

Figure 11. Land Cover Map for 2026 in the Brupis Sacred Forest

With an area of 48 ha, Brupis is the largest Sacred Forest among the three locations. This area has the best land cover conditions, as approximately 96% of its area consists of secondary forest (46 ha). There is only a small area of oil palm plantations (2 ha), and no shrubs, old thickets, or open land were found. These conditions indicate a relatively low level of disturbance and a more intact vegetation structure compared to the other locations.

2. Air Dekakah Sacred Forest

Figure 12. 2026 Land Cover Map of the Air Dekakah Sacred Forest

The Air Dekakah Sacred Forest covers an area of 37 ha and exhibits more diverse conditions. This area consists of 20 ha of shrubs (54%), 12 ha of secondary forest (32%), 2 ha of old thickets (5%), and 3 ha of oil palm plantations (8%). The dominance of shrubland indicates past disturbances or land clearing, which has caused parts of the area to be in a phase of vegetation regeneration. Compared to the other two locations, Air Dekakah has the highest rate of land cover change.

3. Tamtam Sacred Forest

Figure 13. 2026 Land Cover Map of the Tamtam Sacred Forest

The Tantam Sacred Forest is the smallest area, covering 22 ha. Most of the area consists of secondary forest (21 ha, or 95%), with only 1 ha of open land (5%). No significant oil palm plantations or shrublands were found. These conditions indicate that Tantam still has very dominant and relatively well-preserved forest cover, although there are indications of limited disturbance in the open-land areas.

Of the three Sacred Forest areas, Brupis has the largest area and the most dominant forest condition in absolute terms (46 ha of secondary forest), while Tantam has the highest proportion of forest cover (95% secondary forest) with very minimal disturbance. Meanwhile, Air Dekakah exhibits the most degraded conditions, characterized by the dominance of shrubs and the presence of oil palm plantations within the Sacred Forest area. These findings suggest that habitat protection and restoration efforts should be prioritized in Air Dekakah, while efforts in Brupis and Tantam should focus on maintaining the forest's current healthy condition and preventing future land-use conversion.

Correlation with Wildlife

Tree-level vegetation cover is a key pillar of forest ecosystems in providing primary biomass, *canopy* cover, and food sources for wildlife. Based on the analysis of actual vegetation data from the three sites (Brupis Forest, Tamtam Forest, and Air Dekakah Forest), vegetation cover characteristics show a strong correlation with habitat suitability for various taxa of wildlife (birds, mammals, reptiles, and primates).

1. Brupis Forest: Dense, Heterogeneous Cover with Agroforestry Pressure

Brupis Forest is characterized by the densest vegetation cover, with a total of 197 tree stands. However, the structure of this cover is predominantly influenced by rubber trees (*Hevea brasiliensis*), numbering 50 individuals, followed by Laban (*Vitex* pinnata—14 individuals) and Medang (*Polyalthia* sumatrana—12 individuals). Correlation with Wildlife:

- The abundance of rubber trees creates a continuous upper canopy, supporting the movement of arboreal wildlife (such as squirrels, chipmunks, and small primates) as a daily travel corridor.
- The presence of Medang (*Polyalthia sumatrana*) and Mentawa (*Artocarpus anisophyllus*) trees bearing fruit provides an abundant seasonal food supply for frugivorous birds (fruit-eaters) such as hornbills and small hornbills, as well as terrestrial mammals (such as wild boars or mouse deer) that feed on fallen fruit.
- The presence of Kobung trees (*Macaranga gigantea*—10 individuals), a broad-leaved pioneer tree species, serves as a favored microhabitat for insect colonies, which indirectly attracts flocks of insectivorous birds to forage.

2. Tamtam Forest: Natural Forest Cover with High Food-Support Capacity

The Tamtam Forest presents an ideal vegetation cover profile for wildlife, with 106 tree stands. Its canopy structure is naturally dominated by Manggungan (*Elaeocarpus* microphyllus—21 individuals), Punaga (*Calophyllum* inophyllum—11 individuals), and Cempedak (*Artocarpus integer*—10 individuals). Correlation with Wildlife:

- Tree groups from the *Elaeocarpaceae* (Manggungan) and *Moraceae* (Cempedak) families hold critical ecological importance for wildlife, as their fruits serve as *keystone food resources* for primates (such as long-tailed macaques or lutungs) and large birds.
- The combination of minimal disturbance from commercial crops (only 7 rubber trees) indicates a stratified vertical forest structure. This fairly divides the animals' living space: arboreal animals dominate the upper canopy of the Manggungan, while terrestrial mammals feed on fallen cempedak fruits on the forest floor.

- The presence of rare, large-stemmed tree species such as Ulin and Meranti provides natural cavities in the tree trunks that are essential as nesting sites for owls and woodpeckers, or as resting places for nocturnal reptiles.

3. Air Dekakah Forest: Open Canopy and Single-Species Dominance

The Air Dekakah area has significantly limited vegetation cover, with only 59 tree stands recorded. The canopy is homogeneous at the top due to the absolute dominance of Punaga trees (*Calophyllum inophyllum L.*—18 individuals) while the surrounding area tends to be open, marked by the presence of Mahang (*Macaranga* pearsonii—6 individuals) and Acacia (*Acacia* mangium—2 individuals). Correlation with Wildlife:

- The minimal number of mature trees widens the gaps between tree canopies (*canopy gaps*). This becomes a major physical barrier for sensitive arboreal mammals that cannot jump far, making them reluctant to cross the Air Dekakah area due to the high risk of predation if they have to descend to the ground.
- The dominance of Punaga provides specific benefits to certain animal groups; Punaga's hard, high-fat seeds are generally preferred by rodents and large fruit-eating bats (*megachiroptera*).
- However, because the abundance of other food species is very low (most forest fruit species have only one remaining individual, such as the Kalimantan durian and Kalimantan tamarind), the Air Dekakah area is less able to support *food-specialist species*. This open area is primarily utilized by opportunistic wildlife or "*edge* species" of birds that are tolerant of high temperatures and direct sunlight due to the sparse canopy cover.

In general, the Tamtam Forest serves as the best refuge for native rainforest wildlife due to its abundant natural food supply. Brupis Forest has a large roaming capacity, but the wildlife within it is forced to adapt to the agroforestry ecosystem (rubber plantations). Meanwhile, Air Dekakah Forest requires restoration of its vegetation cover because its sparse structure limits movement and the fulfillment of food needs for more complex wildlife communities.

4.1.2 Habitat Structure

Ecologically, the habitat variation diameter (DBH) is directly proportional to estimated tree height. Forests with a random distribution of diameters and trees spanning all life stages exhibit a fully stratified canopy, ranging from the forest floor to emergent trees. The following is a classification of tree height stratification for the three locations:

Table 5. High-Complexity Stratification of Trees by Location

Forest Location	Stratification Classification	DBH and Vertical Structure Characteristics	Canopy Strata Representation
Brupis Forest	COMPLEX	DBH variation is very high, and species richness on the forest floor is abundant, indicating a dense, multi-layered structure.	Strata A, B, C, D, and E (Complete)
Tamtam Forest	MODERATE	The DBH distribution forms an ideal inverted J-curve, indicating that secondary forest succession is proceeding normally and in stages.	Strata B, C, D, and E
Air Dekakah Forest	SIMPLE	Stagnation or condensation of dimensions occurs at certain diameter classes due to swamp/riparian habitat selection; the canopy tends to be uniform.	Strata C, D, and E (Limited Strata A/B)

1. Brupis Forest — COMPLEX Stratification

Brupis forests are categorized as having complex tree stratification. The main indicator can be seen in the explosion of species numbers in the lower regeneration phase (Seedlings S = 55 species and Saplings S = 54 species).

- Dimensional Analysis: This high diversity of saplings is only possible if the upper canopy (mature trees) has a heterogeneous structure with highly contrasting DBH variations. The presence of large-diameter trees from the *Dipterocarpaceae* family creates varying *canopy gaps* on the forest floor.
- Vertical Profile: The canopy layers in the Brupis Forest are fully divided into 5 layers (Strata A through E), ranging from *emergent* trees taller than 30 meters, the main canopy (20–30\tmeters), understory trees, to the understory vegetation. This complex structure reflects the characteristics of a primary forest or an old-growth secondary forest that has not yet experienced massive disturbance.

2. Tamtam Forest — MODERATE Stratification

The Tamtam Forest exhibits moderate tree height stratification (tending toward complex). This area displays a very balanced distribution of individuals across every level, ranging from seedlings (S=28), saplings (S=32), young trees (S=23), to mature trees (S=32).

Dimensional Analysis: The DBH correlation in this forest forms a highly theoretical inverted J-curve, meaning that the number of individuals with small diameters (seedlings/saplings) is much greater and decreases proportionally as tree diameter increases (young trees/mature trees). Vertical Profile: Tree height in the Tamtam Forest is generally concentrated in the middle canopy (Strata C and B, between 10–30 meters), which is dominated by the species *Elaeocarpus microphyllus* (Manggungan). This forest is not as old as Brupis because it still bears traces of introduced stands (*Hevea brasiliensis*), but its natural succession is proceeding steadily, resulting in a neatly tiered stratification.

3. Air Dekakah Forest — SIMPLE Stratification

The Air Dekakah Forest is classified as having a simple tree stratification. This is driven by ecological constraints (*environmental filtering*) in the form of wet and water-saturated riparian soil conditions.

- Dimensional Analysis: There is an extremely severe bottleneck in species richness during the Tihang phase (only 11 species were found). The DBH structure at this site tends to be uniform and is overwhelmingly dominated by a single dominant species, *Calophyllum inophyllum* (Punaga), from the tree to the pole levels.
- Vertical Profile: Because it is dominated by Punaga, which has a relatively uniform tree height architecture, the upper canopy at Air Dekakah tends to be flat and homogeneous (concentrated in Stratum C, ranging from 10 to 20 meters). It is rare to find *emergent* trees (Stratum A) that tower alone. It is this lack of striking variation in tree height that leads to its vertical structure being described as simple

4.1.3 Habitat Quality

Habitat quality at the study sites was evaluated using a comparative scoring method based on 14 key ecological parameters at the three locations—Air Dekakah, Brupis, and Tamtam—derived from stand structure and biodiversity indices. Each parameter was assigned a value on an ordinal scale, with the assessment matrix detailed as follows:

Table 6. Habitat Quality Parameter Scoring Matrix

No	Parameter	Air Dekakah	Score	Brupis	Score	Tamtam	Score
1	Canopy Coverage	37%	1	96%	3	95%	3
2	Vegetation Complexity	Simple (1–2 strata)	1	Complex (>3 strata)	3	Moderate (2–3 strata)	2
3	Vegetation Density	Sparse	1	Dense	3	Moderate	2
4	Vegetation Regeneration	Minimal/none	1	Good (all strata present)	3	Limited	2
5	Habitat Connectivity	Isolated	1	Partially connected	2	Partially connected	2
6	Landscape Fragmentation	High	1	Low	3	Moderate	2
7	Riparian Conditions	Partially disturbed	2	Partially disturbed	2	Partially disturbed	2
8	Water Source Availability	Available year-round	3	Limited	2	Limited availability	2
9	Anthropogenic Disturbances	Moderate	2	Low	3	Moderate	2
10	Encroachment Pressure	Moderate	2	None	3	Moderate	2
11	Presence of Keystone Species	Clearly identified	3	Clearly identified	3	Clearly identified	3
12	Presence of Protected Species	Identified	3	Identified	3	Identified	3
13	Soil Condition	Partially stable	2	Stable/Good	3	Stable/Good	3
14	Microclimate	Hot / open	1	Stable / naturally humid	3	Stable / naturally humid	3
	TOTAL SCORE		24		39		29

(Low category: 14–23, moderate category: 24–32, good category: 33–42)

Based on the scoring results, the Brupis Sacred Forest received the highest score with a total of 39, placing it in the “good” category. Brupis’s high score is supported by its excellent canopy cover (96%), high vegetation complexity with more than three vegetation strata, dense vegetation, good natural regeneration, and low fragmentation. Additionally, this area has low levels of anthropogenic disturbance and encroachment pressure, allowing it to maintain a relatively intact habitat. The presence of key species and protected species identified in this area further reinforces Brupis’s ecological value as a critical habitat for biodiversity within the Manismata Landscape.

The Tantam Sacred Forest received a score of 29 and falls into the moderate category. Habitat conditions in this area remain relatively good, with canopy cover reaching 95%, stable soil conditions, and a microclimate that remains natural. , however, the habitat quality of Tantam is slightly lower than that of Brupis because vegetation complexity and density are in the moderate category, vegetation regeneration is not yet uniform across all strata, and there are still moderate levels of fragmentation and anthropogenic disturbance. Nevertheless, the presence of key species and protected species indicates that this area still serves an important ecological function and has the potential to be enhanced through conservation efforts and vegetation enrichment.

Meanwhile, the Air Dekakah Sacred Forest received a score of 24 and falls into the “moderate” category, though it is at the lower end of that range. Air Dekakah’s low score is primarily due to a canopy cover of only 37%, a simple vegetation structure, sparse vegetation density, and minimal natural vegetation regeneration. Additionally, this area is relatively isolated and experiences a high level of fragmentation, which has the potential to reduce its habitat function for wildlife. Nevertheless, Air Dekakah still possesses several important ecological characteristics, such as year-round water availability and the presence of keystone and protected species. These conditions indicate that the area still holds significant conservation value but requires more intensive restoration and management efforts compared to the other two areas.

Overall, the assessment results show that the Brupis Sacred Forest has the best habitat quality, followed by the Tantam Sacred Forest, while the Air Dekakah Sacred Forest has the lowest habitat quality. Differences in habitat quality among the sites are primarily influenced by vegetation cover conditions, fragmentation levels, habitat connectivity, and pressures from human activities. These findings indicate that conservation management strategies need to be tailored to the conditions of each area. Brupis should be prioritized for the protection and maintenance of its already good habitat conditions; Tantam requires enhanced connectivity and management of disturbances; while Air Dekakah should be prioritized for habitat rehabilitation, increased vegetation cover, and the restoration of the area’s ecological functions.

4.1.4 Landscape Connectivity

A habitat connectivity analysis was conducted to identify the level of connectivity among the remaining natural habitats in the Manismata Landscape and to determine priority areas necessary for maintaining and restoring the landscape’s ecological functions. Based on the analysis results, natural habitats consisting of secondary forest and old-growth scrub still cover an area of 3,886 ha, or approximately 30.2% of the landscape’s total area (12,871 ha). These natural habitats are distributed across several main blocks that serve as core habitats, food sources, shelters, and movement corridors for various species of wildlife.

Although the remaining natural habitat area is still quite significant, its distribution pattern indicates a relatively high level of fragmentation due to the expansion of oil palm plantations and land-use changes over the past decade. This situation has caused parts of the habitat to be fragmented into several isolated patches, thereby reducing the overall ecological effectiveness of the landscape.

Connectivity analysis results indicate that there are 929 ha of priority restoration areas spread across locations that have the potential to serve as connecting corridors between natural habitats but have currently experienced degradation or loss of vegetation cover. This area is equivalent to approximately 23.9% of the total remaining natural habitat. These restoration areas are primarily located around habitat corridors connecting blocks of secondary forest in the central, eastern, and southern parts of the landscape. Restoring vegetation cover in these areas will improve connectivity between habitats, expand effective habitat for wildlife, and strengthen the function of ecological corridors at the landscape level.

In addition, restoration/sustainable oil palm management areas covering 921 ha—or about 23.7% of the total remaining natural habitat—have been identified. These areas are generally located within oil palm plantations that directly border natural habitats, river buffers, or Sacred Forest areas. Given that these areas serve as a source of livelihood for local communities, the recommended approach is not full conversion into conservation areas, but rather the implementation of more environmentally friendly oil palm management practices through the protection of river buffers, enrichment of local vegetation, reduction in the use of agricultural chemicals, and the preservation of remaining natural trees.

Overall, the total area requiring connectivity management interventions amounts to 1,850 ha, consisting of 929 ha of restoration areas and 921 ha of restoration/sustainable oil palm management areas. This area is equivalent to approximately 47.6% of the total remaining natural habitat, indicating that nearly half of the natural habitat in the Manismata Landscape requires management actions to maintain or enhance ecological connectivity between habitats.

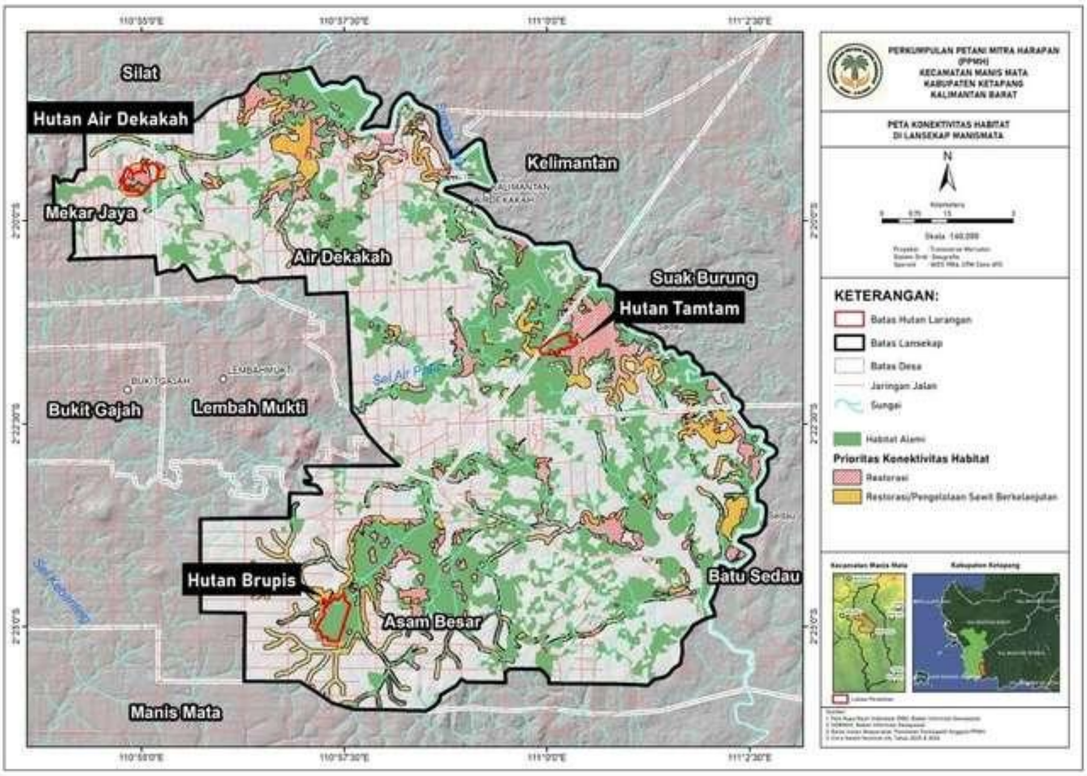

Figure 14. Habitat Connectivity Map of the Manismata Landscape

Based on the spatial patterns shown on the map, the Tantam Sacred Forest has the highest level of habitat connectivity because it remains connected to relatively large blocks of natural habitat in the eastern and northeastern parts of the landscape. Additionally, the presence of swamps and the surrounding river network further strengthens the area’s function as a natural ecological corridor. Therefore, management strategies in this area are focused more on protecting the remaining habitats and preventing further fragmentation.

The Brupis Sacred Forest has a moderate level of connectivity. This area remains connected to several patches of natural habitat through a network of rivers and scattered secondary vegetation in the southern part of the landscape. However, the dominance of oil palm plantations surrounding the area means that connectivity remains only partial. Efforts to strengthen riparian corridors and implement sustainable oil palm management are crucial steps to maintaining the area’s connectivity function.

Meanwhile, the Air Dekakah Sacred Forest exhibits the lowest level of connectivity. The surrounding natural habitats are relatively fragmented and isolated by a matrix of oil palm plantations, hence limiting wildlife movement and genetic exchange between populations. Therefore, this area is a top priority for habitat corridor restoration and the rehabilitation of connecting vegetation to enhance connectivity with other remaining natural habitats.

Overall, the habitat connectivity map indicates that the sustainability of the Manismata Landscape's ecological functions heavily depends on successfully preserving the remaining 3,886 ha of natural habitat, as well as implementing restoration and sustainable management programs across the 1,850 ha of priority connectivity areas. These efforts are expected to improve connectivity between habitats, support wildlife movement, preserve biodiversity, and strengthen the landscape's resilience to future land-use change pressures.

4.1.5 Habitat Fragmentation

Habitat fragmentation was analyzed based on the distribution patterns of natural forest cover in 2026. Fragmentation occurs when a previously relatively continuous expanse of natural habitat is broken up into smaller patches due to changes in land cover, particularly into oil palm plantations, shrubs, thickets, and open land. This condition can degrade habitat quality, hinder wildlife movement, and increase the risk of population isolation.

Based on deforestation data, between 2016 and 2026, 2.355,75 ha of natural forest were lost, spread across nearly the entire landscape. Deforestation not only reduces forest area but also breaks up the remaining forest blocks into smaller, isolated fragments. Currently, the remaining natural forest cover is concentrated in the eastern and central parts of the landscape, while the western and southern parts are dominated by a mosaic of oil palm plantations and non-forest land.

Habitat fragmentation analysis shows that natural habitats in the Manismata Landscape are dominated by small fragments. Of the total 204 natural habitat patches consisting of secondary forest and old-growth scrub, 174 patches (85%) fall into the high-fragmentation category (<25 ha), 23 patches (11%) fall into the moderate-fragmentation category (25–100 ha), and only 7 patches (3%) fall into the low-fragmentation category (>100 ha). These conditions indicate that most natural habitats have been fragmented into small patches due to land-use changes, particularly the expansion of oil palm plantations. Low-fragmentation habitat blocks are still found around the Tantam Sacred Forest and in some central to southern parts of the landscape, which play a crucial role as core habitats and sources of ecological connectivity.

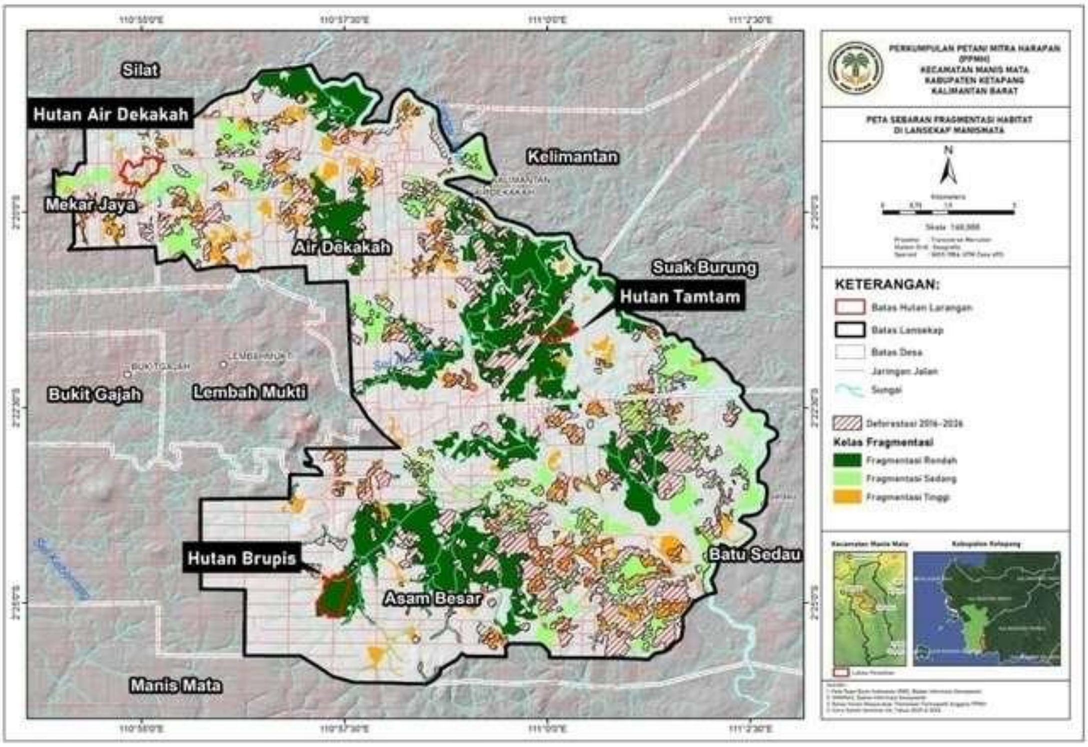

Figure 15. Map of Habitat Fragmentation Distribution in the Sacred Forest landscape

Fragmentation Around the Air Dekakah Sacred Forest

The Air Dekakah Sacred Forest is the area experiencing the highest level of habitat fragmentation. Most of the surrounding area has been converted into oil palm plantations and non-forest land, leaving this Sacred Forest in a relatively isolated state. The remaining natural forest cover around the area consists only of small, disconnected patches. This situation results in low habitat connectivity and has the potential to restrict wildlife movement to other habitats.

Furthermore, the high rate of deforestation in the western part of the landscape indicates that pressure from land-use change remains significant. If no efforts are made to restore habitat corridors, Air Dekakah risks becoming an isolated "*habitat* island" in the midst of a matrix of plantations.

Fragmentation Around the Brupis Sacred Forest

The Brupis Sacred Forest is also surrounded by areas that have undergone fairly intensive land conversion. However, there are still several blocks of secondary forest and natural vegetation in the central to southern parts of the landscape that have the potential to function as stepping-stone habitats. The presence of a network of rivers around the area also helps maintain ecological connectivity, albeit to a limited extent.

The level of fragmentation around Brupis is moderate to high. This fragmentation reduces the effective habitat area for wildlife and increases edge effects; however, the potential for restoring habitat connectivity remains relatively better compared to Air Dekakah.

Fragmentation Around the Tantam Sacred Forest

The Tantam Sacred Forest exhibits the lowest level of fragmentation compared to the other two areas. This area remains connected to relatively large blocks of natural forest in the northeastern part of the landscape. Additionally, the presence of swamps and river networks around the area helps form natural corridors that maintain connectivity between habitats.

Although areas of deforestation have also been found around Tantam, the pattern of forest loss does not appear to completely sever the area's connectivity. Therefore, Tantam still functions as one of *the* primary core habitats that plays a crucial role in sustaining wildlife populations at the landscape level.

Impacts of Habitat Fragmentation

Habitat fragmentation occurring in the Manismata Landscape has the potential to cause several ecological impacts, including:

- A reduction in the effective habitat area for wildlife.
- Decreased connectivity between habitats and wildlife movement corridors.
- Increased *edge* effects, such as changes in microclimate, human disturbance, and the introduction of invasive species.
- Increased risk of human-wildlife conflicts as wildlife moves into plantation areas.
- Decreased opportunities for genetic exchange between wildlife populations due to habitat isolation.

Management Implications

Based on the identified levels of fragmentation, landscape management priorities can be directed as follows:

1. Prohibited Forests Near Water
    - High priority for habitat corridor restoration.
    - Vegetation enrichment in connecting areas leading to the nearest forest patches.
    - Protection of riverbanks as ecological corridors.
2. Brupis Sacred Forest
    - Strengthening connectivity through riparian corridors.
    - Protection and rehabilitation of secondary forest patches around the area.

    - Development of managed buffer zones in oil palm areas directly bordering the forest.

3. Tantam Sacred Forest
    - Prioritizing the protection of forest blocks that are still connected.
    - Preventing new land clearing that could disrupt habitat connectivity.
    - Strengthening the area's function as a core habitat and a hub for landscape connectivity.

Overall, habitat fragmentation in the Manismata Landscape indicates that the Tantam Sacred Forest still has relatively good habitat integrity, Brupis is in moderate condition, while Air Dekakah is the area most vulnerable to habitat isolation due to landscape fragmentation. Therefore, future management efforts need to focus on improving connectivity between forest patches and protecting the remaining ecological corridors.

4.2 Flora Diversity

Vegetation information—in this case the composition and dominance of tree species—is crucial for describing the ecological conditions of a particular area: whether an area is dominated by a single species or whether the importance of that species is evenly distributed among various other species.

1. Diversity (H') and Evenness (E) Flora Parameters

Analysis of flora community diversity in the Manismata PPMH landscape was conducted using two primary ecological parameters:

1. Shannon-Wiener Diversity Index (H'): Measures a combination of species richness and the relative abundance of individuals across species. According to Barbour et al. (1987), values are categorized into three levels: low (H' < \le 1), moderate (1 < H' \le 3), and high (H' > 3).
2. Pielou's Evenness Index (E): Describes the homogeneity of the distribution of individuals across species within a community. E values range from 0 to 1, where a value close to 1 indicates that the forest floor is inhabited by tree species evenly, without extreme dominance by a single species, which correlates with high community stability.

Figure 16. Meranti tree species (*Shorea* sp.) found in the Brupis Forest

Based on the compilation of mathematical data analysis results from the three observation stations (Brupis Forest, Tamtam Forest, and Air Dekakah), the biodiversity index values were obtained as presented in Table 7.

Table 7. Summary of Diversity (H') and Evenness (E) Parameters for Flora

Location	Growth Stratum	Total Species (S)	Diversity Index (H′)	Evenness Index (E)	Ecological Community Criteria
Brupis Forest	*Seedlings*	55	3.1646	0.7897	High Biodiversity, Stable Community
	Sapling	54	3.6361	0.9115	High Diversity, Very High Evenness
	Pole	44	3.396	0.897	High Diversity, Very High Evenness
	Tree	54	3.232	0.810	High Diversity, Very High Evenness
Tamtam Forest	*Seedlings*	28	2.9122	0.8740	Moderate Diversity (Approaching High)
	Sapling	32	3.0036	0.8667	High Diversity, Stable Community
	Tihang (*Pole*)	23	2.8132	0.8972	Moderate Diversity, Even Distribution of Individuals
	Tree	32	2.9384	0.8478	Moderate Diversity (Approaching High)
Air Dekakah	*Seedling*	20	2.3471	0.7835	Moderate Diversity, Stable Community
	Sapling	22	2.5628	0.8291	Moderate Diversity, Stable Community
	Tihang (*Pole*)	11	1.9851	0.8278	Moderate Diversity (Lowest), Stable Community
	Tree	22	2.5628	0.8291	Moderate Diversity, Stable Community

2. Analysis of Flora Diversity by Area

A. Climax Biodiversity Characteristics of the Brupis Forest

The Brupis Forest exhibits the highest level of biodiversity within the study landscape. The Pancang index in Brupis recorded the highest H’ value of 3.6361, with an evenness index very close to perfect (E = 0.9115). This high diversity index is supported by a forest floor rich in saplings of the genus *Dehaasia* (Medang) and *Palaquium rostratum* (Nyatuh).

An evenness index (E) exceeding 0.91 indicates that no single sapling species dominates the area disproportionately. Individuals are evenly distributed among the 54 sapling species found. This vegetation structure reflects the conditions of a climax ecosystem (primary forest or old-growth secondary forest with high integrity), which possesses maximum *ecological resilience* against climate fluctuations or potential attacks by forest plant pests and diseases.

B. Characteristics of Forest Succession Dynamics in Tamtam Forest

The Tamtam Forest area falls into the Moderate to High diversity category, with H' values ranging from 2.8132 to 3.0036. The consistently high evenness (E) values across all growth stages (0.84–0.89) indicate that this secondary forest community is composed of a balanced proportion of individuals. Although during the *tihang* phase the diversity value temporarily dropped to 2.8132 due to competition for growing space with historically introduced species such as rubber (*Hevea brasiliensis*), the understory community (Pancang) managed to rebound with the H' value exceeding 3.0036. This gives a positive signal that the natural enrichment process is proceeding very well, leading to the recovery of the native flora diversity of the Pamah tropical forest in that area.

C. Characteristics of Unique Environmental Pressures in Air Dekakah

The plant communities in Air Dekakah are generally within the “Moderate” diversity corridor, with H' values ranging from 1.9851 (*Tihang*/Pole) to 2.5628 (Tree and Sapling). The low flora diversity index at the pole level (H' = 1.9851) correlates directly with the limited number of species capable of synret in the area (only 11 species).

From an ecological analysis, this limitation is driven by the site’s location, which acts as a hydrological pocket. The microclimatic conditions of wet or water-saturated soil create a form of *environmental* filtering. Only hardy vegetation with specialized root anatomy—such as *Calophyllum inophyllum* (Punaga)—is able to dominate. Although the level of diversity is relatively lower, the stable evenness index (E = 0.78–0.82$) demonstrates that this community remains in a state of equilibrium, forming a characteristic swamp/riparian vegetation association.

Overall, the flora diversity profile of the Manismata PPMH landscape is classified as highly promising for supporting national biodiversity conservation programs.

- Recommendations for the Core Conservation Area (HCVA): The Brupis Forest must be preserved as a core conservation zone because it has an H' value > 3. This area serves as a critical ecological corridor for wildlife and the conservation of rare flora.
- Enrichment Strategy: The Tamtam and Air Dekakah forest areas can be optimized through a system of enriching the vegetation with local (*indigenous*) *species* based on microhabitat suitability, in order to boost species diversity levels toward the optimal threshold.

4.2.1 Species Composition

1. Analysis of Landscape Flora *Species Richness*

Species richness is the most fundamental ecological indicator that describes the total number of unique plant species found within a community or sample area without considering the relative abundance of each individual. This parameter provides a direct picture of the level of genetic diversity, the structural complexity of the habitat, and the capacity to provide *ecological niches* within a forest landscape.

Based on the compilation and cleaning of data from all growth strata (Seedlings, Saplings, Young Trees, and Mature Trees) at the three observation sites, the values for plant species richness in the Manismata PPMH landscape show significant spatial variation, as presented in Table 8.

Table 8. *Species Rich*ness Values by Stratum and Observation Location

Location / Zone	Growth Stratum	Number of Species (Species Richness)	Total Accumulated Individuals (n)
Brupis Forest	*Seedlings*	59 Species	624.96
	Saplings	60 Species	384.54
	Pole	44 Species	143
	Tree	54 Species	197
Tamtam Forest	*Seedlings*	34 Species	237.12
	Sapling	36 Species	145.34
	Pole	23 Species	66.00
	Tree	32 Species	106.00
Water	*Seedlings*	25 Species	206.13
	Sapling	21 Species	59.00
	Pole	11 Species	36.00
	Tree	22 Species	59.00

2. Discussion of Spatial Distribution Patterns of Species Richness

a. Diversity Dominance in the Brupis Forest (Biodiversity Reserve Center)

The Brupis Forest stands out as the area with the highest species richness throughout the Manismata PPMH landscape, recording 59 species at the seedling level and 60 species at the sapling level. This high level of species richness indicates that the Brupis Forest is a remnant fragment of native lowland dipterocarp forest that still possesses excellent ecosystem integrity.

The abundance of growing space and microclimatic variation on the forest floor of the Brupis Forest allow hundreds of plant taxa from the families *Lauraceae*, *Dipterocarpaceae*, and *Myrtaceae* to coexist without experiencing extreme competitive exclusion. Ecologically, this area acts as *a core reservoir*—or primary biodiversity bank—that supplies genetic material to the surrounding landscape.

b. Vertical Gradient of Species Richness in the Tamtam Forest

The Tamtam Forest exhibits an interesting and unique trend in species richness distribution, where the species richness curve fluctuates in a partial “U” shape:

- The Seedling phase (34 species) and Sapling phase (36 species) are followed by a sharp decline in the Pole phase (23 species), but species richness increases significantly again in the Mature Tree phase (32 species). Ecologically, this pattern reflects the area’s succession history.
- The high species richness during the tree phase (32 species) indicates that the Tamtam Forest was historically a rich, heterogeneous natural forest. The decline in species richness during the Pole phase (23 species) resulted from past anthropogenic pressures or the effects of land clearing, which triggered the dominance of a few aggressive pioneer or introduced species (such as the rubber tree, *Hevea brasiliensis*) that suppressed the growth of other species.

Nevertheless, the high species richness that has re-emerged at the seedling and sapling stages (34–36 species) demonstrates that the Tamtam Forest is currently in a phase of very healthy *community re-assembly*, thanks to the influx of tree seeds from the forest’s core zone.

c. Species Depauperation in the Air Dekakah Zone (Hydrological Specialized Area)

The Air Dekakah area exhibits the lowest species richness among the three observation sites, ranging from only 11 species at the pole level to 25 species at the seedling level. The low species richness at this location does not necessarily indicate that the ecosystem is degraded; rather, it reflects strict *environmental filtering*.

Air Dekakah is believed to be a riparian zone or watershed with soil conditions that are frequently waterlogged or exhibit extreme moisture levels. These specific water fluctuation conditions limit the growth of common tree species and allow only specialized plant groups adapted to waterlogged conditions to establish themselves and thrive, such as *Calophyllum inophyllum* (Punaga). The low species richness here is offset by the high value of the area's hydrological services.

3. Implications of Species Richness for Ecosystem Resilience

According to the principles of quantitative ecology, there is a positive linear relationship between species richness and ecosystem stability and resilience to external stresses (such as climate change, pests, diseases, or drought).

1. *Ecological Insurance Effect*: Areas with high species richness, such as the Brupis and Tamtam Forests, possess a safe level of functional redundancy. This means that if one tree species becomes extinct due to a specific disease outbreak, its ecological niche and ecosystem services (e.g., as a carbon sink or food source for wildlife) can be immediately replaced by another species that fulfills a similar role.
2. PPMH Manismata Conservation Management Recommendations: it is advised to prioritize the Brupis Forest as a High Conservation Value Area (HCVA) due to the high species richness in that area. Meanwhile, for the Tamtam Forest, *enrichment planting* can be directed toward enriching the canopy stratum, which has experienced a decline in species richness due to the dominance of secondary vegetation.

4.2.2 Vegetation Structure

1. Stand Structure Based on Growth Classes (Vertical Stratification)

The stand structure of a forest community can be assessed through a quantitative representation of the four life stages or vegetation growth classes: Seedling, Sapling, Pole, and Tree. Based on data compiled from the three observation stations in the Manismata PPMH landscape (Tamtam Forest, Air Dekakah, and Brupis Forest), the community structure generally forms *an inverted J-shaped curve*.

This pattern reflects the condition of a natural forest currently in a phase of active and sustainable regeneration, where the number of individuals in the smallest growth class (Seedling) is extremely high, then decreases proportionally and competitively during the intermediate phases (Sapling and Pole), until only the smallest number of individuals—but the largest in size—remain in the climax phase (Tree).

- Seedling & Sapling Phases: Form the foundation of the lower succession with the highest species richness (e.g., reaching 54–55 species in the Brupis Forest), serving as *a* living *seed bank* that ensures the ecosystem's survival.
- Pole & Tree Phases: These phases act as the primary architects of the canopy (upper and middle layers), controlling the forest's microclimate, forest floor moisture, and above-ground carbon biomass accumulation.

2. Diameter at Breast Height (DBH) Distribution of Key Species

The combination *of diameter at breast height* (DBH) values provides a concrete visualization of the horizontal distribution and maturity levels of individual trees on the forest floor. Based on the analyzed data, there are stark contrasts in diameter architecture among the observation sites:

Table 9. Physical Parameters (DBH) of Dominant Species in the Manismata Landscape

Location / Zone	Growth Stratum	Primary Dominant Species	Number of Individuals (n)	Average DBH (cm)	Total LBDS (cm^2)
Tamtam Forest	Tree	*Elaeocarpus microphyllus*	21	70.67	124,991.41
	Tree	*Artocarpus integer*	10	54.20	32,809.22
	Pole	*Hevea brasiliensis*	9	14.78	1,623.42
	Tihang (*Pole*)	*Dehaasia sp.*	8	14.75	1,432.57
Air Dekakah Forest	Tree	*Archidendron clypearia*	4	48.25	8,238.04
	Tree	*Calophyllum inophyllum*	18	25.50	9,189.14
	Pole	*Macaranga pearsonii*	8	13.00	1,086.99
	Tihang (*Pole*)	*Calophyllum inophyllum*	12	11.17	1,178.59
Brupis Forest	Tree	*Hevea brasiliensis*	50	30.3	40,163.69
	Tree	*Polyalthia sumatrana*	12	35.9	13,426.38
	Pole	*Hevea brasiliensis*	17	15.2	3,231.91
	Tihang (*Pole*)	*Vitex pinnata*	9	13.9	1,420.79

Diameter Variation Analysis:

1. Giant Tree Class (Mega-Phanerophytes): In the Tamtam Forest, the species *Elaeocarpus microphyllus* (Manggungan) recorded the largest average DBH of 70.67

cm with a very massive accumulated basal area (LBDS). This indicates the presence of ancient, old-growth trees that serve as the primary carbon sinks in the area. This is followed by *Artocarpus integer* (Cempedak) with an average diameter of 54.20 cm.

2. Medium-Sized Trees & Homogeneous Stands: In the Air Dekakah zone, the diameter structure is dominated by medium-sized trees. Although *Calophyllum inophyllum* (Punaga) is the absolute dominant species with 18 individuals, its average diameter is 25.50 cm. This structure indicates that the community in Air Dekakah exhibits a stand distribution pattern that tends to be denser with a uniform diameter distribution (*even-aged stand pattern*).
3. Pole Class: All species dominating the pole phase (including Rubber, Medang, and Punaga) fall within the diameter range of 11.17 cm to 14.78 cm. These figures fall within the standard criteria for the forestry pole class (diameter 10–<20 cm) and indicate that the transition in stem dimensions from the lower sapling phase (pole) to the mature tree stage is proceeding without *growth stagnation*.

3. Height Stratification and Forest Canopy Structure

Based on the diameter (DBH) correlations above, tree height stratification in the Manismata PPMH landscape can be classified into standard canopy layer types according to forest sociological strata (Ashton & Raich):

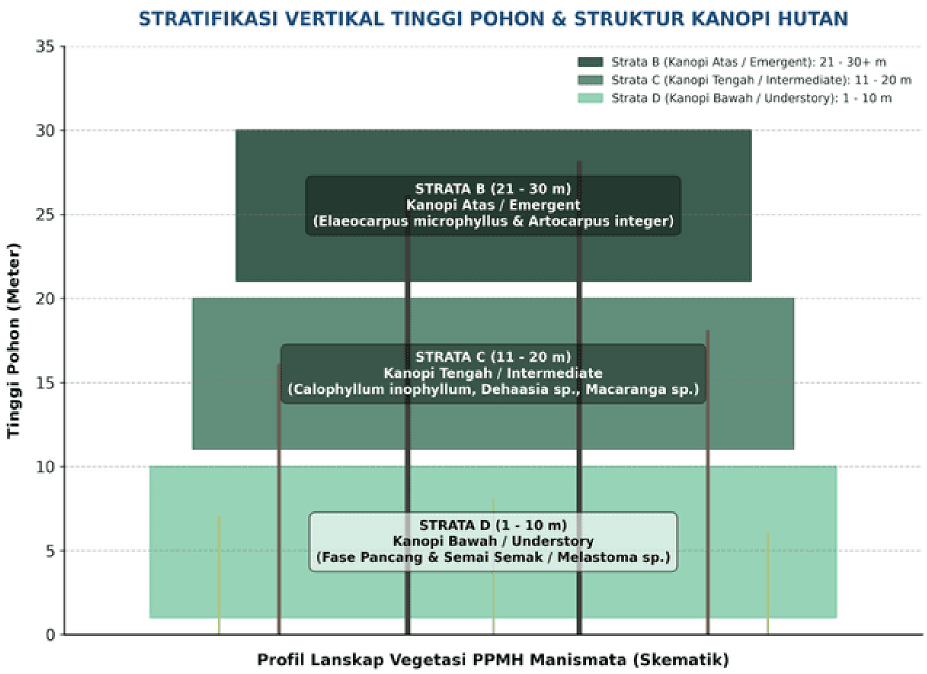

Figure 17. Tree height stratification in the Manismata PPMH landscape

- Stratum B (Upper/Main Canopy—Height 21 to >30 meters): This stratum is formed by *Elaeocarpus microphyllus* and *Artocarpus integer* individuals in the Tamtam Forest. With average stem diameters exceeding 50–70 cm, these trees successfully extend their crowns into the forest's uppermost layer (*emergent canopy*) to capture full sunlight.
- Stratum C (Middle/Intermediate Canopy – Height 11 to 20 meters): Densely populated by Tihang-phase vegetation as well as groups of trees with diameters ranging from 20–30 cm, such as groups *of Calophyllum inophyllum* in Air Dekakah and *Dehaasia sp.* in the Brupis Forest. This Stratum C canopy plays a crucial role in filtering direct sunlight to prevent it from drying out the forest floor.
- Stratum D (Lower Canopy / Understory – Height 1 to 10 meters): Occupied by all species in the *sapling* stratum and tall shrubs (such as *Melastoma malabathricum* at Air Dekakah). This layer is characterized by *shade-tolerant* plants as well as saplings waiting for the parent trees above to fall so they can gain access to sunlight.

Figure 18. A species of fig tree (*Ficus* sp.) found in the Brupis Forest

Analysis of diameter and height data from this study concludes that the Tamtam Forest represents an old-growth mixed secondary forest with a complete layered vertical structure dominated by large-diameter trees. Meanwhile, Air Dekakah exhibits a younger, denser stand structure that functions specifically as a hydrological green belt ( ) with uniform diameter dimensions. All of these dimensional data confirm that the growth capacity within the Manismata PPMH landscape remains within a balanced ecological range capable of supporting the long-term conservation of biodiversity.

4.2.3 Vegetation Regeneration

1. Stand Structure and Forest Vegetation Regeneration Patterns

Analysis of stand structure based on four growth stages—Seedling, Sapling, Pole, and Tree—serves as a fundamental indicator for assessing ecosystem health, community dynamics, and the natural regeneration capacity of a forest area. In general, natural forests in a stable and sustainable condition will form an inverted "J"-shaped curve. This pattern is characterized by a very high abundance of individuals at the seedling stage, which then gradually decreases at the sapling and pole stages, until reaching the lowest number at the mature tree stage.

Based on the results of the vegetation inventory in the Manismata PPMH landscape, the following are the characteristics and discussion of regeneration patterns at each study site:

a. Regeneration Patterns in the Tamtam Forest Area

The Tamtam Forest exhibits a community structure with a fairly dynamic regeneration trend, although it is influenced by the presence of anthropogenic vegetation (secondary commercial crops).

1. Tree Level: Absolutely dominated by *Elaeocarpus microphyllus* (Manggungan), with the highest Importance Value Index (INP) reaching 75.62% (KR: 19.81%, DR: 44.34%). The presence of large-diameter Manggungan trees forms the primary canopy structure. The second-most dominant species is *Artocarpus integer* (Cempedak) with an INP of 27.63%.
2. Pole Stage: A shift in dominance occurred, with *Hevea brasiliensis* (Rubber Tree) becoming the most dominant species with an INP of 42.20%, followed by *Dehaasia sp.* (Medang) with an INP of 36.63% and *Calophyllum inophyllum L.* (Punaga) at 35.42%.
3. *Sapling* Stage: The sapling group was again dominated by *Hevea brasiliensis* (INP: 24.76%) and *Dehaasia sp.* (INP: 19.41%). This indicates stable recruitment from the pole stage to the sapling stage for both species.
4. Seedling Layer: The lowest juvenile generation is dominated by native climax forest species, namely *Alseodaphne sp.* (Medang) with an INP of 32.02% and *Eugenia stafiana King* (Ribu-ribu) with an INP of 20.33%.

Figure 19. One of the fruiting trees in the Tamtam Forest

The vertical structure of the Tamtam Forest reflects the characteristics of an old-growth secondary forest that has experienced past human interference, marked by an abundance of rubber (*Hevea brasiliensis*) at the pole and sapling levels. However, autochthonous components (native to the natural forest), such as the Medang group (*Alseodaphne sp.* and *Dehaasia sp.*), exhibit a very strong pattern of *self*-recovery. This is evident from the abundance of Medang saplings in the seedling and sapling strata. The high stock of Medang saplings ensures that in the future, this forest community will recover to the characteristics of a climax tropical lowland forest, naturally displacing the dominance of rubber trees as the old rubber stands decline due to the end of their life cycle.

b. Regeneration Patterns in the Air Dekakah Forest Area

The Air Dekakah area exhibits distinct functional characteristics, where hydrologically protective vegetation plays a primary role at the tree level, while the understory is dominated by pioneer plants.

1. Tree Layer: The tree community is entirely dominated by *Calophyllum inophyllum L.* (Punaga) with a massive INP of 76.17%. This species is supported by *Archidendron clypearia* (Jengkol), which has an INP of 32.69%.
2. Pole Level: The consistent dominance of *Calophyllum inophyllum L.* (Punaga) continues at the pole level, with an INP surging to 96.45%, leading in density (KR: 33.33%) and basal area dominance (DR: 28.50%).

3. *Sapling* Level: Compiled data show that the abundance of mature Punaga individuals correlates with the high number of Punaga saplings on the forest floor, maintaining the continuity of the intermediate canopy.
4. Seedling Level: The forest floor is, in fact, aggressively dominated by the shrub/pioneer species *Melastoma malabathricum L.* (Karamunting) with the highest INP of 48.18%, followed by Punaga seedlings (INP: 37.07%).

Discussion (Air Dekakah):

The regeneration structure at Air Dekakah shows strong dominance of *Calophyllum inophyllum* (Punaga) from the tree to the pole stages. This phenomenon indicates that this zone is an optimal habitat for Punaga, which plays a crucial ecological role as a stabilizer of the watershed or catchment *area*.

However, the high INP *of Melastoma malabathricum* (Karamunting) at the seedling level indicates the presence of fairly open *canopy gaps* in some subplots, thereby stimulating the growth of *shade-intolerant* pioneer species. Nevertheless, Punaga regeneration continues to proceed safely, as Punaga seedlings rank second highest (37.07%), indicating strong competitive ability under shrub canopy cover.

c. Regeneration Patterns in the Brupis Forest Area

The Brupis Forest exhibits the most stable natural forest regeneration capacity and possesses a high level of species diversity.

1. Sapling Level: The sapling structure in Brupis is dominated by the climax species *Dehaasia sp.* (Medang) with an INP of 14.25%, followed by *Palaquium rostratum* (Nyatuh) with an INP of 11.15%, and *Popowia bancana* (Tugal) at 10.52%. The total species richness at the sapling stage is very high, reaching 54 species with a Pielou Evenness Index (E = 0.91$).
2. Seedling Stage: The seedling group was dominated by *Hevea brasiliensis* (Rubber) with an INP of 27.03%, closely followed by *Alseodaphne sp.* (Medang) at 26.00%, and *Dialium platysepalum Baker* (Kubing) at 12.44%. The total number of species at the seedling level reached 55 species ($H' = 3.16$).

Figure 20. One of the fruiting trees in the Brupis Forest

Discussion (Brupis):

The Brupis Forest exhibits highly ideal ecological signals of regeneration. The Shannon-Wiener diversity index (H') exceeding 3 (H' > 3) at both the seedling and sapling levels indicates that this ecosystem is highly stable and possesses high resilience to environmental pressures.

The presence of high-value commercial saplings from natural forests, such as *Palaquium rostratum* (Nyatuh) and *Dialium platysepalum* (Kubing), alongside the diversity of *the Lauraceae* family (Medang-medangan), demonstrates that the Brupis Forest functions as a critical biodiversity reservoir within the PPMH Manismata landscape. The abundance of sapling species (54–55 species) ensures that the stand succession cycle proceeds seamlessly without any loss of genetic diversity in the native flora.

2. Evaluation of Regeneration Success (Ecological Criteria)

In summary, the comparison of the regeneration status of the flora in the Manismata PPMH landscape is categorized into three main conditions:

1. Perfect Regeneration (Normal/Climax): Indicated by the genera *Dehaasia* and *Alseodaphne* (Medang) in the Tamtam and Brupis Forests. These species consistently rank at the top from the seedling, sapling, pole, to tree stages. This proves that

environmental factors (temperature, forest floor moisture, soil) strongly support the life cycle of the *Lauraceae* community.

2. Disrupted/Fragmented Regeneration (Corridor Pioneers): The massive presence of *Melastoma malabathricum* (Karamunting) at the seedling stage in Air Dekakah serves as a warning of physical forest disturbance (possibly due to historical land clearing or *edge effects*). If left unmanaged, this pioneer shrub species can hinder the growth of climax tree saplings.
3. Critical Species Requiring Attention (*Urgent Conservation*): The discovery of *Dipterocarpus sp.* (Kulim/Keruing) seedlings in the Tamtam Forest (INP: 6.84%) and Brupis Forest (INP: 1.22%) without the presence of mature trees or saplings in the sample areas indicates "disrupt*ed regeneration*." The parent trees of the *Dipterocarpaceae* family are likely located outside the plots or have been subjected to stress; therefore, the seeds that have fallen and grown into seedlings require strict protection of their microhabitat in order to survive and reach the sapling and pole stages.

3. Implications for Landscape Management at the Manismata PPMH

Based on the above regeneration analysis, the recommended species- and ecosystem-based management strategies are:

- Protection of Umbrella Species and Hydrological Functions: Preserving mature stands *of Elaeocarpus microphyllus* in Tamtam and *Calophyllum inophyllum* in Air Dekakah as the primary protective trees for water management and the microclimate.
- Intensive Silviculture and *Enrichment Planting*: Use seedlings of the Medang, Nyatuh, and Kubing species—which have been proven to possess high adaptability and regeneration capacity in the field—for the rehabilitation of degraded corridor areas.
- Protection of Critical Commercial Sapling Stands: Restricting operational activities in zones with an abundance of *Dipterocarpus sp.* seedlings (Brupis and Tamtam Forests) to prevent *the local extinction* of flora with high conservation value (NKT 1)

4.2.4 Importance Value Index (INP)

The species importance value, derived from a combination of calculations of tree density, tree frequency, and basal area, provides a comprehensive picture of the distribution, abundance, and dominance of a specific tree stand. The higher the species importance value, the higher the values for density (K), basal area (BA), and frequency (F) of its distribution.

4.2.4.1 Brupis Forest

In the Brupis Forest, we made 20 plots covering 0.8 ha for trees, 0.2 ha for poles, 0.05 ha for saplings, and 0.024 ha for seedlings, and we successfully identified 54 tree species, 44 poles species, 54 saplings species, and 55 seedling species.

Based on the Importance Value (INP) at the tree level in the Brupis Forest, the species *Hevea brasiliensis* dominates with a value of 61.02%, followed by *Polyalthia sumatrana* with an Importance Value Index of 19.31%. In general, the INP values for each species can be seen in Figures 21 and 22.

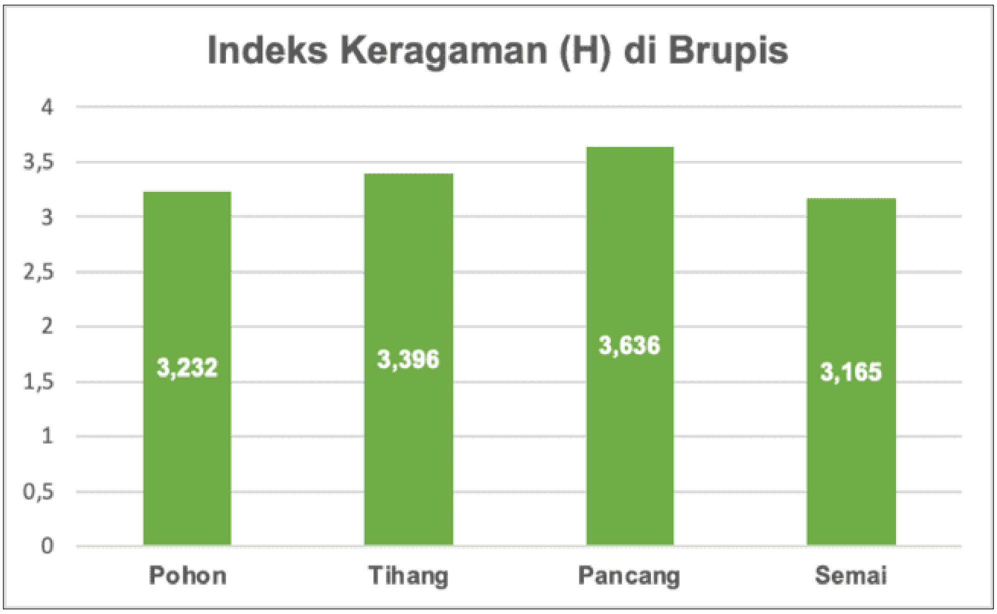

Figure 21. Diversity Index (H) for each stratum in the Brupis Forest

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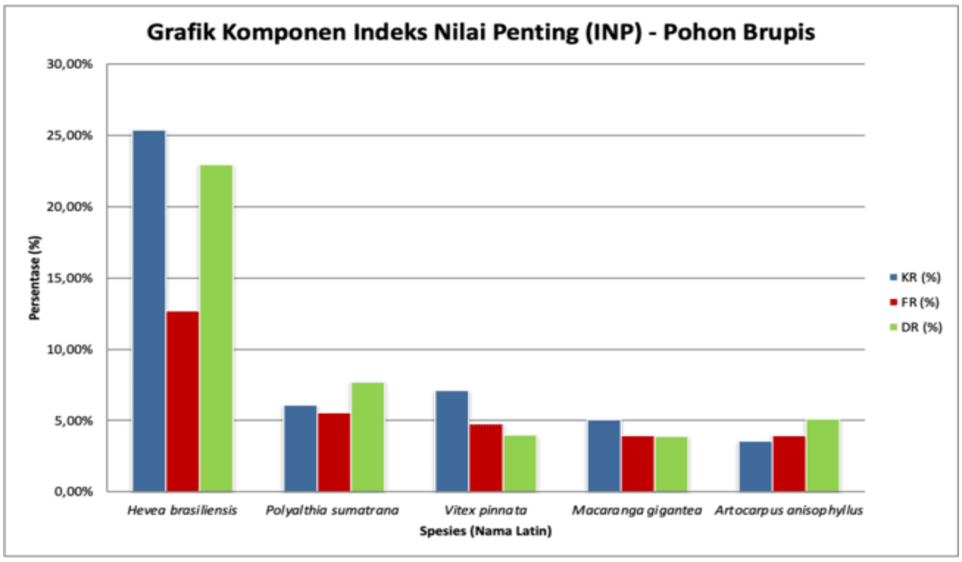
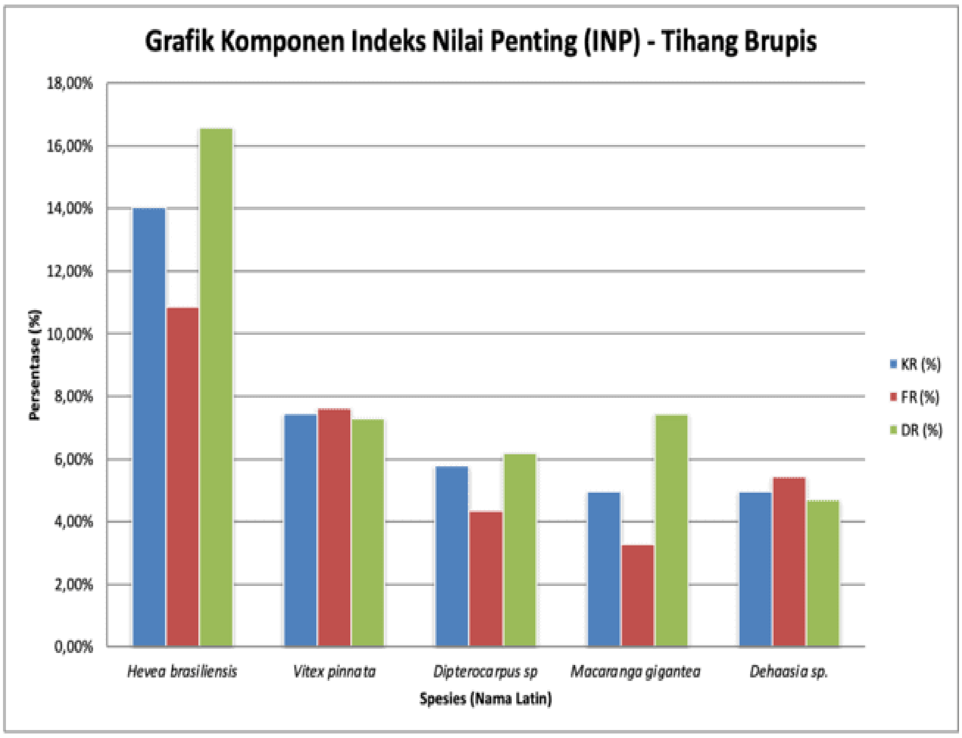
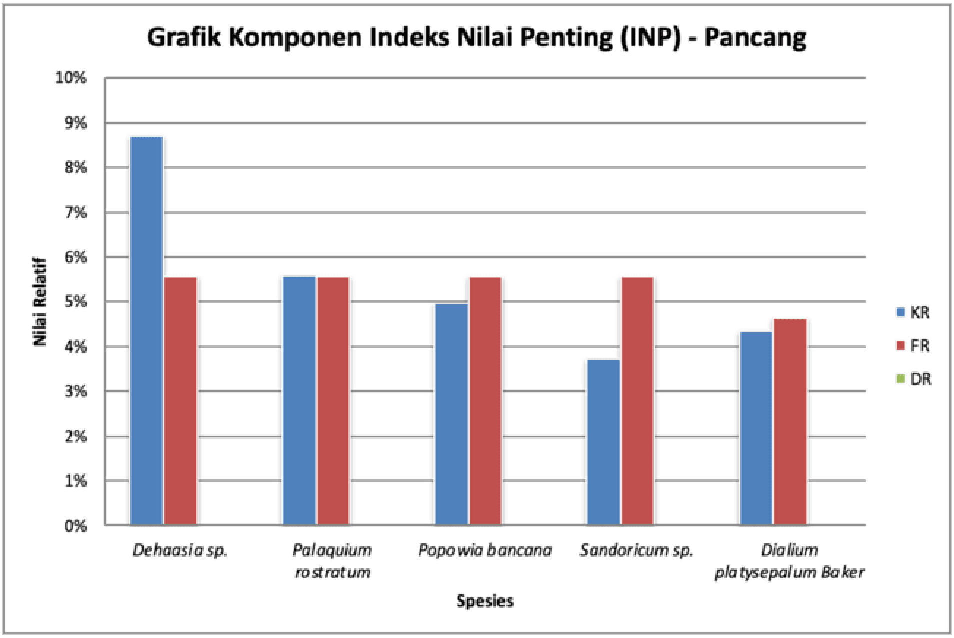
The Shannon-Wiener Diversity Index (H’) indicates the level of species diversity at a site. The higher the diversity value, the more species are found at that location, which also implies greater ecosystem resilience (Odum, 1993). According to Shannon–Weiner (1949) as cited in Sirait *et al.* (2018), a diversity index ranging from 2.19 to 3.6 indicates moderate diversity and a community with sufficient stability. Nevertheless, Rozak *et al.* (2020) note that plant diversity generally ranges from 1.5 to 3.5, and locations with a diversity index exceeding 3.5 are very rare. Diversity values across the life stages of tree, pole, sapling, and seedling in the Brupis Forest are high, indicating that the Brupis Forest has a diverse range of tree species and a stable ecosystem.

Furthermore, among this species diversity, several species were found to be the most dominant at each life stage, as indicated by high Importance Value Index (IVI) values. The IVI consists of density, frequency, and relative dominance, as shown in Figure 22







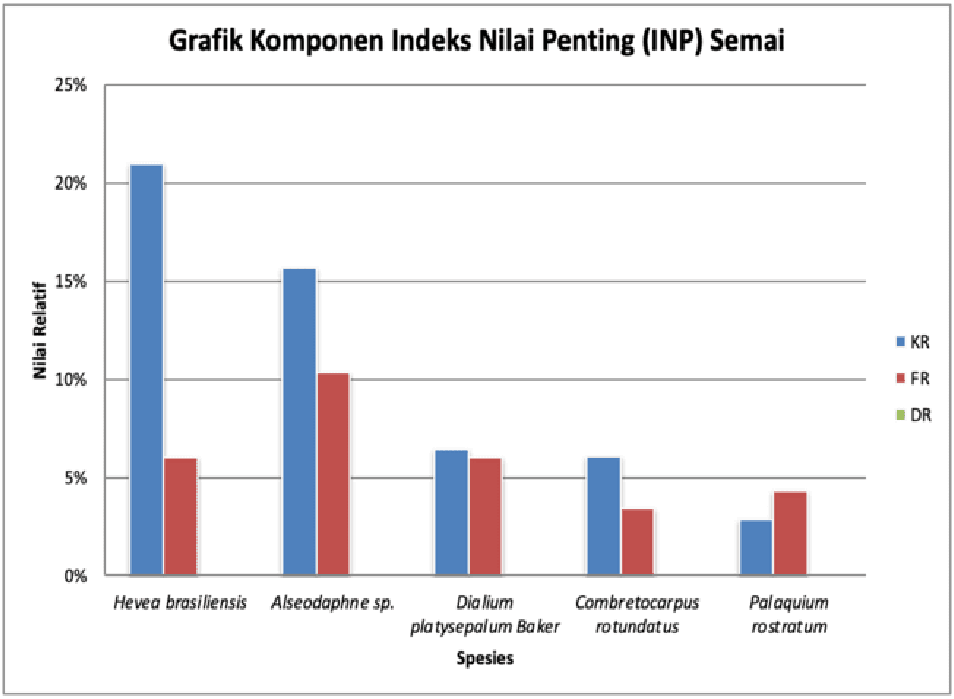


Figure 22. Graph of INP components for the Tree, Pole, Sapling, and Seedling stages in the Brupis Forest

4.2.4.2 Air Dekakah Forest

In the Air Dekakah Forest, we made 15 plots covering 0.6 ha for trees, 0.15 ha for saplings, 0.0375 ha for cuttings, and 0.018 ha for seedlings, and we successfully identified 22 tree species, 11 pole species, 22 sapling species, and 20 seedling species.

Based on the Importance Value (INP) at the tree level in the Air Dekakah Forest, the species *Calophyllum inophyllum* dominates with a value of 76.17%, followed by *Archidendron clypearia* with an Importance Value Index of 32.69%. In general, the INP values for each species can be seen in Figure 23 and Figure 24.

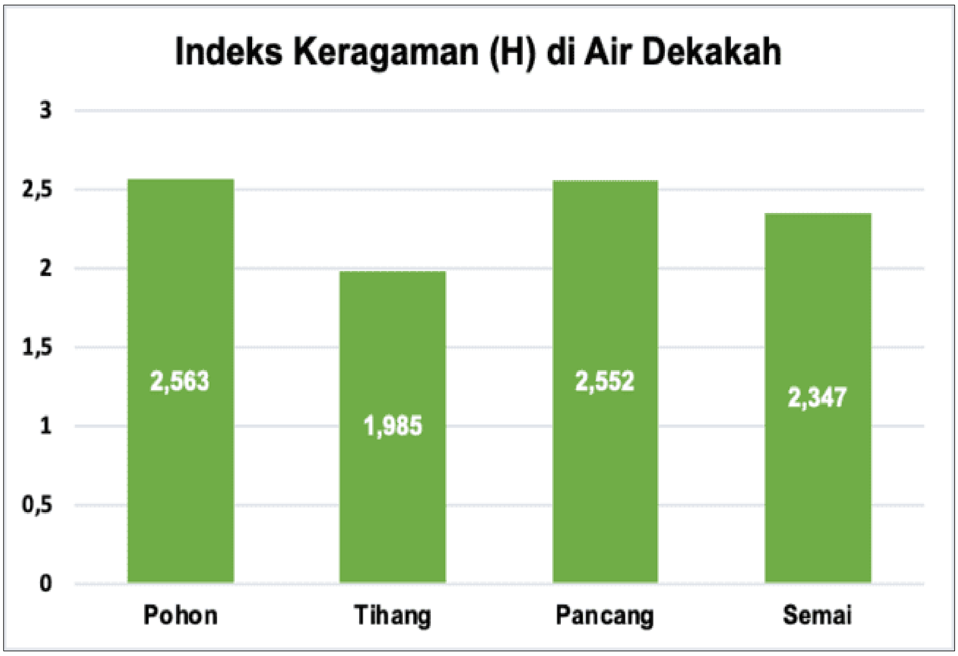
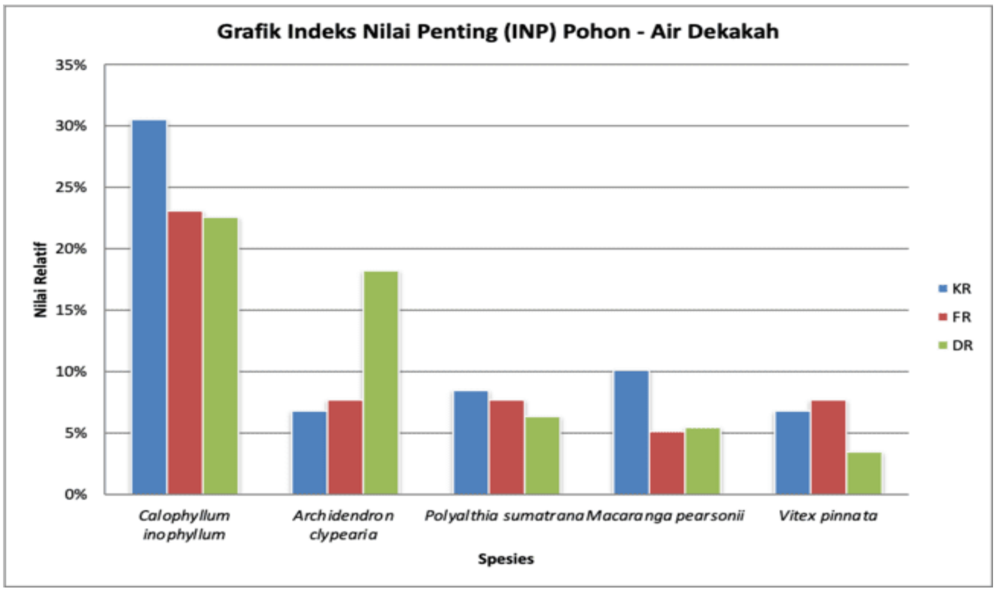
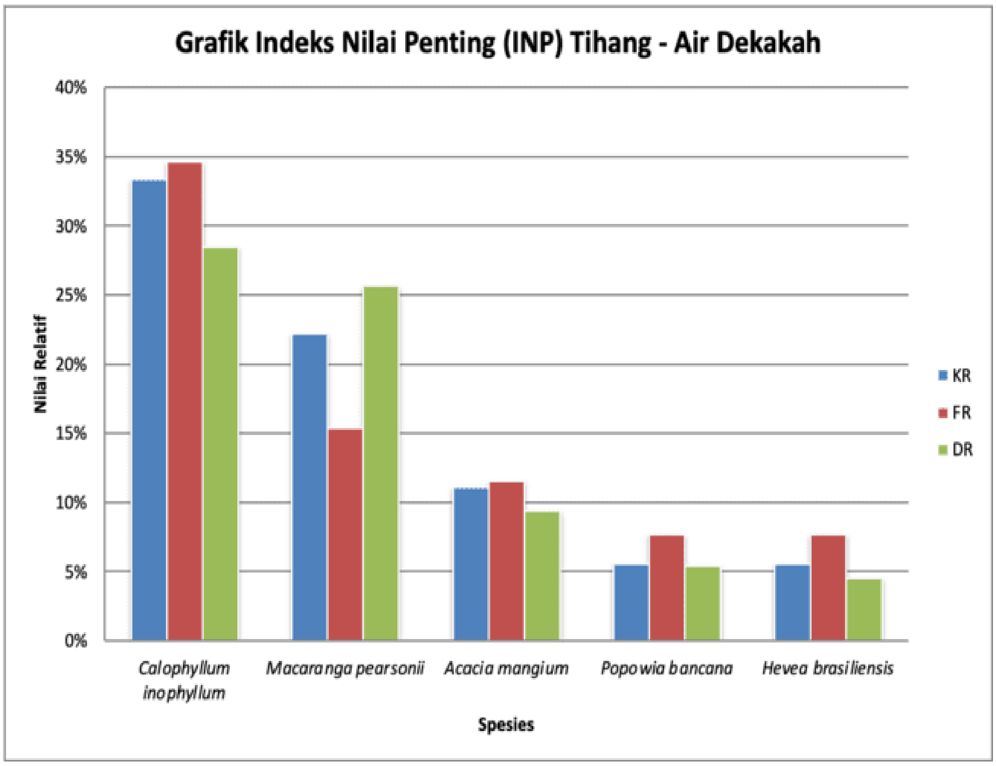


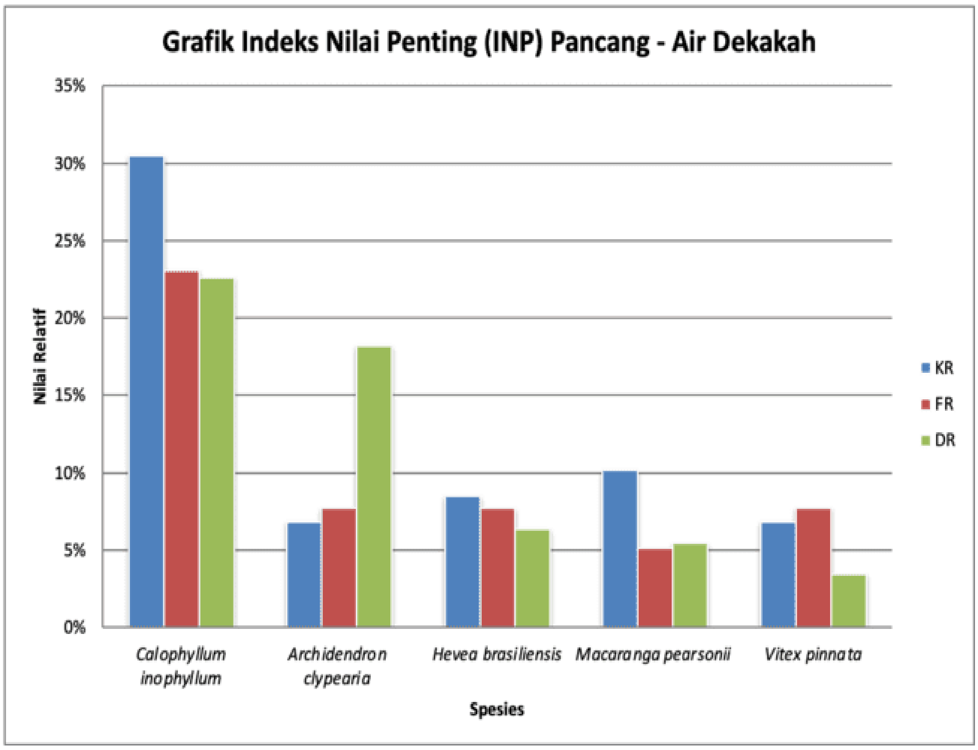
Figure 23. Diversity Index (H) for Each Stratum in the Air Dekakah Forest

The Shannon-Wiener diversity index (H') indicates a moderate level of species diversity across the life stages of trees—mature trees, saplings, and seedlings—in the Air Dekakah Forest. This suggests that the Air Dekakah Forest has a diverse range of tree species and a relatively stable ecosystem.

Furthermore, based on this species diversity, several dominant species were identified for each life stage, as indicated by high Importance Value Index (INP) values. The INP comprises density, frequency, and relative dominance, as shown in Figure 24.


Grafik Indeks Nilai Penting (INP) Pohon - Air Dekakah
35%
30%
25%
20%
15%
10%
5%
0%
Nilai Relatif
KR
FR
DR
Calophyllum inophyllum
Archidendron clypearia
Polyalthia sumatrana
Macaranga pearsonii
Vitex pinnata
Spesies


Grafik Indeks Nilai Penting (INP) Tihang - Air Dekakah
40%
35%
30%
25%
20%
15%
10%
5%
0%
Nilai Relatif
KR
FR
DR
Calophyllum inophyllum
Macaranga pearsonii
Acacia mangium
Popowia bancana
Hevea brasiliensis
Spesies



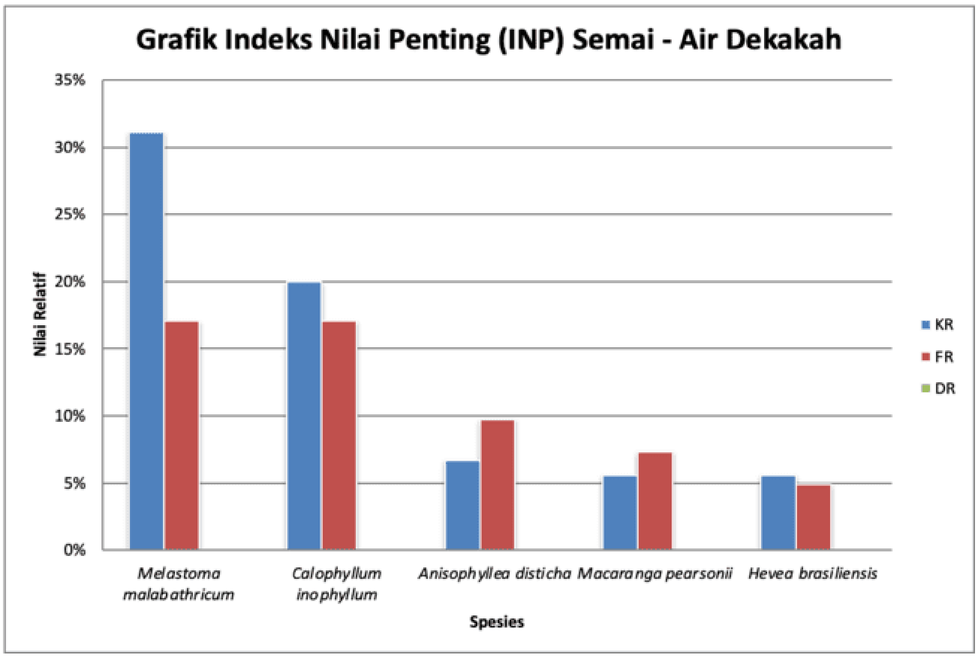


Figure 24. Graph of INP components for the Tree, Pole, Sapling, and Seedling stages in the Air Dekakah Forest

4.2.4.3 Tamtam Forest

In the Tamtam Forest, we made 10 plots covering 0.4 ha for trees, 0.1 ha for poles, 0.025 ha for saplings, and 0.012 ha for seedlings, and we successfully identified 32 tree species, 23 pole species, 32 sapling species, and 28 seedling species.

Based on the Importance Value (INP) at the tree level in the Tamtam Forest, the species *Elaeocarpus macrophyllus* dominates with a value of 75.62%, followed by *Artocarpus integer* with an Importance Value Index of 27.63%. In general, the INP values for each species can be seen in Figure 25 and Figure 26.

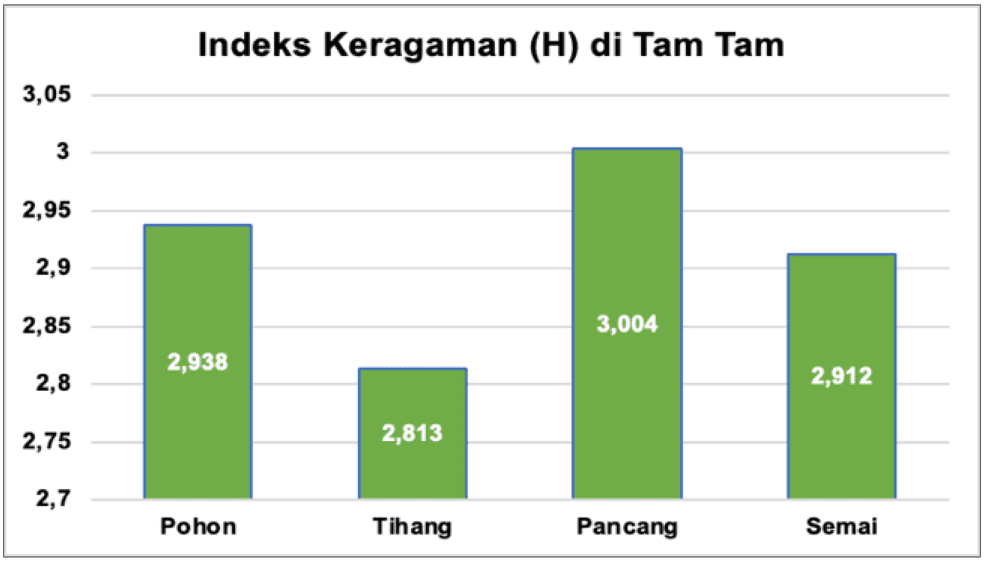
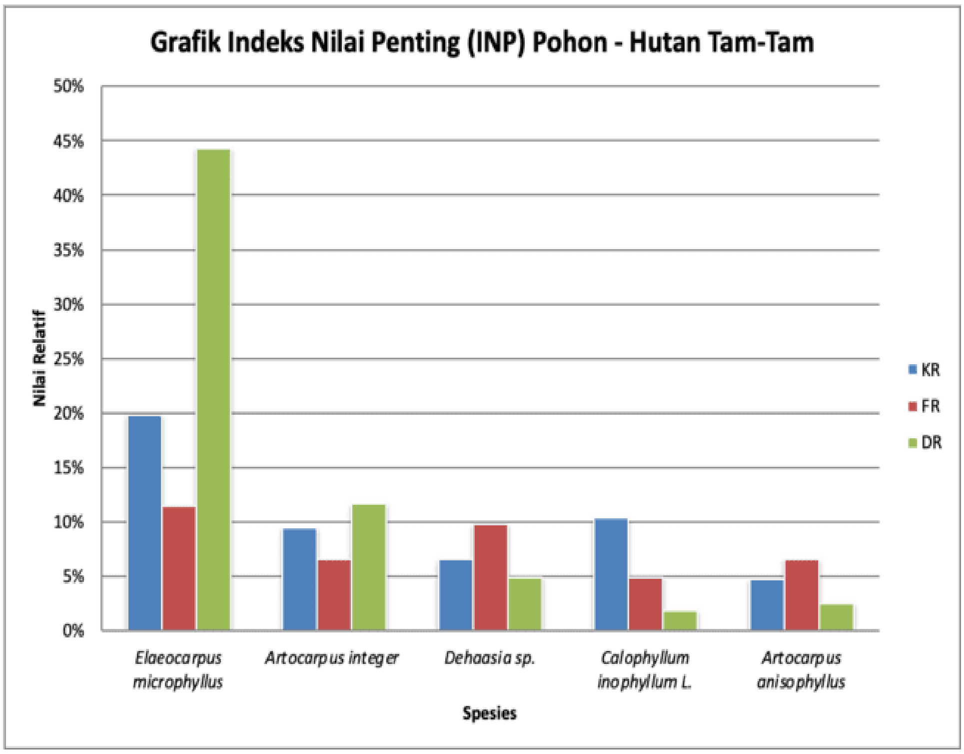
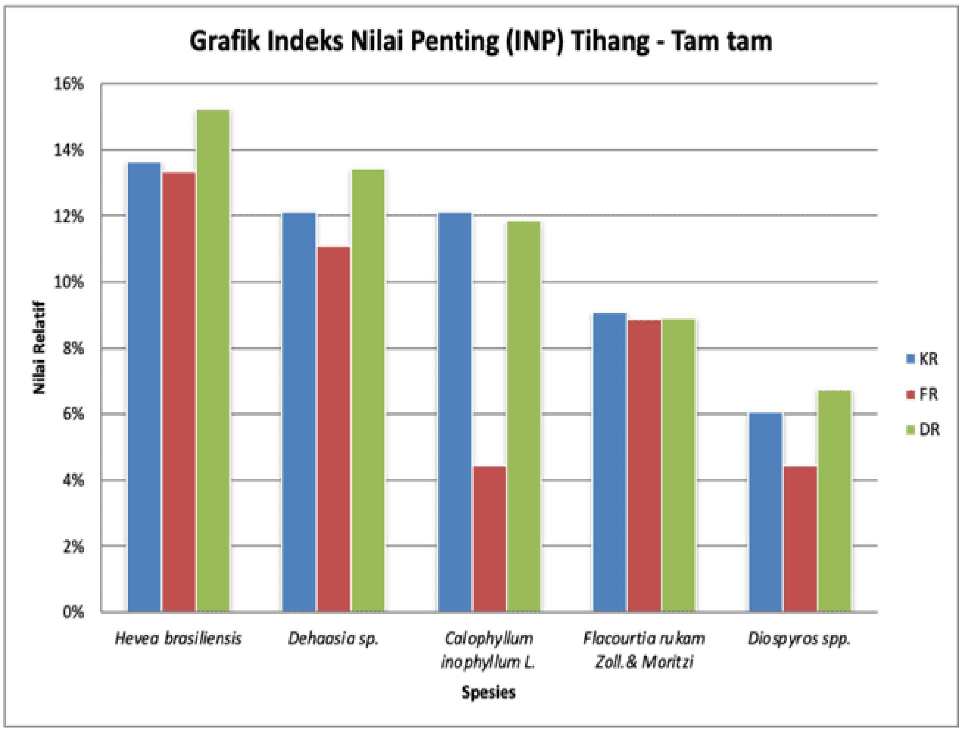


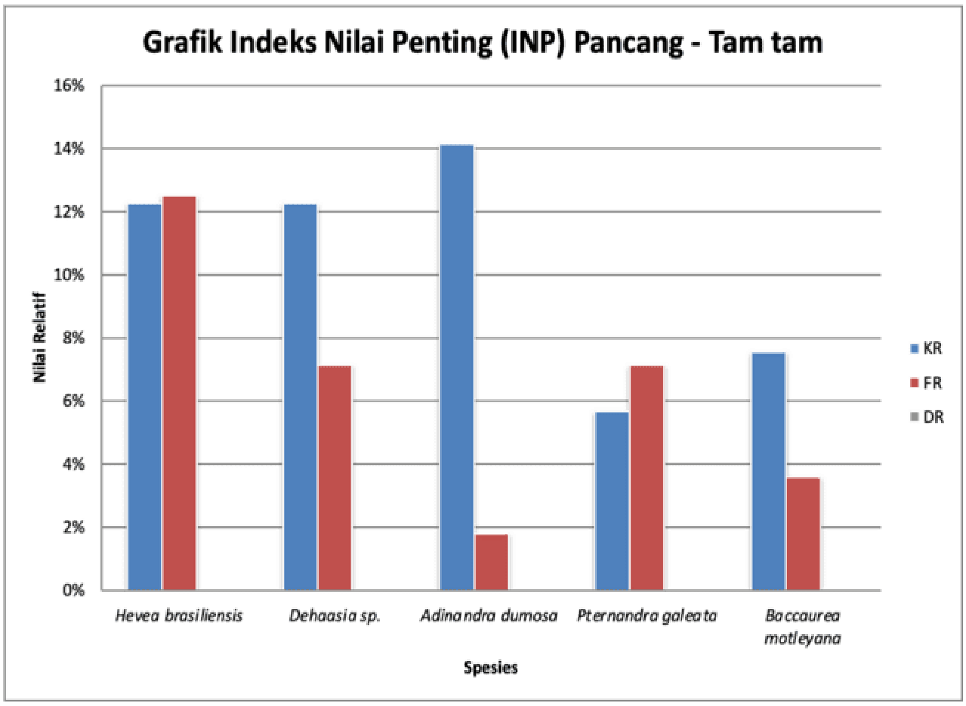
Figure 25. Diversity Index (H) in Tamtam

The Shannon–Wiener Diversity Index (H') indicates that species diversity at the sapling, young tree, and seedling life stages in the Tamtam Forest is moderate, while it is high at the mature tree life stage. This suggests that the Tamtam Forest has a diverse range of tree species and a relatively stable ecosystem.

Furthermore, based on this species diversity, several dominant species were identified for each life stage, as indicated by high Importance Value Index (INP) values. The INP consists of density, frequency, and relative dominance, as shown in Figure 26.


Grafik Indeks Nilai Penting (INP) Pohon - Hutan Tam-Tam
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Nilai Relatif
Elaeocarpus microphyllus
Artocarpus integer
Dehaasia sp.
Calophyllum inophyllum L.
Artocarpus anisophyllus
Spesies
KR
FR
DR


Grafik Indeks Nilai Penting (INP) Tihang - Tam tam
16%
14%
12%
10%
8%
6%
4%
2%
0%
Nilai Relatif
Hevea brasiliensis
Dehaasia sp.
Calophyllum inophyllum L.
Flacourtia rukam Zoll.& Moritzi
Diospyros spp.
Spesies
KR
FR
DR



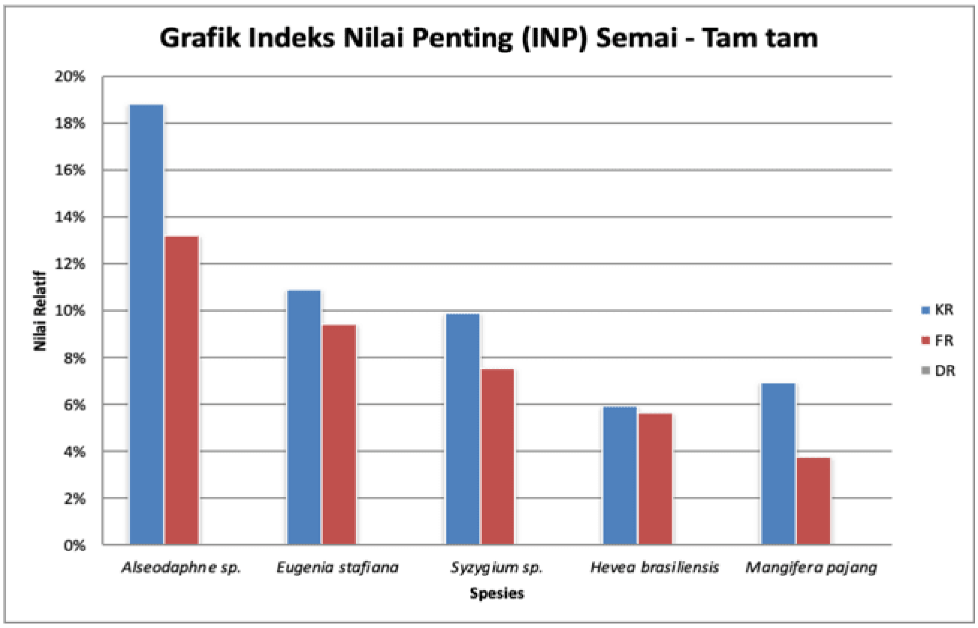


Figure 26. Graph of the IVI components for the Tree, Pole, Sapling, and Seedling stages in the Tamtam Forest.

4.2.5 Important Flora Species

Identification of important species was conducted to determine flora species with high conservation value and a strategic role in maintaining ecosystem functions within the PPMH Manismata landscape study area. This process was based on field survey results combined with national regulations (P.106/MENLHK/2018), global rarity status (IUCN Red List), and socio-cultural significance to the communities surrounding Manismata.

The following is a classification of important species successfully identified across all growth stages (Trees, Poles, Saplings, and Seedlings):

a. Species of High Conservation Value (NKT 1 / HCV 1) & Ecologically Dominant

Species in this category play a strategic role (*as keystone* or *umbrella species*) in maintaining the structure and function of ecosystem services because they dominate biomass, canopy cover, or provide key microhabitats in the study area.

- *Elaeocarpus microphyllus* (Manggungan): This is the most important and absolutely dominant species at the Tree level in the Tamtam Forest, with a Relative Density (RD) of 19.81% and a Relative Dominance (RD) of 44.34% (total INP: 75.62%). This species forms the upper canopy structure of the forest, which is crucial for the nests of arboreal fauna.
- *Calophyllum inophyllum L.* (Punaga): A key species found evenly across various zones. It is recorded as absolutely dominating the Tree layer in the Air Dekakah Forest (INP: 76.17%, KR: 30.51%, DR: 22.59%) as well as the Pole layer in Air Dekakah (INP: 96.45%, KR: 33.33%, DR: 28.50%). The presence of massive Punaga stands plays a vital role in stabilizing *the* local *catchment area.*

b. Threatened Species (Based on the IUCN Red List) and Endemic Species

Assessing the conservation status of vegetation components is a critical tool in determining High Conservation Value (*HCV 1*). By identifying flora classified as globally threatened according to the *International Union for Conservation of Nature* (IUCN) *Red List*, as well as species protected at the national level by the Government of Indonesia, management can formulate appropriate mitigation and spatial protection measures.

Figure 27. Ulin trees (*Eusideroxylon zwageri)* found at two locations in the Brupis Forest and the Tamtam Forest

Table 10. Conservation Status Table for Key Species in the Manismata PPMH Landscape

No	Scientific Name / Taxon	Local Name	IUCN Red List Status	National Status (P.106/2018)	Distribution, Presence, and Study Location
1	*Aquilaria malaccensis* Lamk.	Gaharu	Critically Endangered (CR)	Protected	Brupis / Tamtam Forest
2	*Shorea balangeran*	Balangeran / Kahoi	Vulnerable (VU)	Protected	Air Dekakah / Brupis
3	*Eusideroxylon zwageri*	Ulin / Kayu Besi	Vulnerable (VU)	Not Protected	Brupis / Tamtam Forest
4	*Shorea leprosula* Miq.	Meranti Merah	Near Threatened (NT)	Not Protected	Brupis Forest
5	*Shorea platycarpa* Heim.	Meranti Rawa	Critically Endangered (CR)	Not Protected	Brupis
6	*Shorea parvifolia* Dyer	Meranti Sarang Punai	Near Threatened (NT)	Not Protected	Brupis Forest
7	*Dipterocarpus sp.*	Keruing / Kulim	*Varies* (VU/CR)	Not Protected	Brupis / Tamtam Forest
8	*Alstonia pneumatophora* Backer	Pulai Rawa	Least Concern (LC)	Protected	Air Dekakah / Tamtam
9	*Palaquium rostratum*	Nyatuh / Kanjangan	Least Concern (LC)	Not Protected	Brupis Forest

Categories in the IUCN Red List define a species' risk of global extinction based on population decline rates and habitat fragmentation. The Manismata PPMH landscape has been shown to provide a refuge for several taxa with high threat status:

A. Critically *Endangered* (CR)

Two species with the highest global threat status are found in this landscape: *Aquilaria malaccensis* (Gaharu) and *Shorea platycarpa* (Meranti Rawa).

- *Aquilaria malaccensis* has experienced a drastic global population decline due to overexploitation from the illegal trade in agarwood resin. The presence of saplings or stands of this species in the Brupis/Tamtam Forest confers high international conservation significance on the area.
- *Shorea platycarpa*, a representative of the *Dipterocarpaceae* family, is critically endangered due to the loss of peat swamp and pamah forest habitats in Southeast Asia. These stands must be protected from any land-clearing plans.

B. *Vulnerable* (VU)

This group is represented by *Eusideroxylon zwageri* (Ulin) and *Shorea balangeran* (Balangeran).

- Ulin, despite its legendary wood durability, is *a slow-growing species* with limited seed dispersal; consequently, if harvested, it would take hundreds of years for its population to recover.
- *Shorea balangeran* is highly adapted to the water/swamp transition zones in Air Dekakah and Brupis Forest, but its population is vulnerable to pressure from changes in the landscape's hydrological functions

The Ministry of Environment and Forestry Regulation No. P.106/MENLHK/SETJEN/KUM.1/12/2018 is the most recent regulation revising P.20 and P.92, which establishes strict criminal penalties for the illegal use of listed species. There are unique points of convergence (as well as differences) between national law and the IUCN global status at the study site:

1. Brupis Forest

The Brupis Forest has been identified as the area with the highest conservation significance within the Manismata PPMH landscape. Its structural characteristics, which resemble those of a lowland primary forest, make it a last refuge for species that are globally endangered or nationally protected.

A. Compilation of Species with Special Status

Based on taxonomic data collected at the seedling and sapling levels, the following are the target species for conservation in the Brupis Forest:

- *Aquilaria malaccensis* (Gaharu): Listed as Critically Endangered (CR) on the IUCN Red List and officially protected by the Government of Indonesia under Ministry of Environment and Forestry Regulation P.106/2018.
- *Shorea platycarpa* (Meranti Rawa): Listed as Critically Endangered (CR) on the IUCN Red List (not protected under Ministerial Regulation P.106/2018).
- *Eusideroxylon zwageri* (Ulin / Kayu Besi): Listed as Vulnerable (VU) on the IUCN Red List (not protected under P.106/2018).
- *Shorea balangeran* (Balangeran): Listed as Vulnerable (VU) on the IUCN Red List and protected under P.106/2018.
- *Shorea leprosula* (Meranti Merah) & *Shorea parvifolia*: Listed as Near Threatened (NT) according to the IUCN Red List.

The abundance of saplings from the *Dipterocarpaceae* family (*Shorea* genus) and *Lauraceae family* in the Brupis Forest, combined with the presence of critically endangered species such as Agarwood (*Aquilaria malaccensis*) and Swamp Meranti (*Shorea platycarpa*), confirms that this area meets the criteria for High Conservation Value (HCV 1.2), namely an area that harbors populations of threatened species.

Although Ulin (*Eusideroxylon zwageri*) and Swamp Meranti are no longer listed under the P.106/2018 protection decree, their global threat status—which places them on the brink of extinction (VU and CR)—requires management to designate the Brupis Forest as a Strict Conservation Zone. The presence of *Dipterocarpus sp.* seedlings also requires intensive protection to ensure that these young trees successfully grow into mature trees without being disturbed by surrounding operational activities.

2. Tamtam Forest

The Tamtam Forest is a prime example of a lowland secondary forest with strong natural recovery dynamics. This area is characterized by a mix of historical commercial vegetation (rubber) and native forest elements of conservation value.

In the Tamtam Forest area, several species of concern under international and national regulations include: *Aquilaria malaccensis* (Gaharu): Listed as Critically Endangered (CR) by the IUCN and protected under P.106/2018. Found in the understory sapling stage.

- *Alstonia pneumatophora* (Pulai Rawa): Listed as Least Concern (LC) on the IUCN Red List, but legally protected under P.106/2018 due to its role in regulating the ecosystem's water management.
- *Eusideroxylon zwageri* (Ulin): Listed as Vulnerable (VU) on the IUCN Red List.
- *Dipterocarpus sp.* (Keruing): Classified as Vulnerable/Critically Endangered (VU/CR) depending on the species' global status.

An interesting phenomenon is observed in the Tamtam Forest, where the canopy is dominated by Manggungan (*Elaeocarpus microphyllus*), but at the seedling and sapling levels, high-value species such as Gaharu and Keruing (*Dipterocarpus sp.*) are beginning to emerge. This indicates positive succession, where native vegetation is beginning to recolonize the area following disturbance.

The presence of Pulai Rawa (*Alstonia pneumatophora*), which is protected by law, serves as a key *compliance* anchor for the company. In accordance with Law No. 5 of 1990 and Ministry of Environment and Forestry Regulation P.106/2018, logging of Pulai species is strictly prohibited. Management is recommended to implement *Enrichment Planting* by utilizing local Medang and Ulin seedlings to accelerate the recovery of this secondary forest's canopy structure.

3. Air Dekakah Forest

The Air Dekakah Forest serves a specific function as a riparian ecosystem. Rigorous natural selection resulting from water fluctuations limits the number of species in this area, yet it serves as a crucial habitat for key riparian species that are threatened with extinction.

Although its species richness is relatively lower, Air Dekakah concentrates its populations on species of high conservation value:

- *Shorea balangeran* (Balangeran / Kahoi): Listed as Vulnerable (VU) on the IUCN Red List and included in the Protected Species List under P.106/2018.
- *Shorea platycarpa* (Swamp Meranti): Listed as Critically Endangered (CR) on the IUCN Red List.
- *Alstonia pneumatophora* (Pulai Rawa): Listed as Least Concern (LC) on the IUCN Red List and protected under P.106/2018.

The Dekakah River is dominated by *Calophyllum inophyllum* (Punaga) from the canopy to the understory, indicating the area's important role as a hydrological stabilizer. However, from a conservation perspective, the presence of *Shorea balangeran* (Balangeran) and *Alstonia pneumatophora* (Pulai)—both protected under Law No. — underscores that Air Dekakah must be managed as a Riparian Buffer Zone.

Meranti Rawa (*Shorea platycarpa*), which has a global Critically Endangered (CR) status, also relies on this wetland area for its survival. The primary recommendation for the Air Dekakah Forest is to completely prohibit all forms of land conversion or physical disturbance within a radius of at least 50–100 meters from the water's edge. The massive presence of Karamunting shrubs (*Melastoma malabathricum*) at the seedling stage must be controlled so as not to hinder the growth (succession) of the protected Balangeran and Pulai tree seedlings.

- The Brupis Forest functions as *a Reservoir Core* (Core Zone of High Biodiversity & Critical Species).
- The Tamtam Forest functions as *a Recovery Zone* (Zone for the Recovery and Succession of Natural Commercial Flora).
- The Air Dekakah Forest functions as *a Hydrological Buffer Zone* (Hydrological Protection Zone & Protected Riparian Flora).

c. Climax Community Species and Natural Forest Regeneration

These are flora species that serve as indicators that forest succession is proceeding well and that the ecosystem has the ability to recover on its own (*self-healing ecosystem*).

- *Dehaasia sp.* & *Alseodaphne sp.* (Medang): These genera from the *Lauraceae* family are evenly distributed across all growth stages in the Tamtam and Brupis Forests. They rank among the top 5 species at the Tamtam Pole stage (INP: 36.67%), Tamtam Stake stage (INP: 19.41%), and Tamtam Seedling stage (INP: 32.02%). In the Brupis Forest, *Dehaasia sp.* leads the Pancang level with the highest INP (14.25%). Its presence ensures the supply of future tree regeneration.
- *Palaquium rostratum* (Nyatuh): A high-value plant species found abundantly at the Pancang stage in the Brupis Forest, ranking second highest (INP: 11.15%).

d. Species Important to Local Culture and the Subsistence Economy

Plant species utilized by communities around Manismata Subdistrict to meet non-timber needs, for seasonal fruit, or as food for wild honeybees (Sialang Tree).

- *Artocarpus integer* (Cempedak): Holds significant cultural and seasonal food value for the local community. Mature stands are abundant at the “ ” and “Pohon” stages in the Tamtam Forest (second-highest INP: 27.63%), and there is a secure stock of young trees at the “Pancang” (INP: 7.35%) and “Semai” (INP: 8.63%) stages.
- *Archidendron clypearia* (Jengkol): Identified at the “Tree” level in Air Dekakah with high dominance values (DR: 18.22%, INP: 32.69%), representing the potential for non-timber forest products (NTFPs) based on local knowledge.
- *Mangifera pajang Kosterm.* (Mawang): An exotic fruit endemic to Kalimantan, identified as one of the top five most important species at the seedling stage in the Tamtam Forest (INP: 10.70%).

e. Integrated Exotic/Introduced Species

Hevea brasiliensis (Rubber): An introduced species that has become massively naturalized in the Manismata landscape. This species stands out at the Tiang Tamtam level (INP: 42.20%) and the Pancang Tamtam level (INP: 24.76%), and leads in dominance at the seedling level in the Brupis Forest (highest INP: 27.03%). Its presence reflects the history of traditional agroforestry land use by local communities.

2. Conservation Priority Analysis

Based on the distribution data above, conservation priorities were established to optimize the management plan for the Manismata PPMH area:

Table 11. Conservation Priorities for the Manismata PPMH Area

Urgency Level	Flora Species Groups	Ecological Justification & Technical Criteria	Land Corridor / Stratum	Focus of Management Actions
PRIORITY I (Highest / Critical)	Dipterocarpus sp. (Kulim/Keruing), Sindora sp. (Sindur)	Listed as globally endangered (IUCN Red List). Their seedlings are highly vulnerable to trampling, fragmentation, or outcompetition by weeds if the upper canopy is cleared.	Seedlings (Tamtam & Brupis), Trees (Air Dekakah)	• Strict protection of microhabitats. • Prohibition on the felling of *seed trees*. • Periodic monitoring of *survival rates*.
PRIORITY II (Medium / Strategic)	Elaeocarpus microphyllus (Manggungan), Calophyllum inophyllum (Punaga), Dehaasia sp. (Medang)	Keystone species of the local ecosystem with the highest INP value. Damage to mature stands of this group will collapse the lower canopy structure and trigger the degradation of hydrological ecosystem services.	Tree & Pole (Tamtam & Air Dekakah), Pancang (Brupis)	• Designation of local protected areas or High Conservation Value Forests (HCVF). • Enrichment *planting* in degraded areas using Medang and Punaga species.
PRIORITY III (Monitoring / Sustainable Use)	Artocarpus integer (Cempedak), Mangifera pajang (Mawang), Archidendron clypearia (Jengkol)	Species of high value for meeting the traditional food needs of local communities, with a fairly stable natural regeneration pattern from seedling to mature tree.	All Strata (Especially in the Tamtam Forest)	• Collaborative management with local communities (*community-based conservation*). • Zoning regulations for the traditional harvesting of non-timber fruits to ensure they do not disrupt the forest's core stands.

The results of this conservation priority identification and analysis provide a scientific strategic foundation for formulating the following policies:

1. Integration into the Area Management Plan: Designating the distribution zones of threatened commercial tree species (*Dipterocarpus sp.*) and hydrologically protective trees (*Calophyllum inophyllum*) as the core zone of the conservation area, which must remain undisturbed.
2. Species-Based Management Strategy: Develop standard operating procedures (SOPs) for the special protection of seedlings (saplings and young trees) of the Medang (*Dehaasia sp.*) and Nyatuh (*Palaquium rostratum*) species in the Brupis and Tamtam Forests to prevent them from being displaced by potential expansion of operational activities.
3. Biodiversity and Ecosystem Sustainability: Data on the abundance of dominant species (such as *Elaeocarpus microphyllus*) are used as *baseline data* in periodic environmental monitoring documents (UKL-UPL/AMDAL) to demonstrate PPMH Manismata's commitment to meeting palm oil and forestry sustainability certification standards (*sustainability compliance*).

4.3 Faunal Diversity

Survey activities in the three Sacred Forest areas included the inventory and identification of fauna species diversity in the study target areas. The fauna groups targeted in this study were:

A. Mammals
B. Birds
C. Amphibians
D. Lepidoptera

These fauna groups were selected because they are relatively easy to identify in the field and require a relatively short observation period; thus, their species diversity can serve as a reference for characterizing the state of biodiversity in the three Sacred Forest areas.

4.3.1 Mammals

Observations of mammal species diversity in the study areas across the three locations within the Sacred Forests were conducted along pre-planned transects and at other sites where information on mammal presence was expected to be obtained. Mammals are generally more difficult to observe than birds, and there are various methods for observing and studying them. The best approach depends on the mammal species and its preferred habitat; most mammal species are found in lowland rainforests, while fewer species are found in kerangas forests or swamp forests. Many mammal species are able to adapt to changes in habitat (generalist species) and are often easily spotted in secondary forests or even plantations.

Based on size, mammals are divided into small and large mammals. According to the International Biological Program's definition, small mammals are those with an adult body weight of less than five kilograms, while the rest are classified as large mammals (Amir, 1978). This study focuses on mammal species diversity based on each mammalian order. Each mammal species has a specific distribution range based on geographical and ecological conditions (Heaney et al., 1998). The distribution of mammal species based on ecological factors can be determined through the vegetation composition of a given habitat type. Jati (1998) states that the correlation coefficient between plants and mammals is high at 0.799. This value indicates that mammals' dependence on plants is quite high. The ways in which mammals depend on the presence of plants ( ) include: as a food source, a place to sleep, and for shelter from predators.

To survey the biodiversity of wild mammals at the three locations in the Sacred Forest, two observation methods were used: indirect observation (footprints, droppings, scratch marks, sounds, calls, etc.) and direct field observation. Combined observations were also conducted at night by traversing forest trails with the aid of flashlights.

Indirect observations of terrestrial mammals were also made by looking for *signs* indicating their presence at the observation sites, including *footprints* sought on sandy soils, muddy soils, riverbanks, and other bodies of water. Other signs include scratch marks, bite marks on tree trunks and fruit, nest holes, and *feces*.

Figure 28. A Tarsius primate (*Tarsius bancanus*) encountered in the Larangan Forest

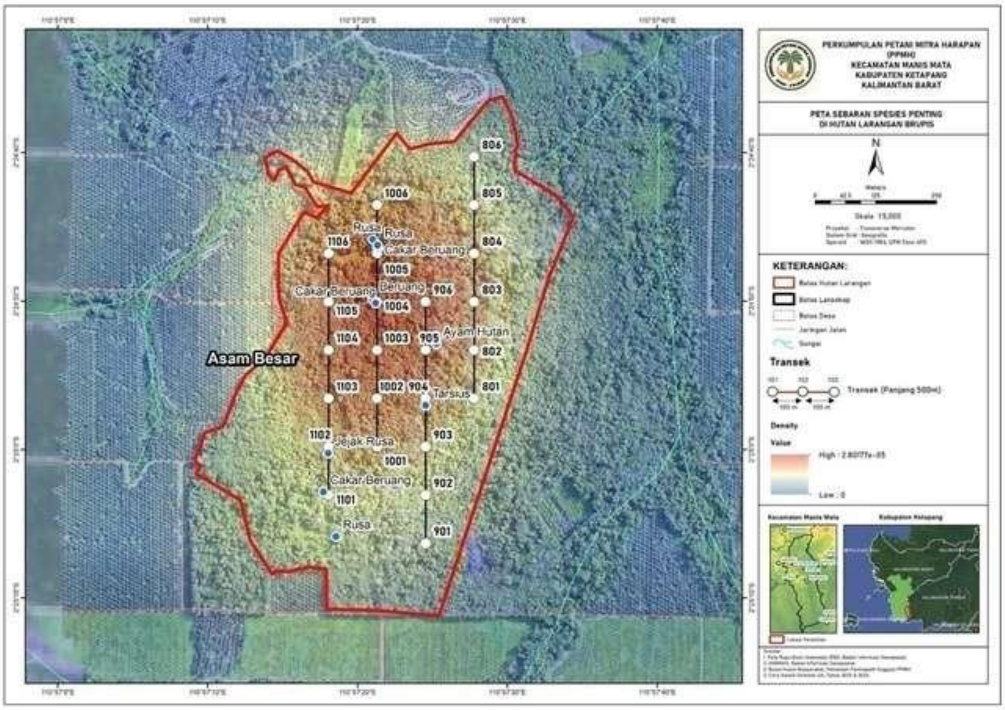


Figure 29. Map of the Distribution of Key Species in the Brupis Sacred Forest

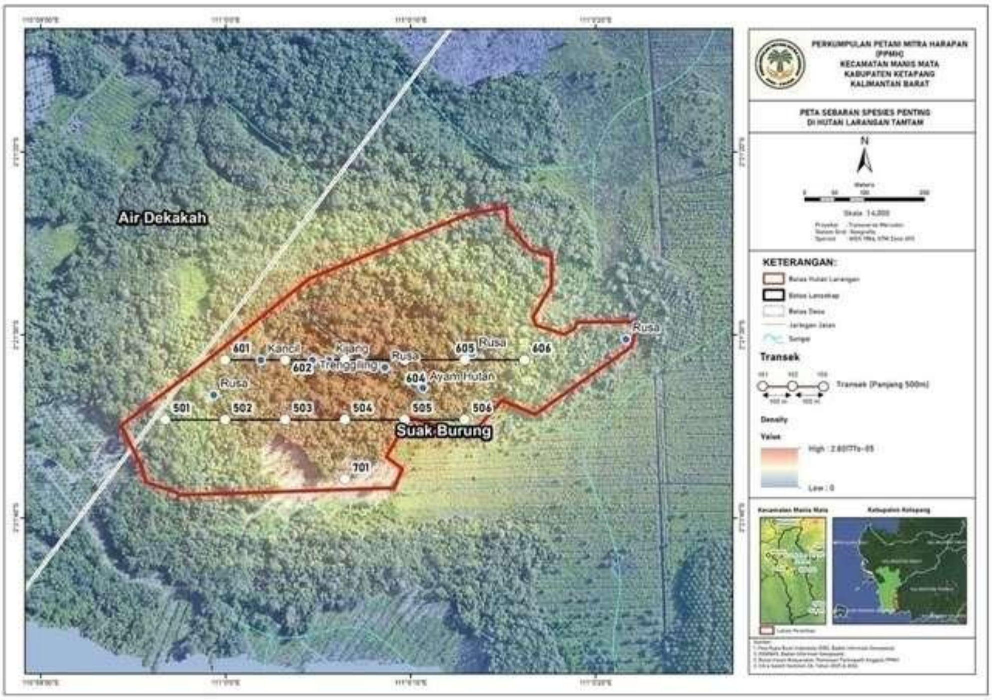


Figure 30. Distribution map of key species in the Tamtam Sacred Forest

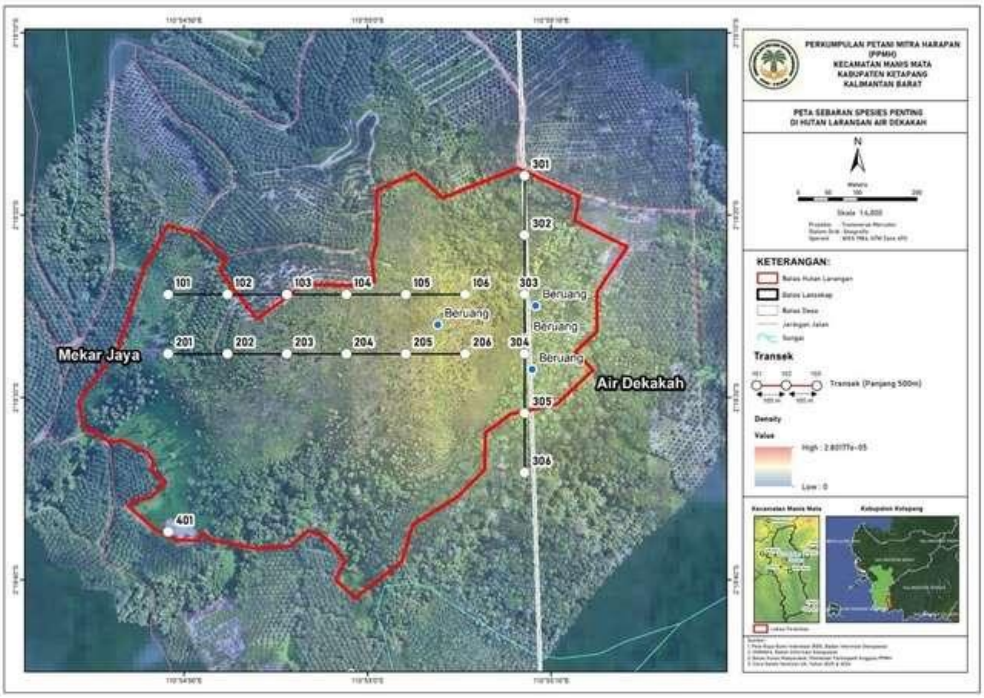


Figure 31. Distribution map of key species in the Air Dekakah Sacred Forest

A total of 12 species of terrestrial mammals were successfully detected, primarily at observation sites that still consist of natural forest cover. Based on their conservation status, 8 of these 12 mammal species are nationally protected under Indonesian Government Regulation No. 7 of 1999, namely the Tarsius (*Tarsius bancanus*), the Sun Bear (*Helarctos malayanus*), the Napu Mouse-deer (*Tragulus napu*), the *Javan* Pangolin (*Manis javanica*), Sambar Deer (*Rusa unicolor*), and Muncak Deer (*Muntiacus muntjak*). One species is classified as “Endangered” on the IUCN Red List: the Pangolin.

In general, the number of mammal species and the number of protected mammals are divided into three groups: herbivores, carnivores, and omnivores. In all three Sacred Forest areas, there is still variation in mammal diversity based on their feeding patterns. This can serve as an indicator that the food chain and ecosystem networks in these areas are still functioning relatively well. On the other hand, although several protected species have been found, they generally belong to the generalist group (Muntjac, Sambar Deer, Napu Muntjac, and Tarsier)—that is, species with diverse feeding patterns or those with a higher adaptive capacity to their environment.

Table 12 provides information on the presence of terrestrial mammal groups in the Sacred Forest area based on direct observations as well as indirect observations (tracks, scratch marks, droppings, sounds, interviews, and other data). Table 12 also includes information on their conservation status according to the IUCN Red List and their national status, as referenced in Ministry of Environment and Forestry Regulation No. P.20/MENLHK/SETJEN/KUM.1/6/2018 *as amended* by P.92/MENLHK/SETJEN/KUM.1/8/2018 *and* P.106/MENLHK/SETJEN/KUM.1/12/2018 Regarding Protected Plant and Animal Species.

Table 12. List of mammal species successfully identified in the Sacred Forest area.

No.	Species Name		Family	Status		Method Observation
	Local	Latin		National	IUCN	
1	Tarsius	*Tarsius bancanus*	Tarsiidae	D	Vu	Direct Observation
2	Kera Ekor Panjang	*Macaca fascicularis*	Cercopithecidae	TD	LC	Calls
3	Pelanduk Napu	*Tragulus napu*	Tragulidae	D	LC	Footprints
4	Rusa Sambar	*Unicolor Deer*	Cervidae	D	Vu	Tracks
5	Kijang Muncak	*Muntiacus muntjak*	Cervidae	D	LC	Traces
6	Babi Berjenggot	*Sus barbatus*	Suidae	TD	Vu	Footprints and wallows
7	Pelanduk kancil	*Tragulus javanicus*	Tragulidae	D	DD	Traces
8	Jelarang	*Ratufa affinis*	Sciuridae	TD	NT	Direct Observation
9	Bajing Kerdil	*Exilisciurus exilis*	Sciuridae	TD	DD	Direct Observation
10	Beruang Madu	*Helarctos malayanus*	Ursidae	D	Vu	Direct observation, claw marks
11	Trenggiling	*Manis javanica*	Manidae	D	En	Nest, Claw marks
12	Tenggalung Malaya	*Viverra tangalunga*	Viverridae	D	LC	Tracks, Claw marks

Notes:
D: Protected, TD: Not Protected
LC: *Least Concern* Vu: *Vulnerable*
NT: Near Threatened *En*: *Endangered* (Critically Endangered)
Conservation statuses *LC, Vu, NT,* and *En* according to the IUCN Red List.

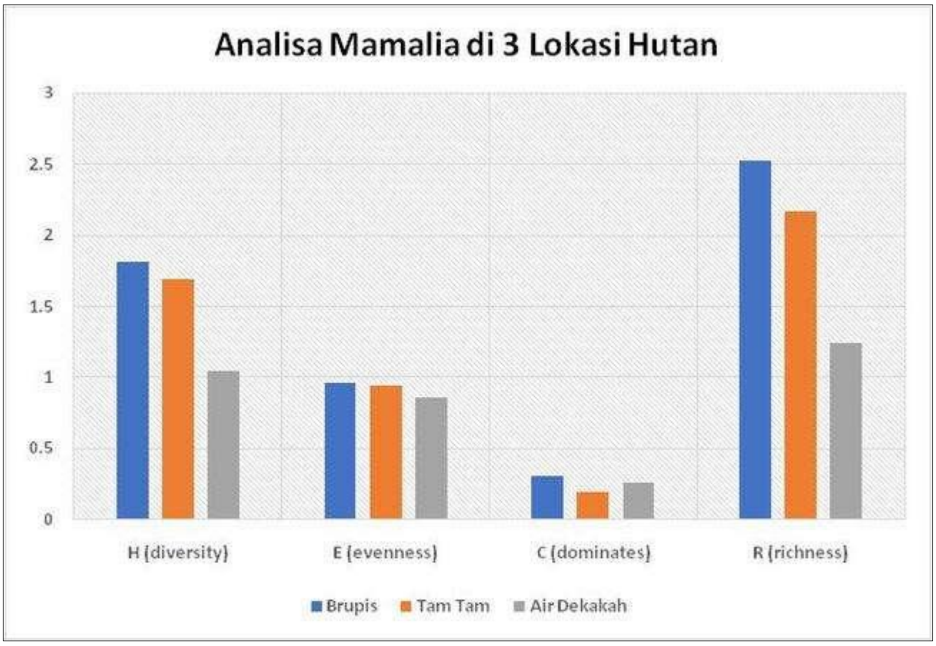


Figure 32. Results of Mammal Analysis at Three Sacred Forest Locations

4.3.2 Birds

Tropical rainforests are important habitats for birds and other wildlife, as these areas are densely covered with vegetation that serves as a food source and shelter. Birds provide significant benefits to communities, including helping to control insect pests, aiding in flower pollination, and having economic value. Birds can be utilized for various recreational attractions, as a source of genetic resources, and as subjects for research and education (Hernowo and Prasetyo, 1989).

Rapid population growth, accelerated development, and the widespread conversion of land to mining and oil palm plantations have led to increasing ecological pressure on forest ecosystems. Changes in vegetation conditions—which differ from those of natural forests—have resulted in shifts in communities and a decline in bird species within them (Utari, 2000)

Figure 33. Bird species such as the Kingfisher (*Alcedo meninting*), the Javan White-eye (*Rhipidura javanica),* and the Spotted Flycatcher (*Centropus sp.*) found in the Sacred Forest area.

Species Diversity

In general, bird observations were conducted throughout the day on each workday. However, the observations were concentrated during two time periods: morning and afternoon. These two time periods are when bird groups are most active. A total of approximately 39 bird species were recorded during the observation period. This number is considered quite high, given the relatively small study area and the relatively short observation period. The possibility of discovering new species will certainly remain open if the study area is expanded and the observation period is extended.


Figure 34. Birdwatching activity

The bird species commonly found at the observation site generally belong to the *insectivore* group and/or are a mix of insectivores and frugivores. Species with a broad dietary range (*generalists*) generally fare better in the environment than those specialized in a single food type. From an ecological perspective, it is certainly fascinating to observe the presence of bird species in relation to the availability of food sources within the area.

The Tamtam Forest has the best bird community conditions, with the highest diversity (H') and species richness (R), indicating the most diverse habitat that supports a wide variety of bird species. The Brupis Forest also exhibits high diversity with a stable community. Meanwhile, Air Dekakah has the lowest diversity and species richness values, suggesting a relatively lower habitat quality. All three locations have high evenness indices (E) and low dominance indices (C), meaning no single species dominates the bird community. Overall, Tamtam is the best bird habitat, followed by Brupis, while Air Dekakah is a priority for habitat quality improvement through vegetation restoratio

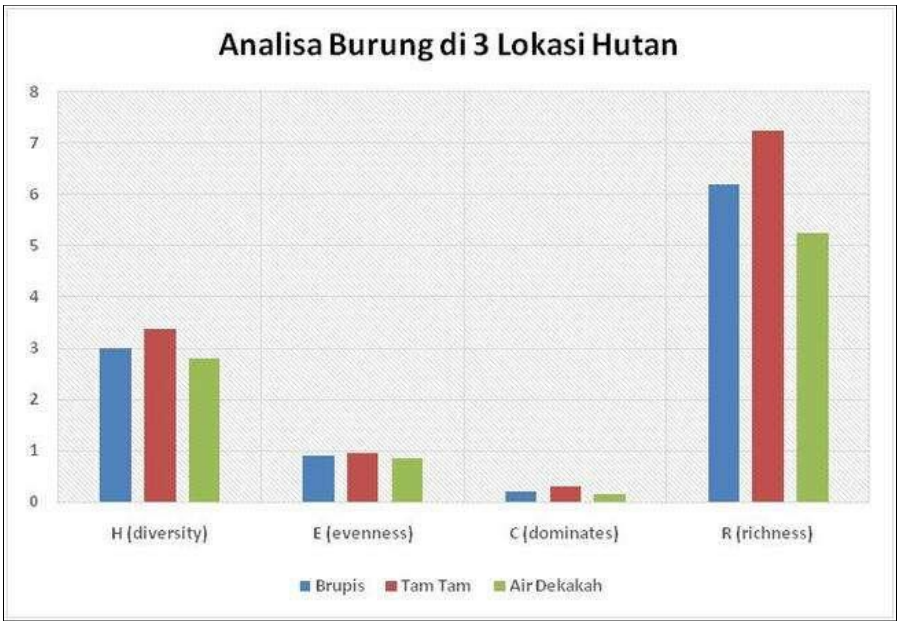


Figure 35. Results of Bird Analysis at Three Sacred Forest Locations

4.3.3 Herpetofauna

The world's highest diversity of amphibians is found in tropical forests, and they represent the majority of the vertebrate fauna in these forests. Amphibians are a crucial component of the food web in tropical regions as they are the primary terrestrial insectivores (Duellman and Heatwole, 1998). However, tropical forest amphibian populations are experiencing a dramatic global decline caused by a range of factors, including habitat loss, climate change, and disease. The International Union for Conservation of Nature (IUCN) reported in 2008 that one-third of the world's species are threatened. Specifically, approximately 16,928 (38%) species are threatened out of a total of 44,838 recorded species. Among the most critically endangered (at risk of extinction) are frogs and toads.

Amphibians are a vital component of both freshwater and terrestrial habitats. Their presence offers numerous benefits, both ecologically and economically. Ecologically, amphibians not only serve as a key component of the food chain but also function as bioindicators of environmental quality—particularly in aquatic ecosystems such as rivers. One of the objectives of this research is to determine the diversity of amphibian species at the study site—a forested area surrounding an oil palm plantation located within the Sacred forest reserve. By identifying the number of species present, we hope to gain insight into the condition and quality of the habitat at the study site.

Table 13. Conservation status of herpetofauna found in the Sacred Forest area and its surroundings

No	Local Name	Scientific Name	Status		
			IUCN	Ministry of Environment and Forestry Regulation	CITES
1	Katak tegalan	*Fejervarya limnocharis*	LC	N/A	-
2	Ular cobra	*Naja sumatrana*	LC	N/A	-
3	Katak Kongkang	*Chalcorana raniceps*	LC	N/A	-
4	Biawak sungai	*Varanus salvator*	LC	N/A	Appendix II
5	Katak Kongkang Gading	*Hylarana erythraea*	LC	N/A	-
6	Kadal kebun	*Eutropis multifasciata*	LC	N/A	-

A study of amphibians in the Sacred Forest area identified three species. The species encountered were *Fejervarya limnocharis*, *Chalcorana raniceps*, and *Hylarana erythraea*. These results were obtained by surveying the forest and small rivers around the Larangan Forest area. If data collection were conducted over a longer period and a wider area, the diversity of species found would likely be greater. In addition to amphibians, other herpetofauna species found around the Larangan Forest area include *Naja sumatrana*, *Varanus salvator,* and *Eutropis multifasciata*.

Figure 36. Herpetofauna observations

To obtain an overview of the ecological conditions and community structure at the study site, a quantitative analysis was conducted using several ecological indices, namely: the Shannon-Wiener Diversity Index (H'). The diversity index value (H') obtained was 1.732. Based on the index value criteria (where 1 < H' ≤ 3 is categorized as moderate diversity), the herpetofauna community at the study site is at a moderate level of diversity. This indicates that environmental conditions at the site sufficiently support the presence of a variety of herpetofauna species, but have not yet reached a climax or highly stable state.

Table 14. Herpetofauna Diversity Index

No	Nama lokal	Nama Ilmiah	Status			Total Individu	Pi ln Pi	H' (Diversity)	E (Evenness)	C (Dominance)	R (Richness)
			IUCN	Permen LHK	CITES						
1	Katak tegalan	*Fejervarya limnocharis*	LC	-	-	2	-0,34657359			0,0625	
2	Ular cobra	*Naja sumatrana*	LC	-	-	1	-0,259930193			0,015625	
3	Katak Kongkang	*Chalcorana raniceps*	LC	-	-	1	-0,259930193			0,015625	
4	Biawak sungai	*Varanus salvator*	LC	-	Appendix II	1	-0,259930193			0,015625	
5	Kongkang Gading	*Hylarana erythraea*	LC	-	-	1	-0,259930193			0,015625	
6	Kadal kebun	*Eutropis multifasciata*	LC	-	-	2	-0,34657359			0,0625	
					Total	**8**	**-1,732867951**	**1,7329**	**0,9671**	**0,1875**	**2,4045**
								Moderate	High	No species dor	Low

Pielou Evenness Index (E) The evenness value (E) obtained is very high, at 0.967. This figure is close to 1 (E > 0.6$), meaning that the species evenness at this location is classified as high (High). This high evenness value indicates that the number of individuals across species is relatively balanced and evenly distributed, with no striking population imbalances among the six species. Simpson's Dominance Index (C)

Consistent with the high evenness value, the dominance value (C) was observed to be very low at 0.1875. Based on the criterion that C ≤ 0.50, it can be concluded that no species dominates within that community. This condition indicates that there is no extreme pressure from a single population on the populations of other species in that habitat. Margalef Species Richness Index (R)

The species richness value (R) was recorded at 2.404. Based on the classification that R < 2.5, the level of species richness at this location is categorized as low. Although the distribution of individuals is even, the total number of species (6 species) and total number of individuals (8 individuals) found is relatively small. This may be influenced by the limited observation time, the size of the sampling area, or weather conditions during data collection.

Figure 37. A *Chalcorana raniceps* frog found in the Sacred Forest area

Overall, the observation site exhibits a healthy herpetofauna community structure in terms of ecological balance (high evenness and no dominance), although the diversity of species and the number of individuals remain relatively low. From a conservation perspective, wildlife protection efforts at this site remain focused on preventive monitoring, with special attention given to the management of *Varanus salvator* utilization due to its Appendix II status.

4.3.4 Lepidoptera

Butterflies, known for their beauty, are organisms that occupy diverse ecological niches corresponding to the stages of metamorphosis they undergo—from the egg, larva, and pupa phases to the adult (imago) stage. During the active phases of their life cycle, butterflies possess unique characteristics with specific roles: in the larval stage, they are phytophagous (plant-eaters), and upon reaching the adult stage, they act as pollinators.

Based on their ecological roles and characteristics, this group of insects is expected to serve as an indicator of species diversity; research on the species diversity of this insect group was conducted at several locations within the three Sacred Forest areas.

Field observations identified 7 butterfly species across the three Sacred Forest areas. These species are *Pathysa antiphates, Trogonoptera brookiana, Graphium eurypylus, and Idea stolli*. As for dragonflies, three species were found: *Orthetrum sabina*, *Orthetrum chrysis*, and *Neurothermis ramburii*.

Table 15. Several Species of Flying Insects (Butterflies and Dragonflies) Found in the Three Sacred Forest Areas

No	Scientific Name (Species)	Local/Common Name	Order
1	*Pathysa antiphates*	Kupu-kupu Ekor Pedang	Lepidoptera
2	*Trogonoptera brookiana*	Kupu-kupu Raja Brooke	Lepidoptera
3	*Graphium eurypylus*	Kupu-kupu Jaya	Lepidoptera
4	*Troides amphrysus*	Kupu-kupu Raja Emas	Lepidoptera
5	*Idea stolli*	Kupu-kupu Kertas	Lepidoptera
6	*Elymnias hypermnestra*	Kupu-kupu Daun Kering	Lepidoptera
7	*Tanaecia ioptera*	-	Lepidoptera
8	*Orthetrum sabina*	Capung Sambaran Hijau	Odonata
9	*Orthetrum chrysis*	Capung Merah	Odonata
10	*Neurothemis ramburii*	Capung Jala Merah	Odonata

Figure 38. *Elymnias hypermnestra* butterfly found during research in the Larangan Forest area

4.3.5 Protected and Endangered Species

4.3.5.1 Brupis Forest

The Brupis Forest is the site with the highest mammal species richness in the entire study landscape. Of the total 9 animal species identified there, 8 actively use the Brupis Forest as their habitat.

Table 16. Conservation Status of Key Species in the Brupis Forest

No	Scientific Name / Taxon	Local Name	IUCN Red List Status	National Status (P.106/2018)
1	*Tarsius bancanus*	Tarsier	Vulnerable (VU)	Protected
2	*Javan mouse-deer*	Mouse-deer	Least Concern (LC)	Protected
3	*Unicolor deer*	Rusa	Vulnerable (VU)	Protected
4	*Muntiacus muntjak*	Muntjac	Least Concern (LC)	Protected
5	*Helarctos malayanus*	Sun bear	Vulnerable (VU)	Protected
6	*Viverra tangalunga*	Tenggalung	Least Concern (LC)	Protected
7	*Sus barbatus*	Wild boar	Vulnerable (VU)	Protected
8	*Ratufa affinis*	Jelarang	Least Concern (LC)	Not Protected

B. Ecological Discussion (Brupis)

The presence of unique primates such as the Tarsier (*Tarsius bancanus*), which was successfully identified through direct observation, confirms that the lower canopy structure and the density of pole vegetation in the Brupis Forest remain very well preserved. The Tarsier is a sensitive arboreal species that requires continuous vegetation to leap about while hunting insects.

Furthermore, the Brupis Forest is the only location where the presence of highly solitary small ungulates such as the Greater Mouse-deer (*Tragulus napu*) and the Muntjac (*Muntiacus muntjak*) has been successfully detected through footprints. The same applies to the Jelarang Giant Squirrel (*Ratufa affinis*), which has only been found at this station. Taken together, this data indicates that the Brupis Forest acts as *a "Biodiversity Core Area*," providing a complete ecological niche for wildlife that is highly sensitive to human disturbance.

4.3.5.2 Air Dekakah Forest

Dekakah Wetland Forest, with its riparian ecosystem characteristics and waterlogged areas, exhibits the most limited diversity of mammal species. Based on recorded data, only three species were successfully detected at this location.

Table 17. Conservation Status of Key Species in the Air Dekakah Forest

No	Scientific Name / Taxon	Local Name	IUCN Red List Status	National Status (P.106/2018)
1	*Unicolor Deer*	Rusa	Vulnerable (VU)	Protected
2	*Helarctos malayanus*	Beruang madu	Vulnerable (VU)	Protected
3	*Exilisciurus exilis*	Bajing Kerdil	*Data Deficient* (DD)	Not Protected

B. Ecological Discussion (Air Dekakah)

Although the number of species is minimal, Air Dekakah plays a very specific hydrological and functional role for large mammals. Sambar deer (*Rusa unicolor*) and Sun Bears (*Helarctos malayanus*) use this riverbank area as their primary *watering site*. Sambar deer require a constant water supply and soft riparian vegetation for grazing, while Malayan sun bears frequently explore the riverbank areas in search of wild honeybee nests or termites in riparian trees such as Punaga.

The low wildlife diversity in Air Dekakah is influenced by the unstable and waterlogged geomorphological conditions of the land, which limit the movement of small terrestrial mammals (such as mousedeer and porcupines). However, for small arboreal species such as the Dwarf Squirrel (*Exilisciurus exilis*), the canopy density along the Air Dekakah river corridor still provides adequate habitat.

4.3.5.3 Tamtam Forest

The Tamtam Forest, characterized by secondary forest areas with a history of secondary commercial plant cultivation, plays a strong functional role as *a foraging area* and wildlife corridor. Based on the data collected, eight animal species were identified at this station.

A. Conservation Status of Key Species in the Tamtam Forest

Table 18. Conservation Status of Key Species in the Tamtam Forest

No	Scientific Name	Local Name	IUCN Red List Status	National Status (P.106/2018)
1	*Manis javanica*	Pangolin	Critically Endangered (CR)	Protected
2	*Tragulus javanicus*	Mouse Deer	Least Concern (LC)	Protected
3	*Unicolor deer*	Rusa	Vulnerable (VU)	Protected
4	*Muntiacus muntjak*	Muntjac	Least Concern (LC)	Protected
5	*Helarctos malayanus*	Sun bear	Vulnerable (VU)	Protected
6	*Sus barbatus*	Wild boar	Vulnerable (VU)	Protected

B. Ecological Discussion (Tamtam)

The most crucial finding in the Tamtam Forest was the detection of the Javan pangolin (*Manis javanica*) through the discovery of nests and scratch marks. On the list, the Javan pangolin is a species found exclusively in the Tamtam Forest and not recorded at other stations. Globally, this scaly mammal is classified as *Critically Endangered*. Its presence indicates an abundance of ant and subterranean termite colonies around the decaying wood stands in the Tamtam Forest, which serve as its primary food source.

In addition to the pangolin, large wildlife with globally Vulnerable status—such as the sun bear (*Helarctos malayanus*) and the bearded pig (*Sus barbatus*)—also actively utilize this site. Sun bears were detected through scratch marks on the bark of host trees, while bearded pigs left distinctive footprints and mud wallows. The structure of the Tamtam Forest, which is beginning to be overgrown with pioneer plants, produces an abundance of seasonal forest fruits that attract these large omnivorous animals to stop by in search of food.

4.3.6 Keystone and Indicator Species

Analysis *of Keystone Species* by Location

Keystone species play a crucial role in maintaining the structural balance of forest ecosystems. The presence of large mammals and omnivores/carnivores at all three locations provides insight into the different functional roles of these ecosystems:

- Tamtam Forest (Primary Keystone Species: Pangolin):

Based on the findings, the pangolin (*Manis javanica*) was found only in the Tamtam Forest and has the highest conservation status, namely *Critically Endangered* (CR). Ecologically, the pangolin is a keystone species that controls the population of soil-dwelling insects (ants and termites) and helps aerate the forest soil through its digging activities. The loss of this species in the Tamtam Forest could trigger a termite population explosion that threatens the integrity of living trees.

- Brupis Forest (Most Key Species):

  Based on the findings, the Brupis Forest has the highest diversity of keystone species, with 8 species identified. The presence of the Sun Bear (*Helarctos malayanus*), classified as *Vulnerable* (VU), at all three locations (Brupis, Tamtam, and Air Dekakah) underscores its role as the primary seed *disperser* for large-fruited forest plants and as a creator of cavities in decaying wood, which serve as microhabitats for small wildlife.

- Air Dekakah Forest (Minimalist Ecosystem):

  Based on the findings, only three keystone species (deer, Sun Bear, and pygmy squirrel) were identified at this location. This indicates that the functional food web structure in Air Dekakah is simpler or experiences higher habitat pressure compared to the other two locations.

Analysis of Environmental Health Indicator Species

Indicator species are used to assess habitat health, forest fragmentation, and canopy cover quality:

A. Indicators of Primary Forest and Dense Canopy Cover (Sensitive)

- Tarsier (*Tarsius bancanus*): Identified only in the Brupis Forest (WhatsApp Image 2026-06-20 at 15.48.40.jpeg) with a *Vulnerable* (VU) status. As a small arboreal primate sensitive to disturbances, the presence of the Tarsier serves as a strong bioindicator that Brupis Forest still contains areas of primary forest with dense understory and vertical vegetation, as well as low levels of anthropogenic noise.
- Jelarang (*Ratufa affinis*) and Dwarf Squirrel (*Exilisciurus exilis*): The Jelarang was found in Brupis Forest (WhatsApp Image 2026-06-20 at 15.48.40.jpeg), while the Dwarf Squirrel was found in the Air Dekakah Forest (WhatsApp Image 2026-06-20 at 15.46.07.jpeg). The presence of these *arboreal* rodents indicates good forest canopy continuity, allowing them to move without having to descend to the forest floor, where they are vulnerable to predators.

B. Indicators of the Availability of Flat Foraging Areas and Understory Vegetation

- Sambar Deer (*Rusa unicolor*), Muntjac (*Muntiacus muntjak*), and Wild Boar (*Sus barbatus*):

  This combination of three large mammals is consistently found in the Tamtam Forest and the Brupis Forest. Their presence indicates an abundance of understory food (grass, fallen fruit, litter) as well as terrestrial movement corridors that have not yet been severely fragmented by roads or plantations. At Air Dekakah, only the Sambar Deer was found, suggesting a potential limitation on terrestrial range for ungulates at that location.

C. Comparison of Conservation Status and Legal Protection

All three documents show a consistent national legal protection status based on Regulation P.106/2018, with exceptions for several species:

Table 19. Protected mammal species in the three Sacred Forest areas

Characteristics / Location	Air Dekakah Forest	Tamtam Forest	Brupis Forest
Critically Endangered (CR) Species	None found	Pangolin (*M. javanica*)	Not found
Protected Species (P.106/2018)	Deer, Sun Bear	All listed species (6 species)	7 of 8 protected species (except the Jelarang)
Unprotected Species	Dwarf Squirrel (*E. exilis*)	None	Jelarang (*R. affinis*)

4.4 High Conservation Value

The results of the identification and mapping of High Conservation Value (HCV) areas indicate that the Manismata Landscape still contains important areas that play a role in maintaining biodiversity, providing ecosystem services, meeting the needs of local communities, and preserving cultural values passed down through generations. Most HCV areas are concentrated around the Air Dekakah, Brupis, and Tamtam Sacred Forests, as well as along river corridors, swamps, and the remaining natural habitats within the landscape.

In general, the analysis identified the presence of NKT 1, NKT 3, NKT 4, NKT 5, and NKT 6, while NKT 2 was not identified because the landscape has undergone significant fragmentation and no longer forms a vast, intact natural landscape.

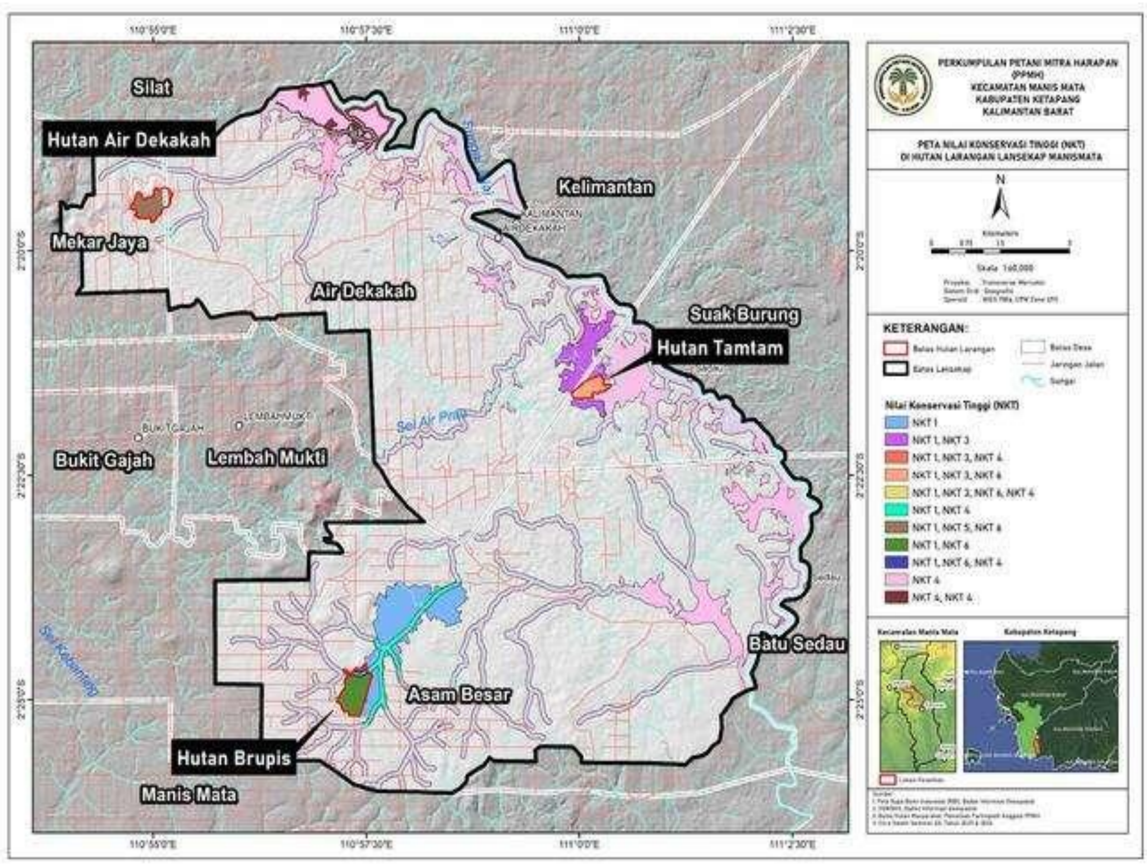


Figure 39. High Conservation Value (HCV) Map

HCN 1: Important Biodiversity

HVC 1 is found in all three Sacred Forests and their surrounding natural habitats, which serve as habitats for various flora and fauna species of high conservation value. The presence of species such as the Javan pangolin (*Manis javanica*), Malayan sun bear (*Helarctos malayanus*), Javan tarsier (*Tarsius bancanus*), deer, and pitcher plants (*Nepenthes* spp.) indicates that this area still serves as a critical habitat for protected species and possesses high biodiversity value. Therefore, the entire Sacred Forest has been designated as a priority area for biodiversity conservation.

NKT 3: Rare or Threatened Ecosystems

NKT 3 is primarily identified in the Tamtam Sacred Forest and the relatively intact blocks of secondary forest surrounding it. This area is one of the best remaining natural habitats within the landscape and has a more complex vegetation structure compared to other locations. The presence of increasingly limited natural forest ecosystems amid the dominance of oil palm plantations makes this area of critical conservation value that must be preserved.

NKT 4: Important Ecosystem Services

NKT 4 is the most widespread category within the landscape. This area primarily includes riverbanks, swamps, riparian zones, and natural habitats that play a role in regulating water, reducing erosion, controlling surface runoff, and storing carbon. The map shows that river corridors and swamps form an ecological network connecting various parts of the landscape and serving as natural corridors for wildlife. Additionally, the Brupis and Tamtam Sacred Forests also serve as important carbon sinks within the landscape.

NKT 5: Meeting the Basic Needs of the Community

NKT 5 is primarily identified in areas related to water sources and watersheds utilized by the surrounding communities. This function is most prominent around the Air Dekakah Sacred Forest, which serves as a provider of clean water for the local community. The sustainability of the area's hydrological functions is crucial given the community's dependence on water resources originating from this area.

NKT 6: Cultural Value and Community Identity

NKT 6 is found throughout the Sacred Forest, which holds historical, cultural, and spiritual value for the local community. This area is a heritage forest passed down through generations and safeguarded according to customary laws and community beliefs. The presence of ancient burial sites, traditional sites, and the sacred values associated with the area make the Sacred Forest not only ecologically important but also an integral part of the cultural identity of the Manismata community.

Overlapping Conservation Values

The NKT map shows that most of the core areas of the Sacred Forest contain more than one NKT category simultaneously. The Tamtam Sacred Forest is the area with the highest concentration of conservation values because it contains a combination of NKT 1, NKT 3, NKT 4, and NKT 6. This indicates that the area serves critically important functions in terms of biodiversity, ecosystem services, and cultural value.

The Brupis Sacred Forest exhibits a combination of NKT 1, NKT 4, NKT 5, and NKT 6 related to habitat function, carbon storage, and community ties to the area. Meanwhile, the Air Dekakah Sacred Forest has a strong combination of NKT 1, NKT 4, NKT 5, and NKT 6, particularly related to hydrological functions and the community's basic needs.

The presence of various NKT categories within the Manismata Landscape indicates that this area possesses high conservation value despite being situated within a landscape dominated by smallholder oil palm plantations. Therefore, area management should focus on protecting the Sacred Forest as a core conservation area, maintaining river and swamp corridors as providers of ecosystem services, strengthening habitat connectivity between patches of natural forest, and preserving the cultural values that underpin the sustainability of the Sacred Forest system.

Additionally, areas where multiple NKT categories overlap should be prioritized as protected zones because they provide the greatest ecological and social benefits for the sustainability of the Manismata Landscape. Thus, the presence of NKTs serves as a crucial foundation for developing management zoning, conservation strategies, and future action plans for restoration and sustainable management.

4.5 Community Social Study

4.5.1. Village Profile

The Sacred Forest area is located within three (3) officially recognized villages: Suak Burung Village, Air Dekakah Village, and Asam Besar Village, in Manismata Subdistrict, Ketapang Regency, West Kalimantan Province. The presence of these three villages influences the condition of the Manismata PPMH Sacred Forest. A general overview of the three study villages is as follows:

Suak Burung Village

Suak Burung Village covers an area of 240.40 km^2—representing 8.26% of Manismata Subdistrict's total area—and includes the 48-hectare Tamtam Sacred Forest. The village has a population of 1,765 people, with a population density of 7.34 people per km^2 and a sex ratio of 109%. The village is located 45 km from the subdistrict capital and 248 km from the regency capital. Most residents of Suak Burung Village work as farmers.

Air Dekakah Village

Air Dekakah Village covers an area of 80.20 km^2—2.75% of the total area of Manismata Subdistrict—and the 20-hectare Air Dekakah Sacred Forest is located within the village's boundaries. The village has a population of 1,295 people, with a population density of 16.15 people per km^2 and a sex ratio of 106%. The village is located 25 km from the subdistrict capital and 250 km from the regency capital. Most residents of Air Dekakah Village earn their livelihood as farmers.

Asam Besar Village

Asam Besar Village covers an area of 125.00 km^2—or 4.29% of the total area of Manismata Subdistrict—and the 48-hectare Brupis Sacred Forest is located within the village's boundaries. The village has a population of 3,653, with a population density of 29.22 people per km^2 and a sex ratio of 112%. The village is located 10 km from the subdistrict capital and 2,650 km from the regency capital. Most residents of Asam Besar Village earn their livelihood as farmers.

4.5.2 Characteristics of the Communities Surrounding the Sacred Forest Area

4.5.2.1. Characteristics of Respondents

The number of respondents in this study was 13 people, representing a distribution across three villages: Suak Burung, Air Dekakah, and Asam Besar. Among the respondents, the majority were aged 31–45 years (69.23%) and 46–65 years (15.38%), with 92.31% being male. Each respondent provided information on their household and represented their cultural and ethnic identity; specifically, the respondents were indigenous residents who had settled in these three villages. More than half of the respondents were residents of Air Dekakah Village (61.54%), while the majority of respondents' primary occupations were as farmers (53.83%), as shown in Figure 40 and Figure 41.

Characteristics of respondents based on length of residence in the study village: 84.62% were native residents, and their length of residence was equal to their age. Meanwhile, the respondents' relationship to the PPMH Sacred Forest area was as follows: 38.36% were farmers and 30.77% were area managers, as shown in Table 20.

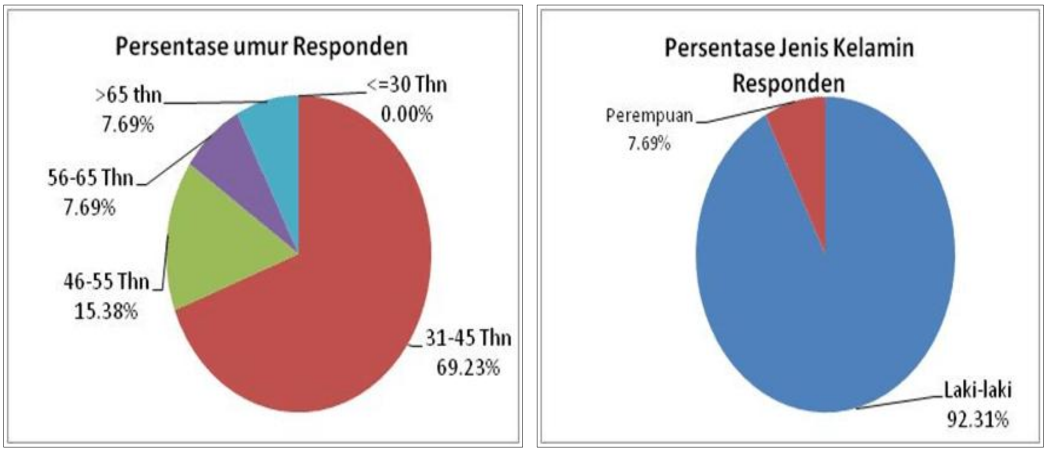


Figure 40. Age and Gender of Respondents

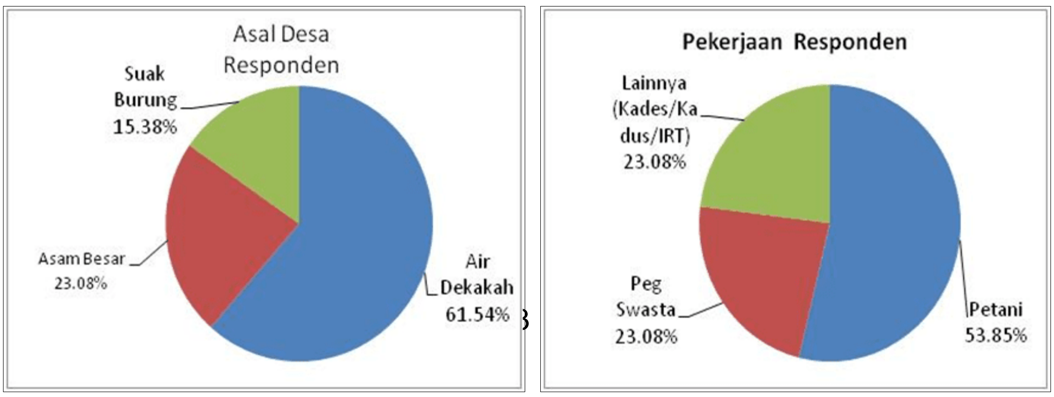


Figure 41. Village of Origin and Occupation of Respondents

Table 20. Characteristics of Respondents Based on Length of Residence and Relationship to the Area

Length of Residence		Connection to the Sacred Forest	
years	%	Relationship	%
<10	0	Farmers	38.46
11<20	7.69	Indigenous leaders	7.69
21-30	7.69	Hunter	7.69
>30	84.62	Non-Timber Forest Product Collectors	0
		Area Manager	30.77
		Others: (forest owners, village forests)	15.38
Total	100.0	Total	100.0

4.5.2.2 General Information on Sacred Forest Areas

The three Sacred Forest areas managed by PPMH Manismata—namely, the Tamtam, Air Dekakah, and Brupis Sacred Forests—are well-known and recognized by the communities in the villages of Sauk Burung, Air Dekakah, and Asam Besar. According to respondents, the most well-known Sacred Forest areas are the Tamtam Sacred Forest (46.15%), the Air Dekakah Sacred Forest (35.46%), and the Brupis Sacred Forest (15.38%). Respondents' understanding of the existence and functions of these Sacred Forest areas varied considerably; among the most commonly cited functions were protection of water sources (31.58%) and wildlife habitat (26.32%), as shown in Table 21.

Changes in forest management have impacted the surrounding climate, a fact felt by communities living near the Sacred Forest areas. When asked about changes in forest conditions compared to the past, 76.92% of respondents answered "Yes, there have been changes," while 23.08% answered "No changes." Respondents' answers regarding the changed forest conditions included: wildlife has become increasingly rare (36.84%) and forest area has decreased (26.32%); the full results are presented in Figure 42.

Table 21. The Most Well-Known Sacred Forests and Respondents' Knowledge of Their Functions

The Most Well-Known Sacred Forests	
Sacred Forests	%
Tamtam	46.15
Air Dekakah	38.46
Brupis	15.38
Total	100.0

Respondents' Knowledge of Functions of Sacred Forests	
Functions	%
Wildlife habitat	26.32
Water Source Protection	31.58
Flood/Erosion Prevention	15.79
Traditional/Cultural Sites	-
Forest product suppliers	-
Environmental stabilizers	21.05
Other: garden	5.26
Total	100.0

Figure 42. Respondents' responses regarding changes in current forest conditions

4.5.2.3. Information on Flora/Plants

Residents in the three villages possess basic knowledge regarding the status of forest areas surrounding their villages. Although this knowledge is not evenly distributed, it is sufficient to indicate that information about the existence of these forest areas has reached the residents.

The presence of Sacred Forests—which are biological natural resources expected to support improved livelihoods and a higher standard of living—contributes to the achievement of a prosperous community. The community's knowledge of Sacred Forests—which harbor a variety of tree and plant species—is considered quite good. This is evidenced by interview results with respondents, which indicate that there are 20 tree and plant species considered important by the community; among them are the Ulin tree (11.11%), fruit trees (11.11%); pasak bumi, agarwood, durian, and bajakah, each at 8.33%. The tree and plant species considered important are also shown in Figure 43.

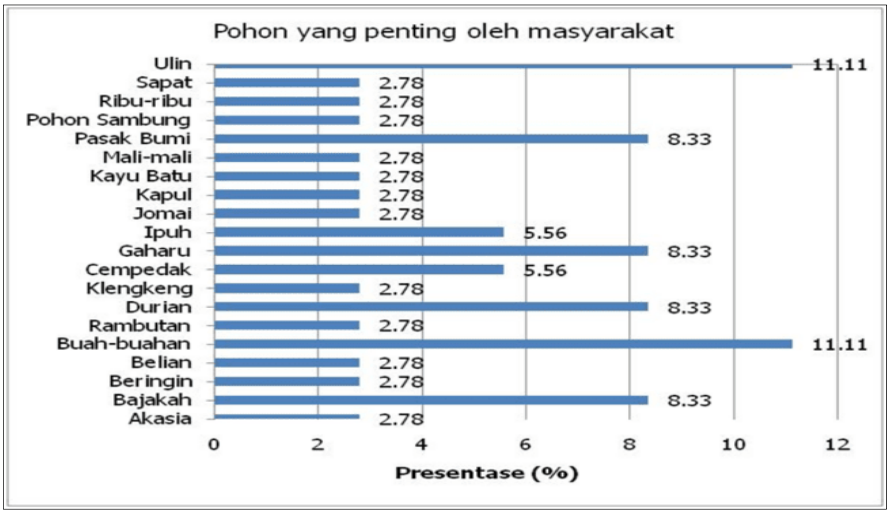


Figure 43. Types of trees/plants considered important

Based on the interview results, 92.31% of respondents stated that there are tree and plant species that are now becoming difficult to find, while 69.23% were aware of species that are rare or protected. There were 11 tree and plant species reported as becoming increasingly difficult to find and 8 species categorized as rare or protected. The Ulin tree was the most frequently mentioned species, cited by 33.33% of respondents as a species that is difficult to find and by 38.46% as a rare or protected species (Figure 44).

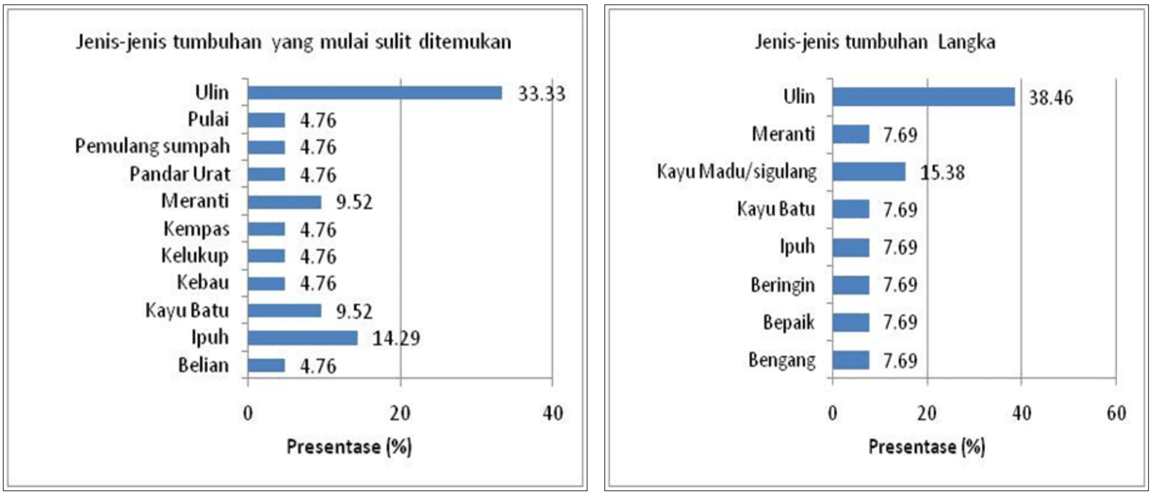


Figure 44. Tree and plant species are becoming increasingly difficult to find, and some are rare or protected

4.5.2.4. Information on Fauna (Wildlife)

The local community living near the forest area is quite familiar with various types of fauna; a total of 21 species have been recorded as having been encountered in the forest and its surroundings. Among these, 13.89% of respondents reported seeing monkeys, and 11.11% reported seeing bears; other fauna species encountered by the community are shown in Figure 45.

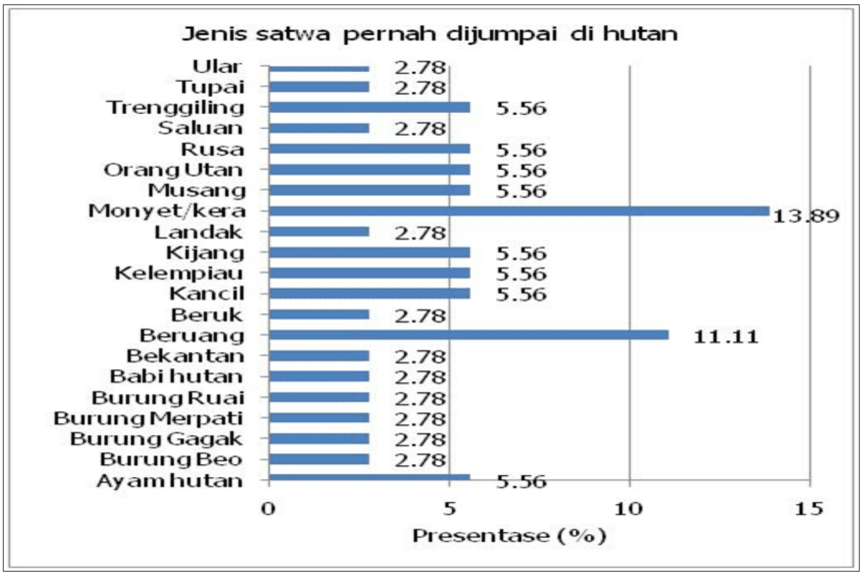


Figure 45. Types of wildlife encountered by the community

Based on interviews with respondents, 9 (nine) species of wildlife were frequently encountered, including monkeys (26.32%) and squirrels (21.05%). There were 15 species of wildlife that are becoming increasingly rare, including deer (23.33%) and bears (13.33%). Wildlife species frequently encountered and those becoming increasingly rare among the local community (Figure 46).

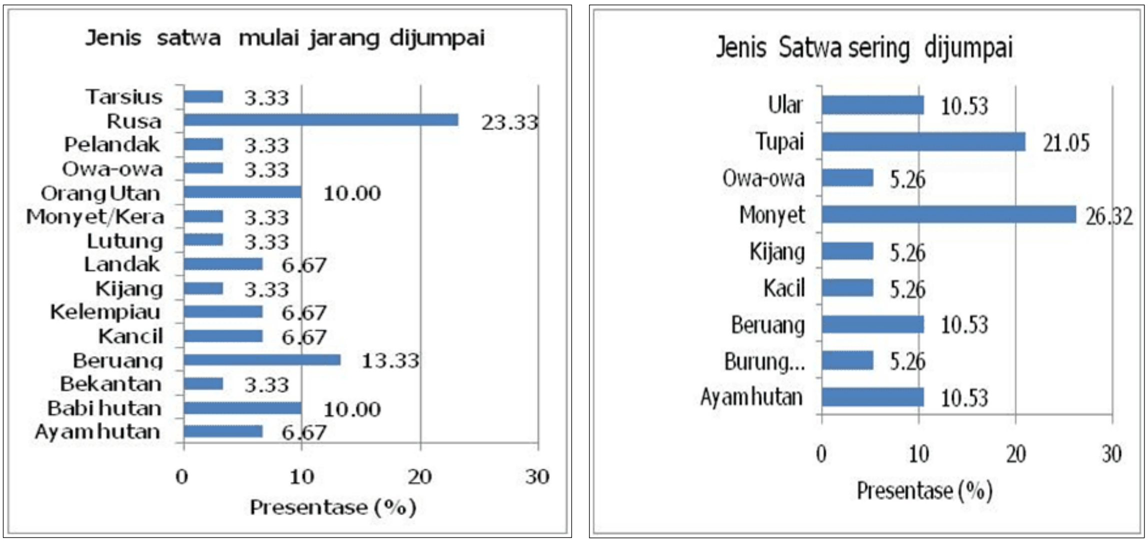


Figure 46. Species that are commonly encountered and those rarely encountered by the public

When asked whether there are any animals considered important, sacred, or protected by the community, 53.85% of respondents answered “Yes ” and 46.15%

answered “No.” According to the respondents, there are 9 (nine) species of fauna considered important, sacred, or protected by the community, including the Ruai bird (30%). Species of fauna considered important, sacred, or protected by the community are shown in Figure 47.

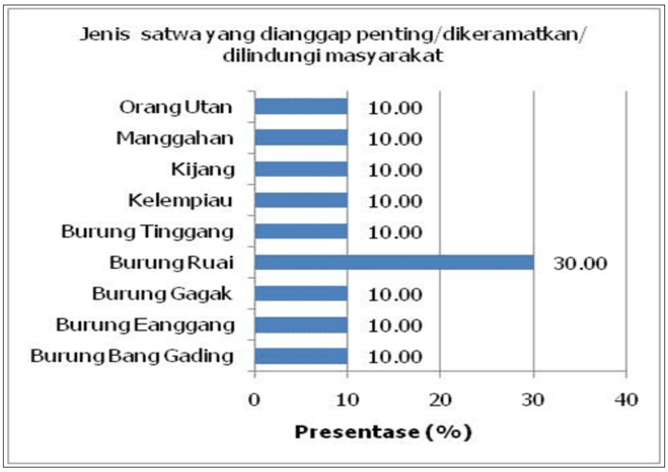
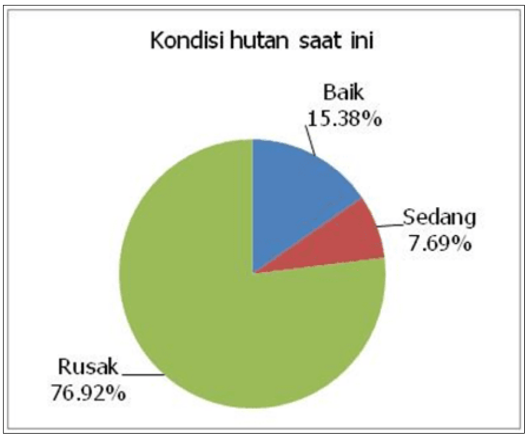


Figure 47. Types of fauna considered important, sacred, or protected by the community

4.5.2.5. Habitat Conditions and Ecosystem Services

Regarding community assessments of habitat conditions and ecosystem services—specifically the current condition of the forests surrounding their communities—the majority of respondents indicated that the forests are 76.92% (degraded), 15.38% (good), and 7.69% (moderate). Meanwhile, regarding whether forest areas play a role in water availability, respondents stated that they have a very significant impact (84.62%) and a significant impact (15.38%). Furthermore, when asked whether forest areas help regulate local temperature/climate, respondents answered “Yes” (92.31%) and “No” (7.69%). Respondents’ assessments of current forest conditions and their impact on water availability are presented in Figure 48.



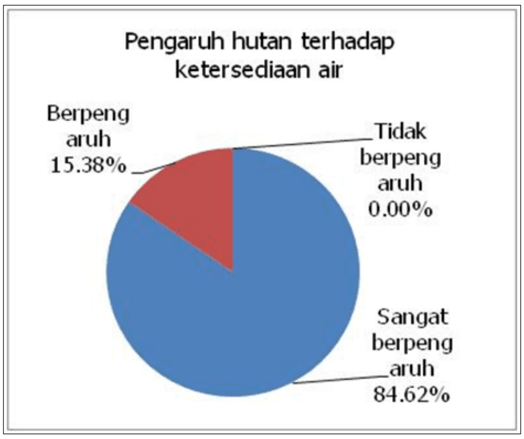


Figure 48. Respondents’ Assessment of Current Forest Conditions and Their Impact

Communities living near forest areas utilize non-timber forest products (honey, rattan, medicinal plants, etc.). This is evident from the interview results, with 92.31% utilizing non-timber forest products. The types utilized include honey, bajakah root, rattan, and pasak bumi. Figure 49.

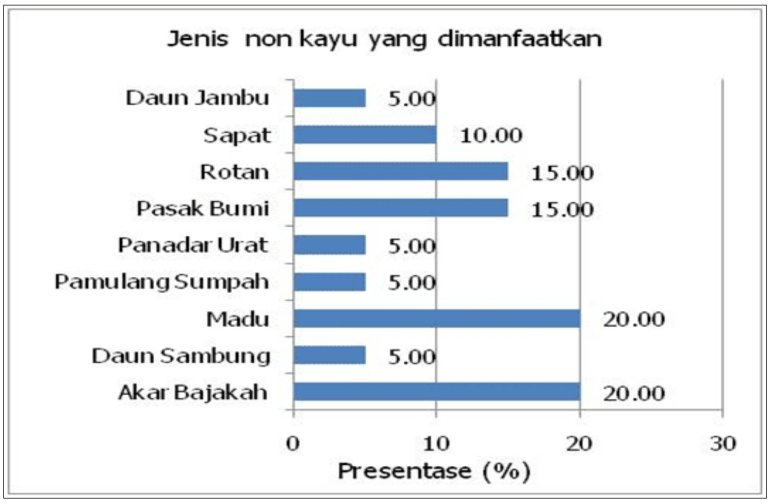


Figure 49. Non-timber resources utilized by the community

4.5.2.6. Threats to Biodiversity

Managers of the three Sacred Forest areas are well aware that these forest areas face threats, both natural and those resulting from inappropriate management practices. Community awareness of threats to forest conditions and biodiversity varies considerably; interview results with respondents indicate that forest fires are the dominant threat at 32.14%, followed by land clearing at 25.00%. Other threats affecting forest conditions and biodiversity are shown in Figure 50.

Figure 50. Potential threats affecting forest conditions and biodiversity

Land-use changes can reduce the carrying capacity of wildlife habitats, either due to a decrease in area or the loss of food sources for wildlife; this can cause wild animals to leave their natural habitats, leading to conflicts with humans. Interview results showed that 7.69% answered “Yes,” and 92.31% answered “No.” The form of conflict between wildlife and humans that has occurred involved the destruction of a chainsaw; respondents suspected that the animal responsible for the disturbance or damage was a bear. Regarding this incident, respondents stated that no one witnessed it, no action has been taken yet, and relevant parties have not yet been involved.

4.5.2.7 Management and Conservation

In general, the communities in the three villages understand the existence, benefits/functions, and current condition of the three Sacred Forests. This was revealed by two questions posed to the respondents: 1) Do the communities support the protection of the Sacred Forests?, and 2) Are the communities willing to participate in biodiversity conservation/monitoring activities? 100.00% of respondents supported protection and were willing to participate in biodiversity conservation and monitoring activities. The respondents’ views and suggestions regarding activities needed to preserve the area’s forest biodiversity are shown in Figure 51.

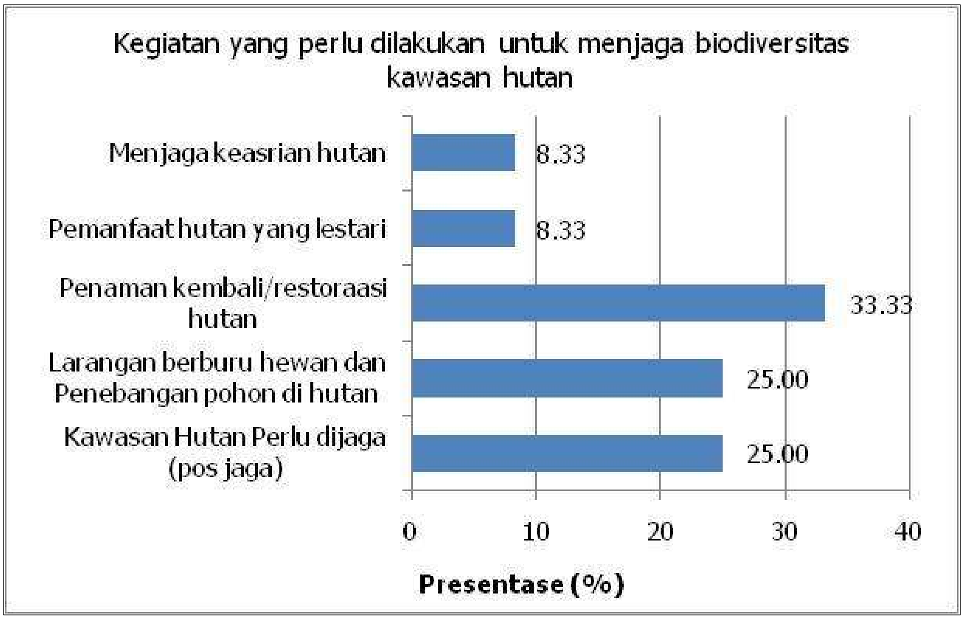


Figure 51. Activities Needed to Preserve Forest Biodiversity

4.6 Ecosystem Services

In addition to serving as a bastion for biodiversity conservation, the Sacred Forest area—which encompasses the regions of Brupis, Tamtam, and Air Dekakah—possesses ecosystem services of high economic value. This discussion will outline the potential for the holistic development of environmental services, ranging from utilizing the unique fauna for *nature tourism*, optimizing the forest's function as a carbon sink (*carbon sequestration*), to protecting the watershed in Air Dekakah as a provider of hydrological services for the surrounding areas.

4.6.1 Provisioning Services

As a well-preserved forest ecosystem, the Brupis and Tamtam regions—and particularly the Air Air Dekakahshed—play a crucial role as providers of material natural resources for the surrounding areas. This discussion of *Provisioning* Services will highlight how the forest's hydrological functions provide a sustainable supply of clean water, as well as the potential of non-timber forest products (NTFPs) such as wild honey, wild fruits, and rattan, the utilization of which must be strictly managed so as not to disturb the ranges of key wildlife species.

Table 22. *Provisioning* Services

No	Location	Primary Provisioning Services	Community Use	Ecological Constraints / Key Species
1	Brupis Forest	Non-Timber Forest Products (Latex) & Building Materials	Rubber tapping and firewood from Laban branches.	Cutting down Ulin/Pantung trees is prohibited because they serve as natural *refugia* and habitats for tarsiers
2	Tamtam Forest	Plant-Based Food Sources (Wild Fruits)	Subsistence consumption of fallen fruit or cultivation of local seedlings.	Restrictions on picking fruit for commercial purposes directly from the trees that serve as food sources for pangolins and sun bears.
3	Air Dekakah Forest	Domestic Clean Water	Consumption of clean drinking water for the village's domestic needs.	It is mandatory to protect the trees so that the water flow remains clear, as this is the primary drinking source for deer

Figure 52. Spring source in the Air Dekakah Forest

4.6.2 Regulating Services

In addition to its biodiversity, the Sacred Forest area plays an unseen yet vital role through *the Regulating Services* it provides. This discussion will explain how the interaction between forest vegetation and soil structure in the Air Dekakah, Tamtam, and Brupis areas functions to regulate the hydrological cycle (preventing floods and droughts), curb soil erosion, and how the presence of animals such as the Javan pangolin (*Manis javanica*) acts as *a* natural *biological control* against pest insect populations.

Table 23. *Regulating* Services

No	Location	Primary Regulating Services	Real Ecological Reference Data	Natural Mechanisms	Impact on Key Species
1	Brupis Forest	Microclimate & Carbon Regulation	Highest Density and Greatest Species Diversity	A dense canopy blocks solar radiation and maintains forest floor moisture.	Supports animal food sources and insect populations
2	Tamtam Forest	Regulation of the Nutrient and Soil Cycle	Highest evenness and dominance	Natural litter decomposition maintains soil fertility and physical structure.	Provides food for wildlife
3	Air Dekakah Forest	Hydrological Regulation & Erosion	Low density and low dominance	Tree roots anchor riparian slopes and filter river sediment.	Ensures clean water and watering holes for wildlife

4.6.3 Supporting Services

Supporting Services are a set of fundamental ecosystem processes that underpin and enable all other environmental services—whether provisioning, regulating, or cultural—to function properly. In the Brupis, Tamtam, and Air Dekakah forest areas, these supporting services manifest as *soil formation*, nutrient cycles, and primary production by forest vegetation, which serve as the very foundation for providing habitat and food chains for all mammals identified in these areas.

Table 24. Summary: *Supporting Services*

No	Location	Primary Supporting Services	Real Ecological Foundation	Basic Role of the Ecosystem	Sustainability of Key Species
1	Brupis Forest	Habitat Formation & Biodiversity	Highest diversity of species	Provides a complex vertical canopy structure.	Ensures daily refuge for wildlife
2	Tamtam Forest	Nutrient Cycle & Food Chain Stability	Perfect structural diversity without monoculture	Maintaining stable primary forest biomass production.	Supporting soil microhabitats
3	Air Dekakah Forests	Soil Conservation & Natural Succession	Tall trees	Act as anchors to retain riparian soil nutrients and prevent erosion.	Provide a physical foundation for wildlife corridors

4.6.4 Cultural Services

Cultural Services encompass all non-material benefits that humans derive from ecosystems, such as spiritual enrichment, cognitive development, recreation, and aesthetic reflection. In the Sacred Forest area, which includes Brupis, Tamtam, and Air Dekakah, these cultural services are strongly tied to the area's status as 'Sacred Forest' itself, reflecting the local wisdom of indigenous communities in upholding taboos and customary laws to respect nature—which indirectly serves as a natural protector for the survival of the sacred and protected wildlife within it.

Table 25. Summary: *Cultural Services*

No	Location	Primary Cultural Services	Ecological & Wildlife Resources	Community Values & Concrete Actions	Cultural Targets/Outputs
1	Brupis Forest	Natural Heritage & Nocturnal Education	Ulin, Meranti, Pekawai, & Tarsiers	• Special-interest *night trekking* tour to see tarsiers. • Education on the conservation of traditional Ulin timber.	Pride in local identity and non-extractive economic alternatives.
2	Tamtam Forest	Indigenous Knowledge & Exclusive Protection	High Equity & Pangolins	• Enforcement of traditional taboos prohibiting hunting. • Strengthening of village customary laws (*awig-awig*).	Self-managed protection of sacred zones/core areas of virgin forest.
3	Air Dekakah Forest	Therapeutic Recreation & *Voluntourism*	Riparian Landscape	• Utilizing the river's aesthetic appeal for nature therapy (*healing*). • Volunteer tree-planting tour packages.	Community-based restoration of green riparian landscapes.

4.7 Conservation Value of the Area

The assessment of the Conservation Value of the Area in the Brupis, Tamtam, and Air Dekakah regions is not only based on the richness of individual species but also on the landscape's function as a whole—as a single ecosystem. By integrating biodiversity data from these three locations, this chapter will examine how these areas meet the criteria as providers of vital ecosystem services, migration corridors for large mammals such as Sambar deer and Sun bears, and protectors of genetic resources that serve as the last line of defense for regional biodiversity.

4.7.1 Biodiversity Value

Biodiversity value in the Larangan Forest area is measured not only by the total number of species found, but also by the variation and distribution of taxa across the three observation sites: Air Dekakah, Tamtam, and Brupis. This discussion will examine how differences in biophysical characteristics at each location shape unique patterns of mammal distribution—ranging from the high species richness in the Brupis Forest to the presence of specific critically endangered species in the Tamtam Forest—which collectively form a complex and balanced web of life

4.7.2 Important Habitat Values

The designation of Key Habitat Values in the Brupis, Tamtam, and Air Dekakah Forests is based on the presence of a number of indicator species that have very specific habitat requirements and are sensitive to degradation. The presence of canopy rodents such as the Jelarang and arboreal primates such as the Tarsier serves as scientific evidence that the physical structure and vegetation architecture in these forest areas remain intact, thus necessitating a strict habitat protection scheme against all forms of fragmentation.

Figure 53. Ipuh Tree (*Antiaris toxicaria*) in the Tamtam Forest

4.7.3 Ecosystem Services

The discussion on Ecosystem Services in the Brupis, Tamtam, and Air Dekakah Forests aims to integrate all environmental goods and services—both material and non-material—generated by the Sacred Forest area. As a single, intact landscape, this assessment of ecosystem services serves as a vital tool for mapping how natural functions at these three locations work simultaneously to sustain the lives of surrounding communities while ensuring the conservation of protected wildlife habitats within them

4.7.4 Conservation Significance of the Area

This analysis of the Conservation Significance of the Area aims to establish a strong rationale for why the Brupis, Tamtam, and Air Dekakah Forests must be preserved as sovereign protected areas. Through a review of the numerous wildlife species protected under Government Regulation No. P.106/2018 in these three locations, this chapter will highlight the importance of these areas as natural laboratories for scientific research, educational resources for future generations, and the last bastion of high-value natural heritage.

Figure 54. *Nepenthes rafflesiana* pitcher plant in the Tamtam Forest

4.8 Threat Analysis

4.8.1 Land Cover Dynamics

An analysis of land cover changes in the Manismata Landscape during the 2016–2026 period reveals significant landscape transformation, primarily due to the expansion of oil palm plantations, which has led to a decline in the area of natural forest cover. Although the total area of the landscape remains at 12,871 ha, changes in its land cover composition reflect increasing pressure on forest resources.

The most striking change occurred in the secondary forest class, which decreased from 5,297.97 ha (41.2%) in 2016 to 2,916.52 ha (22.7%) in 2026. Thus, over the course of nine years, there was a loss of 2,381.45 ha of secondary forest, or approximately 45% of the 2016 secondary forest area. This decline indicates the conversion of forested areas to other land uses, primarily oil palm plantations (Table 26).

Table 26. Dynamics of Landscape Cover Change in Manismata

NO	TUTUPAN LAHAN	PERUBAHAN TUTUPAN LAHAN (HA)	
		2016	2026
1	Belukar Tua	516.75	1,012.53
2	Hutan Sekunder	5,297.97	2,916.52
3	Hutan Tanaman	0.98	0.98
4	Kolam/Badan Air	4.45	4.45
5	Perkebunan Sawit	4,860.66	6,469.04
6	Permukiman dan Tempat Kegiatan	150.86	154.20
7	Rawa	391.93	252.09
8	Semak	1,445.46	1,670.09
9	Sungai	146.71	146.71
10	Tanah Terbuka	54.98	244.13
TOTAL		12,871	12,871

In line with the decline in forest cover, the area of oil palm plantations increased significantly from 4,860.66 ha to 6,469.04 ha, an increase of approximately 1,608.38 ha. By 2026, oil palm plantations had come to dominate approximately 50% of the total landscape, making them the largest land cover type in the study area. This increase indicates that the oil palm plantation sector is the primary factor driving land-use change in the Manismata Landscape.

Changes in land cover are also evident in the increase in the area of old scrub from 516.75 ha to 1,012.53 ha, as well as in the area of shrubland from 1,445.46 ha to 1,670.09 ha. The rise in both of these categories indicates that certain areas have undergone disturbance or land clearing and are subsequently experiencing natural vegetation regeneration in the early to intermediate stages.

Meanwhile, open land experienced a significant increase, from 54.98 ha to 244.13 ha. This nearly fourfold increase indicates that land clearing, infrastructure development, or areas in the process of transitioning to other land uses are still ongoing. This situation also shows that landscape changes will continue through 2026.

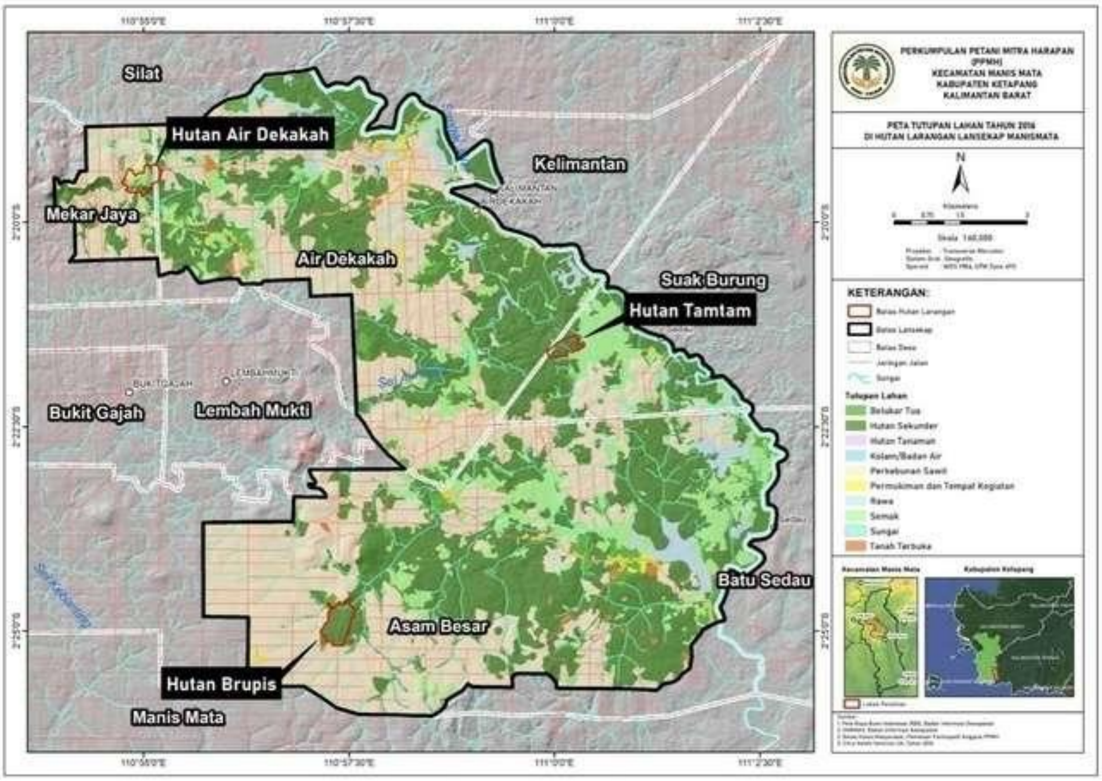


Figure 55. 2016 Landscape Land Cover Map

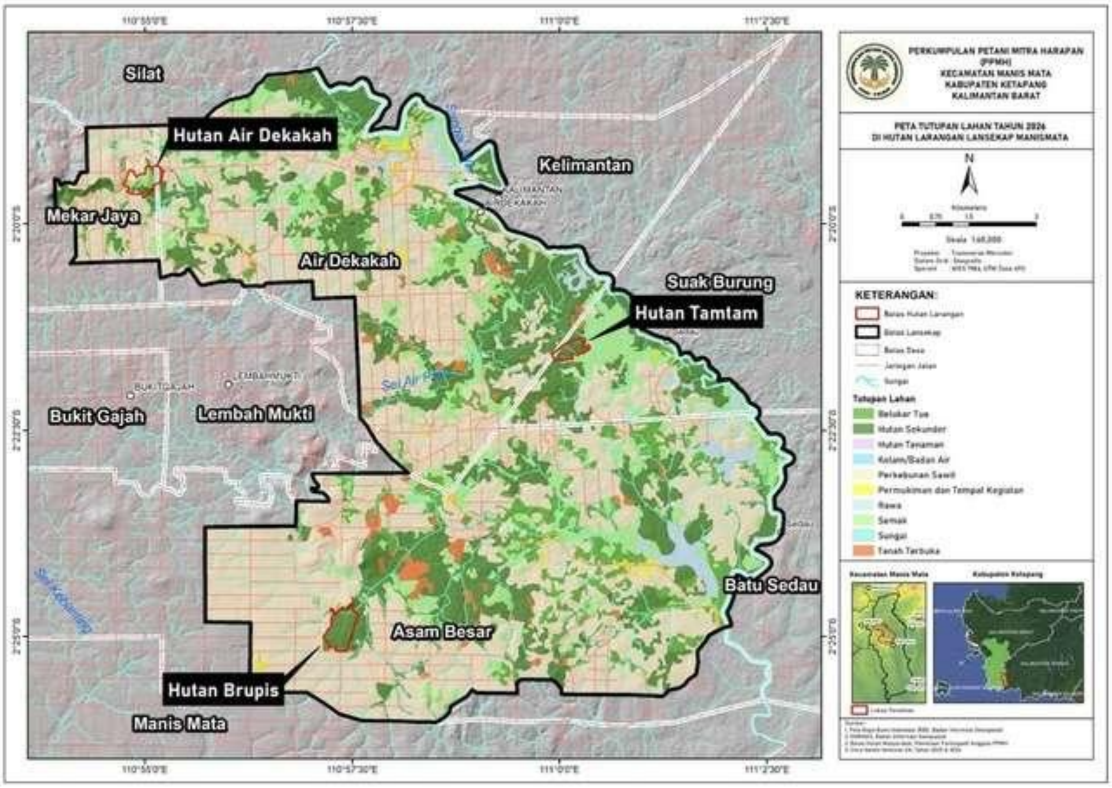


Figure 56. 2026 Landscape Land Cover Map

In contrast to other land cover types, the area of wetlands decreased from 391.93 ha to 252.09 ha, a reduction of approximately 139.84 ha. This decline indicates changes in wetland conditions that are likely influenced by land conversion, changes in hydrology, or land management activities in the surrounding areas.

Other land cover classes, such as settlements and activity sites, rivers, ponds/water bodies, and plantation forests, remained relatively stable and showed no significant changes during the observation period.

Overall, land cover dynamics from 2016 to 2026 show a trend of landscape shift from forest dominance toward oil palm plantation dominance. The substantial loss of secondary forest, coupled with an increase in the area of oil palm plantations, indicates strong pressure on forested areas within the landscape. Nevertheless, the presence of remaining forest blocks—particularly in the Air Dekakah Sacred Forest, Tantam Sacred Forest, and Brupis Sacred Forest—serves as a critical element in maintaining the landscape's ecological functions, including as wildlife habitat, wildlife movement corridors, carbon sinks, and providers of ecosystem services for surrounding communities.

These findings highlight the importance of sustainable landscape management efforts that can balance plantation production needs with the protection of remaining forest areas, so that the ecological and social functions of the Manismata landscape can be preserved in the future.

4.8.2 Habitat Fragmentation

The Air Dekakah, Tamtam, and Brupis Sacred Forests, which are secondary forests, serve as fragmented habitats for wildlife. These three areas are largely separated by oil palm plantations, shrubs and thickets, and other areas such as settlements and public facilities belonging to communities surrounding the Sacred Forests. These changes in forest cover have led to the formation of isolated or fragmented wildlife habitats (habitat fragmentation). Habitat fragmentation limits wildlife's ability to migrate or carry out their daily activities. Some wildlife species, which require extensive home ranges for foraging and breeding, are particularly vulnerable to threats to their survival.

This habitat fragmentation has led to a decline in the diversity of flora and fauna, as evidenced by the low number of wildlife sightings in these three areas compared to information gathered from interviews with local communities living near the forests. Some wildlife species still found in these three areas include: deer, muntjacs, sun bears, mouse deer, tarsiers, pangolins, wild boars, pygmy squirrels, long-tailed macaques, and small bird species. Fauna species previously encountered by local communities in the three Sacred Forest areas and their surroundings include large birds such as the jungle fowl, hornbill, enggag, and ruai; while mammals such as proboscis monkeys, orangutans, kelempui, lutung, and owa-owa are now rarely seen. This situation serves as an indicator of the decline in the quality of wildlife habitats due to the reduction in the area of contiguous and undisturbed forest.

4.8.3 Anthropogenic Disturbances

Anthropogenic disturbances are damages, environmental changes, or disasters directly caused by human actions, errors, or negligence. Anthropogenic disturbances resulting from forest/land conversion can lead to species extinction and the disruption of food chains due to habitat destruction, and can trigger ecological disasters such as increased frequency of floods, extreme droughts, and landslides that exacerbate the water cycle.

Human activities play a major role in forest changes, land clearing, hunting, illegal logging, fires, and other human activities. Around the three Sacred Forests—which are surrounded by oil palm plantations and other intensively cultivated lands with high levels of human activity—these activities also disrupt the daily lives of wildlife that are sensitive to human presence within the Sacred Forests.

4.8.4 Pressures on Wildlife

The loss of natural wildlife habitat caused by changes in forest function, deforestation, and forest encroachment, as well as land and forest fires, poses a threat to wildlife diversity and populations; furthermore, poaching adds to the pressures on the survival of wildlife. Wildlife possesses both ecological and economic value.

The current surge in illegal wildlife trade in Indonesia highlights the pressures on wildlife populations in the forests. There is a growing demand in local, national, and even international markets for Indonesia's rare wildlife. Wildlife trafficking has expanded into digital platforms in addition to conventional markets. The high economic value of wildlife encourages communities living near forests to hunt and capture wildlife within forest areas.

Hunters' activities in the forest can last a day, a week, or even longer, depending on the target species. To capture their prey, hunters typically set traps, use arrows, or even firearms. Bird traps include mist nets, decoys, and conventional snares; hunters often clear paths or openings by cutting down small trees. To hunt large mammals for their meat, hunters typically set traps or shoot them; these hunting activities within the forest disrupt the behavior of the wildlife living there.

Conflicts between wildlife and humans occur, such as on the island of Sumatra, where elephants attack oil palm plantations and Sumatran tigers and orangutans enter plantations or residential areas; in Kalimantan, where orangutans and elephants wander into oil palm plantations; and in Java, where a leopard once attacked sheep in a pen near the Gunung Sawal forest area in Ciamis, West Java.

Wild animals may leave their natural habitats because those habitats are no longer supportive—whether due to a scarcity of food sources or competition among animals—which creates vulnerabilities to the animals' safety. Public perceptions of animals that damage plantations or residents' livestock vary; some people view these animals as pests that need to be captured or neutralized, while others believe they should simply be driven away or chased off.

Based on interviews with respondents in the vicinity of three Sacred Forest areas, there have been incidents of damage to logging machinery, strongly suspected to have been caused by bears. These incidents indicate potential pressure on wildlife. Managing human-wildlife conflicts requires educating communities living near forests.

4.8.5 Landscape Deforestation

Table 27. Deforestation, 2016–2026

HUTAN ALAM 2016	DEFORESTASI NON HUTAN ALAM 2026	LUAS (HA)	PERSEN (%)
Hutan Sekunder	Belukar Tua	611.93	26%
Hutan Sekunder	Perkebunan Sawit	907.06	39%
Hutan Sekunder	Permukiman dan Tempat Kegiatan	3.30	0%
Hutan Sekunder	Semak	634.11	27%
Hutan Sekunder	Tanah Terbuka	199.34	8%
	TOTAL	2,355.75	100%

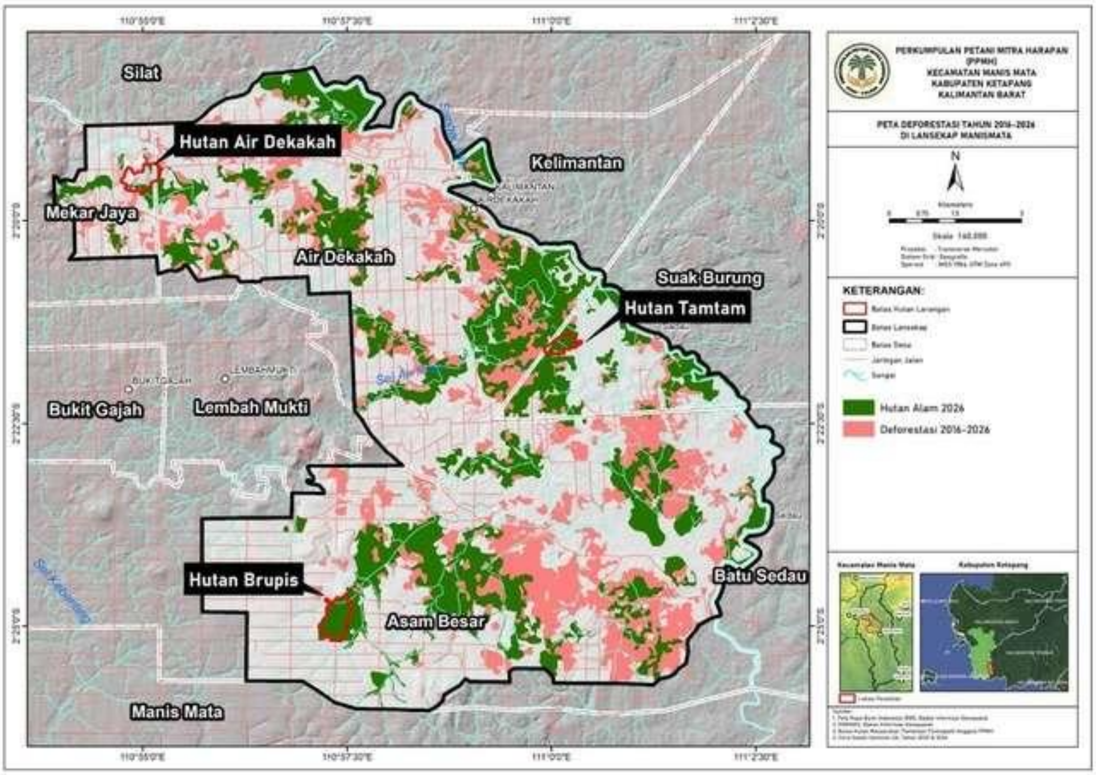


Figure 57. Deforestation Map for 2014-2014 in the Manismata Landscape

An analysis of land cover changes shows that during the 2016–2026 period, the Manismata Landscape experienced deforestation covering an area of 2,355.75 hectares, resulting from the conversion of secondary forest in 2016 into various non-forest categories by 2026. This deforestation area is equivalent to approximately 44.5% of the total secondary forest area in 2016, which stood at 5,297.97 ha, indicating significant pressure on the natural forest within the landscape.

The largest conversion of forest occurred into oil palm plantations, covering 907.06 ha (39%) of the total deforestation. This indicates that the expansion of oil palm plantations is the primary driver of forest cover loss in the Manismata Landscape. In addition, approximately 634.11 ha (27%) were converted to shrubland and 611.93 ha (26%) to mature scrub, indicating that forest areas have undergone degradation or land clearing and subsequently developed into secondary vegetation. Meanwhile, 199.34 ha (8%) were converted to open land, indicating relatively recent land-clearing activities, while the conversion to settlements and activity sites amounted to only 3.30 ha (<1%).

The analysis period spans 10 years (2016–2026). With a total forest loss of 2,355.75 ha, the average deforestation rate is 235.58 ha/year. When calculated as a percentage of the forest area at the beginning of 2016, the average rate of forest loss reached approximately 4.45% per year. This figure indicates that nearly half of the secondary forest cover present in 2016 has been lost over the past decade.

Implications for the Landscape

This deforestation has the potential to degrade wildlife habitat quality, reduce connectivity between forest areas, decrease carbon stocks, and disrupt the landscape's hydrological functions. Nevertheless, several remaining forest pockets—such as the Air Dekakah Forest, the Brupis Forest, and the Tantam Forest—play a crucial role as habitats for biodiversity and community-based conservation areas. Therefore, protecting these areas is a strategic step toward curbing the rate of deforestation and maintaining the ecological sustainability of the Manismata Landscape.

Overall, the analysis results indicate that the expansion of oil palm plantations is the dominant factor driving deforestation in the Manismata Landscape, while other areas have degraded into shrubland, old scrub, and open land due to land clearing and disturbances to forest cover.

Table 28. Summary of Deforestation, 2016–2026

Parameter	Nilai
Luas Hutan Sekunder 2016	5.297,97 ha
Total Deforestasi	2.355,75 ha
Proporsi Hutan Hilang	44,5%
Periode Analisis	10 tahun
Laju Deforestasi	235,58 ha/tahun
Pendorong Utama Deforestasi	Konversi menjadi perkebunan sawit (39%)

4.9 Potential Carbon Stocks in Sacred Forests and Landscapes

4.9.1 Biomass of Sacred Forest Stands

Biomass in the three forest areas—namely, the Air Dekakah, Tamtam, and Brupis Sacred Forests—varies significantly. The Air Dekakah forest consists of shrubland and secondary forest, while the Tamtam and Brupis forests consist of secondary forest. The conditions of this forest cover that influence biomass potential include tree species diversity, density, and the biomass of the tree stands themselves. Analysis of the biomass of tree stands with diameters of 10 cm or greater showed that in shrubland, the average total biomass was 13.48 metric tons/ha, while in secondary forest, the average biomass was 357.52 metric tons/ha.

1) Biomass of the Air Dekakah Forest

The forest cover in Air Dekakah consists of shrubland and secondary forest. In the shrubland cover, tree stands with diameters above 10 cm were recorded at 179.17 individuals/ha; stand diameters ranged from 10 cm to 29 cm, with an average tree diameter of 16.29 cm and an average tree height of 11.23 m, resulting in a total biomass of 13.48 metric tons per hectare. In the secondary forest, there were 497.50 trees per hectare with diameters greater than 10 cm; tree diameters ranged from 10 cm to 80 cm, with trees under 30 cm in diameter dominating the stand. The average tree diameter was 22.24 cm and the average tree height was 14.16 m, with a total biomass of 161.83 metric tons per hectare. The results of the biomass analysis in the Air Dekakah forest are presented in the following table.

Table 29. Biomass potential of tree-level and pole-level vegetation stands, based on forest cover, in the Air Dekakah Sacred Forest area, 2026

Location	Forest Cover	Strata	N (individuals/ ha)	Average Diameter (cm)	Average Height (m)	Biomass (metric tons/ha)
Surface Water	Shrubs and Undergrowth	Trees	37.50	21.00	14.17	7.78
	Shrubs and Underbrush	Pole	141.67	11.59	8.29	5.70
Total/Average			179.17	16.29	11.23	13.48
Air Dekakah	Secondary forest	Trees	170.83	32.00	21.17	148.80
	Secondary forest	Poles	316.67	12.47	7.16	13.03
Total/Average			487.50	22.24	14.16	161.83

2) Tamtam Forest Biomass

The Tamtam area has secondary forest cover. The number of trees with a diameter greater than 10 cm is recorded at 770.83 individuals per hectare. The diameter structure of the stand ranges from 10 cm to 190 cm, dominated by trees with diameters of 19–19 cm (71.35%), 20–29 cm (14.32%), 30–39 cm (5.95%), 40–49 cm (14.32%), and 50 cm and above (6.22%), with an average tree diameter of 29.07 cm and an average tree height of 14.08 m, resulting in a total biomass of 664.36 metric tons per hectare. The results of the biomass analysis in the Tamtam forest are presented in the following table,

Table 30. Biomass potential of tree-level and pole-level vegetation stands, based on forest cover, in the Tamtam Sacred Forest area, 2026

Location	Forest Cover	Strata	N (individuals/ha)	Average Diameter (cm)	Average Height (m)	Biomass (metric tons/ha)
Tamtam	Shrubs and Undergrowth	Trees	220.83	44.13	19.92	631.65
	Shrubs and Undergrowth	Poles	550.00	14.02	8.24	32.71
Total/Average			770.83	29.07	14.08	664.36

3) Brupis Forest Biomass

The Brupis area is covered by secondary forest. The number of trees with a diameter greater than 10 cm was recorded at 709.38 individuals per hectare. The diameter structure of the stand ranges from 10 cm to 80 cm, dominated by trees with diameters of 19–19 cm (71.07%), 20–29 cm (13.66%), 30–39 cm (8.08%), 40–49 cm (4.11%), and 50 cm and above (3.9%), with an average tree diameter of 29.01 cm and an average tree height of 19.17 m, resulting in a total biomass of 246.38 metric tons per hectare. The results of the biomass analysis in the Brupis forest are presented in the following table,

Table 31. Biomass potential in tree- and pole-stage vegetation stands, based on forest cover, in the Brupis Sacred Forest area, 2026

Location	Forest Cover	Strata	N (individuals/ha)	Average Diameter (cm)	Average Height (m)	Biomass (metric tons/ha)
Brupis	Shrubs and Undergrowth	Trees	205.21	31.79	24.50	195.11
	Shrubs and Underbrush	Poles	504.17	14.02	13.85	51.27
Total/Average			709.38	22.91	19.17	246.38

4.9.2 Carbon Stock in Sacred Forests

The potential carbon stock in the three Sacred Forests within the Manismata Landscape shows considerable variation, influenced by land cover conditions, stand structure, and vegetation maturity. The Air Dekakah Sacred Forest consists of secondary forest and scrub, resulting in a relatively lower carbon stock compared to the other two areas, which are dominated by secondary forest. Based on calculations of tree biomass with diameters ≥10 cm, the carbon stock in the secondary forest of the Tamtam Sacred Forest reaches 312.25 tC/ha, far higher than that of the Brupis Sacred Forest at 115.89 tC/ha and the Air Dekakah Sacred Forest at 76.06 tC/ha. Meanwhile, the shrubland cover in Air Dekakah has a carbon stock of only 6.34 tC/ha.

Based on the identified areas of secondary forest and shrubland cover, the total carbon stock in the three Sacred Forests is estimated at 13,958.11 tC, equivalent to 51,180.53 tCO_2eq. The Tamtam Sacred Forest holds the largest carbon stock, at 6,557.25 tC (24,043.33 tCO_2eq), even though its area is only about 21 ha. This high carbon stock indicates that the area still has relatively healthy forest stands and high biomass. The Brupis Sacred Forest ranks second with total carbon stocks of 5,562.72 tC (20,396.50 tCO_2eq), while the Air Dekakah Sacred Forest stores approximately 1,838.14 tC (6,740.70 tCO_2eq).

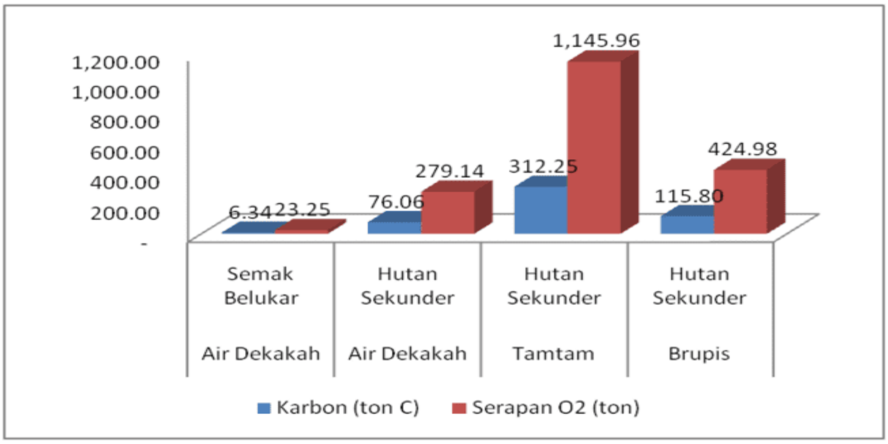


Figure 58. Potential carbon stock in Sacred Forests based on land cover

These results indicate that forest stand quality has a greater influence on carbon stock levels than area size alone. Therefore, the Tamtam and Brupis Sacred Forests play a crucial role as primary carbon sinks in the Manismata Landscape, while the Air Dekakah Sacred Forest has significant potential for improvement through restoration and vegetation enrichment activities to enhance carbon stocks and the area's ecological functions in the future.

Table 32. Carbon Potential of Sacred Forests

Sacred Forest	Land Cover	Area (Ha)	Carbon Stock (tC/ha)	Total Carbon (tC)	Total tCO_2eq
Surface Water	Shrubland/Scrubland	14	6.34	88.76	325.72
Surface Water	Secondary Forest	23	76.06	1,749.38	6,414.98
Brupis	Secondary Forest	48	115.89	5,562.72	20,396.50
Tamtam	Secondary Forest	21	312.25	6,557.25	24,043.33
Total		**106**		**13,958.11**	**51,180.53**

4.9.3 Carbon Analysis in the Manismata Landscape

Based on the estimated biomass and carbon stocks for each land cover class, the total carbon stock in the Manismata Landscape in 2016 was estimated at 1,072,122 metric tons of carbon (tC), equivalent to 3,934,688 metric tons of CO_2e. During this period, the majority of carbon stocks were stored in secondary forest cover, which spans an area of 5,298 ha with a carbon stock of 716,013 tC—representing approximately 67% of the landscape's total carbon stock. In addition to secondary forests, carbon stocks were also stored in oil palm plantations at 309,802 tC, while other land cover types contributed relatively little.

By 2026, the total landscape carbon stock is projected to decrease to 890,928 metric tons of carbon (tC), equivalent to 3,269,707 metric tons of CO_2e. Although carbon stocks in oil palm plantations increased to 412,316 tC as the plantation area expanded, the decline in carbon stocks in secondary forests to 394,163 tC caused the total landscape carbon stock to continue to decline. Secondary forests remain the largest carbon sink, contributing approximately 44% of the total landscape carbon stock in 2026, followed by oil palm plantations at 46%.

Table 33. Decline in Carbon Stocks from 2016 to 2026 in the Manismata Landscape

NO	TUTUPAN LAHAN	2016			2026		
		LUAS	tC	tCO2eq	LUAS	tC	tCO2eq
1	Belukar Tua	517	38,570	141,553	1,013	75,576	277,365
2	Hutan Sekunder	5,298	716,013	2,627,767	2,917	394,163	1,446,578
3	Hutan Tanaman	1	62	228	1	62	228
4	Kolam/Badan Air	4	-	-	4	-	-
5	Perkebunan Sawit	4,861	309,802	1,136,974	6,469	412,316	1,513,198
6	Permukiman dan Tempat Kegiatan	151	419	1,538	154	428	1,572
7	Rawa	392	-	-	252	-	-
8	Semak	1,445	7,256	26,628	1,670	8,383	30,766
9	Sungai	147	-	-	147	-	-
10	Tanah Terbuka	55	-	-	244	-	-
	TOTAL	12,871	1,072,122	3,934,688	12,871	890,928	3,269,707

These changes in carbon stock composition indicate a shift in landscape function from a forest ecosystem-dominated landscape toward one increasingly dominated by oil palm plantations. Although oil palm plantations are capable of storing a certain amount of carbon , their carbon storage capacity remains lower than that of natural forests; thus, the conversion of forests to other land uses continues to cause an overall decline in carbon stocks.

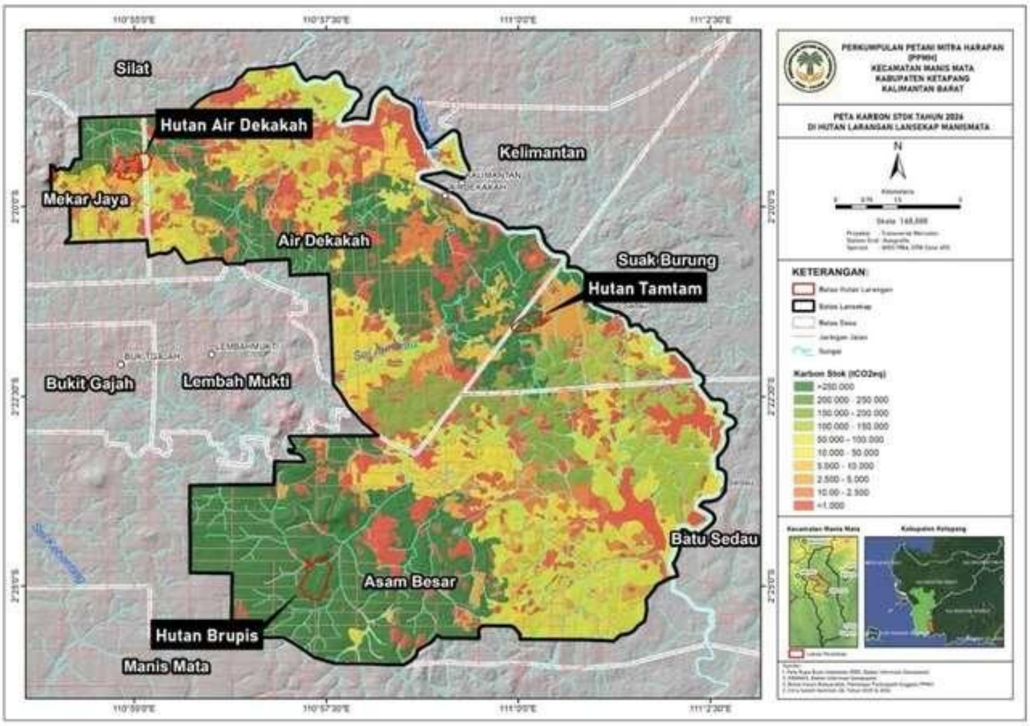


Figure 59. 2026 Carbon Stock Map

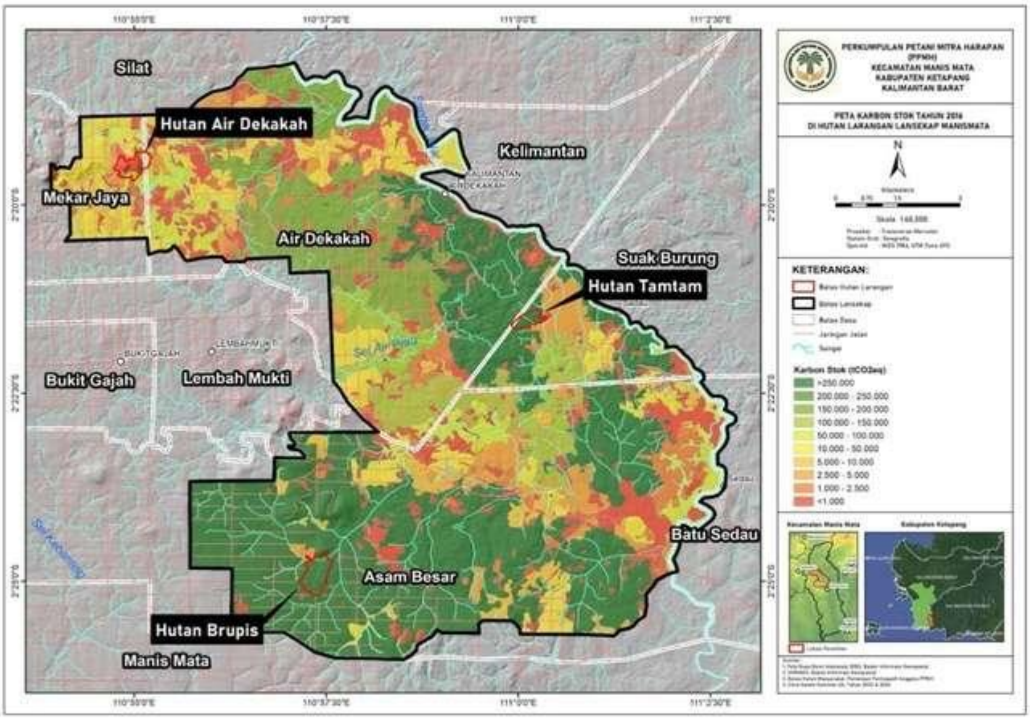


Figure 60. 2016 Carbon Stock Map

Changes in Carbon Stocks and Emissions

During the 2016–2026 period, the total carbon stock of the Manismata Landscape decreased from 1,072,122 tC to 890,928 tC, representing a loss of 181,194 tC. This decrease is equivalent to 16.9% of the total carbon stock at the beginning of 2016. When converted to greenhouse gas emissions, this loss in carbon stock is equivalent to 664,981 metric tons of CO_2e over the ten-year observation period.

Thus, the average annual emissions resulting from land-cover changes amount to approximately 66,498 metric tons of CO_2e. These findings indicate that the loss of forest cover in the Manismata Landscape not only impacts biodiversity and ecological functions but also reduces the landscape's capacity to store carbon and contributes to increased greenhouse gas emissions.

4.10 Contribution of Sacred Forests to the Landscape

4.10.1. Biodiversity Functions

Tree-level vegetation biodiversity serves dual ecological functions: it provides a variety of microhabitat niches for wildlife and acts as a refuge for the conservation of local genetic resources against extinction. Based on a compilation of actual ecological index data from the three study sites, the analysis of biodiversity functions can be summarized as follows:

1. Brupis Forest: A Megabiodiversity Refuge and Niche Complex

The Brupis Forest recorded the highest ecological value as a primary *refugia* area, with a richness of 54 tree species and a total density of 197 stands. The Shannon-Wiener diversity index (H') value in this area falls into the high category, at 3.23.

Role as a Habitat and Refuge:

- The high H' value indicates that the Brupis Forest possesses exceptional community stability to support a wide variety of wildlife taxa. The presence of trees from the Dipterocarpaceae family (Kepayang—6 individuals) and the Lauraceae family (Medang Bulan, Medang Sandak, Medang Pulut) creates a complex canopy stratification, serving as a multifunctional vertical space for both upper-canopy birds and arboreal reptiles.
- This area serves as *a* vital *refuge* for endangered lowland endemic tree species. The discovery of three individuals of the ironwood species Ulin (*Eusideroxylon zwageri*) and two individuals of Pantung (*Dyera lowii*) confirms that this area serves as a crucial *gene pool* for the island's native flora. The abundance of litter and species

diversity on the forest floor also supports a thriving population of macroinvertebrates and soil microorganisms. The Brupis Forest holds the highest priority as a Genetic Resource Refuge because it harbors the most abundant populations of protected rare species (Ulin and Pantung).

2. Tamtam Forest: Protected Habitat for Specialized-Diet Wildlife

The Tamtam Forest exhibits moderate to high biodiversity, with an H' index of 2.94, comprising 32 species and 106 stands. The species evenness (E) at this site is the highest among the three locations, at 0.84.

Role as a Habitat and Refuge:

- The evenness index (E = 0.84), which is close to 1, confirms that the tree community in the Tamtam Forest grows in a balanced manner without any extreme single-species dominance. These conditions are highly beneficial for *specialist species*. The vegetation structure is supported by natural forest fruit trees such as Cempedak (*Artocarpus integer*)—10 individuals, Pekawai (*Durio kutejensis*)—3 individuals, and Kerantungan (*Durio oxleyanus*)—2 individuals.
- The presence of these wild fruit trees from the *Durio* and *Artocarpus* genera makes Tamtam Forest a *core* habitat providing *keystone resources* for primate groups and frugivorous birds year-round. The presence of one Ulin tree and two Meranti trees reinforces Tamtam Forest's role as a provider of natural nesting sites as well as a wildlife *refuge* with minimal human agricultural intervention. Tamtam Forest plays a vital role as a Primary Wildlife Food Habitat due to the even and abundant distribution of its forest fruit trees.

3. Air Dekakah Forest: A Vulnerable Area and Loss of Refuge Function

The Air Dekakah Forest has the lowest and most alarming biodiversity function score. The Shannon-Wiener diversity index is only 2.56 (moderate-low category) with very limited species richness, namely 22 species and 59 stands.

Role as Habitat and Refuge:

- The low level of biodiversity in this area is caused by a highly skewed species composition, in which Punaga (*Calophyllum inophyllum L.*) s absolutely dominates with 18 individuals. This single-species dominance narrows the range of food niches available to wildlife, meaning only opportunistic species (omnivores) are able to survive in this location.
- The area's function as a biodiversity *refuge* has seriously declined. The absence of large, climax tree species, coupled with the invasion of open-space pioneer species

such as Mahang (*Macaranga pearsonii*)—with 6 individuals—and exotic introduced plants such as Acacia (*Acacia mangium*)—with 2 individuals—serves as a strong indicator of ecosystem degradation. Due to the open canopy gaps and low genetic variation in the native flora, Air Dekakah's capacity to protect sensitive wildlife and serve as *a* biodiversity *refuge* is at a critical level. The Air Dekakah forest has lost much of its biodiversity functions. This area needs to be restored through *the enrichment* of local flora that serves as animal forage so that it is not completely isolated and abandoned by the fauna community.

4.10.2 Hydrological Functions

Tree-level vegetation in riparian zones (along riverbanks or water sources) serves vital hydrological functions, namely as a sediment filtration system, a stabilizer of slopes against erosion, and a regulator of groundwater infiltration. Based on the actual ecological characteristics derived from vegetation analyses in the three areas, the hydrological functions of each habitat are outlined as follows:

1. Tamtam Forest: Optimal Natural Water Management Function

The Tamtam Forest exhibits the most stable and optimal hydrological function capacity. This is supported by the natural dominance of 11 Punaga (*Calophyllum inophyllum L.*) trees and 21 Manggungan (*Elaeocarpus microphyllus*) trees.

Hydrological Mechanism: The Punaga tree is ecologically recognized as a resilient littoral and riparian species. Its deep, extensively branched root system is highly effective at binding soil aggregates along the water's edge, preventing *riverbank erosion*.

The high density of Manggungan trees with large trunk diameters creates a layered canopy architecture. This canopy serves to *intercept* the kinetic energy of direct rainfall, thereby reducing the damaging impact of raindrops on the forest soil surface and maximizing water absorption into the soil (*infiltration*) to replenish the groundwater aquifer. The presence of primary forest climax tree species such as Medang (*Dehaasia sp.*) and Nyatuh (*Palaquium obtusifolium*) enriches the litter layer on the forest floor, which acts as a natural water-retaining sponge. The Tamtam Forest should be designated as a Primary Water Protection Zone due to its exceptional ability to naturally maintain the local hydrological cycle.

2. Brupis Forest: Modification of Hydrological Functions Due to Agroforestry Stands

The Brupis Forest has the highest number of stands (197 individuals), but ecologically, its natural hydrological functions have been altered due to the absolute dominance of rubber trees (*Hevea brasiliensis*), numbering 50 individuals.

Hydrological Mechanism: Although rubber trees help cover the earth's surface, the evapotranspiration rate in pure rubber stands tends to be very high, which has the potential to draw more groundwater reserves during the dry season compared to natural water-retaining forest vegetation.

The riparian protection function in Brupis is evident in the presence of Laban (*Vitex* pinnata—14 individuals) and Medang (*Polyalthia* sumatrana—12 individuals). Laban exhibits high resilience to water level fluctuations, and its root system helps stabilize swamp soil and riparian zones. The presence of Kepayang (*Dipterocarpus sp.*) and Pantung (*Dyera lowii*)—native wetland and lowland vegetation—strengthens the structure of the riparian stand by filtering *surface runoff* containing sediment from agroforestry activities before it enters the main water body. The Brupis Forest requires restrictions on the expansion of rubber plantations around riverbanks to prevent native riparian vegetation such as Laban and Medang from being displaced.

3. Air Dekakah Forest: Critical and Vulnerable Hydrological Functions of the Riparian Zone

The Air Dekakah area contains springs that provide water for residents' daily needs, indicating the most vulnerable and critical hydrological conditions. This area is supported by only 59 mature trees, with a highly skewed dominance of Punaga (*Calophyllum inophyllum L.*), comprising 18 individuals.

Hydrological Mechanisms: Although the presence of these 18 Punaga trees serves as the last line of defense against erosion along the Air Dekakah edge, the minimal total number of other accompanying species (most of which consist of only a single individual, such as Kondang, Sindur, and Pulai) contributes to the vulnerability of Airhydrological functions. The low overall tree density leaves many gaps in the canopy (*canopy gaps*). When heavy rain occurs, rainwater strikes the ground directly without adequate canopy cover to slow it down. Consequently, surface erosion (*sheet erosion*) increases, and leads to high sedimentation in the Dekakah River's riparian water body.

The emergence of pioneer species such as Mahang (*Macaranga pearsonii*) and Acacia (*Acacia mangium*) confirms that this riparian zone is under stress or in a post-disturbance state, where the soil tends to be drier and its water retention capacity is significantly lower compared to secondary natural forests. The Air Dekakah forest requires a specialized *enrichment planting* program for deep-rooted riparian tree species (such as fig trees (*Ficus* sp.) or meranti (*Dipterocarpus* sp.)) to close canopy gaps and restore critical hydrological functions.

4.10.3 Climate Functions

Carbon Storage

- Sacred Forests serve as important natural carbon sinks within the landscape. The remaining tree stands, particularly in the Brupis and Tantam Sacred Forests—which are dominated by secondary forests—store biomass in the form of trunks, branches, roots, and litter, functioning as long-term carbon reserves. The existence of these areas helps reduce carbon emissions resulting from land-use changes and contributes to climate change mitigation at both the local and regional levels.
- Furthermore, Sacred Forests serve as a more stable source of carbon stock compared to surrounding cultivated lands. The loss of these areas would lead to carbon releases into the atmosphere and further deplete the landscape's overall carbon reserves.

Microclimate Regulation

- Sacred Forests also play a role in regulating the surrounding microclimate. Dense vegetation cover lowers air temperature, increases humidity, reduces wind speed, and maintains the stability of the local water cycle. These conditions create a cooler and more humid environment compared to open areas or monoculture plantations.
- This microclimate function is particularly important in the Brupis and Tantam Sacred Forests, which still have high canopy cover. The presence of these forests helps mitigate *the "heat island effect,"* which is common in landscapes dominated by plantations and open land.

Connectivity Function

Ecological Corridors

- The Air Dekakah, Brupis, and Tantam Sacred Forests serve as part of a network of ecological corridors that support wildlife movement within the Manismata Landscape. Although the landscape is currently dominated by oil palm plantations and experiences significant habitat fragmentation, the presence of Sacred Forests that still maintain natural vegetation cover provides movement pathways for various wildlife species to travel between habitats.
- The function of these ecological corridors is primarily supported by the presence of secondary forests, old-growth thickets, riverbanks, and remaining wetland areas surrounding the Sacred Forests. These corridors allow wildlife to access food sources, shelter, and breeding sites, while also maintaining genetic exchange between populations. Based on the results of habitat connectivity analysis, the Tantam Sacred Forest plays the most important role as a landscape connectivity hub, while the Brupis Sacred Forest functions as a connecting corridor through the river network and

surrounding patches of secondary forest. Meanwhile, the Air Dekakah Sacred Forest requires corridor reinforcement through habitat restoration and the rehabilitation of connecting vegetation.

Stepping Stone Habitat

- In addition to functioning as ecological corridors, Sacred Forests also serve as *stepping stone habitats*—temporary stopover sites for wildlife moving through a fragmented landscape. In a landscape dominated by oil palm plantations, the presence of small- to medium-sized patches of natural habitat is crucial as places for rest, temporary shelter, foraging, and continuing movement toward other habitats.
- This *stepping-stone* function is particularly relevant for species with limited range or those that avoid open areas. The Air Dekakah, Brupis, and Tantam Sacred Forests, together with surrounding patches of secondary forest and old-growth thickets, form a habitat network that allows wildlife to move between major habitat blocks. The presence of these stopover habitats helps mitigate the impacts of landscape fragmentation, increases opportunities for genetic exchange between populations, and supports the long-term survival of wildlife populations.
- Thus, despite their relatively limited size, these three Sacred Forests play a strategic role as elements of landscape connectivity that maintain ecological connectivity and enhance biodiversity resilience amid the dominance of oil palm plantation land use.

CHAPTER V. MANAGEMENT AND RESTORATION RECOMMENDATIONS

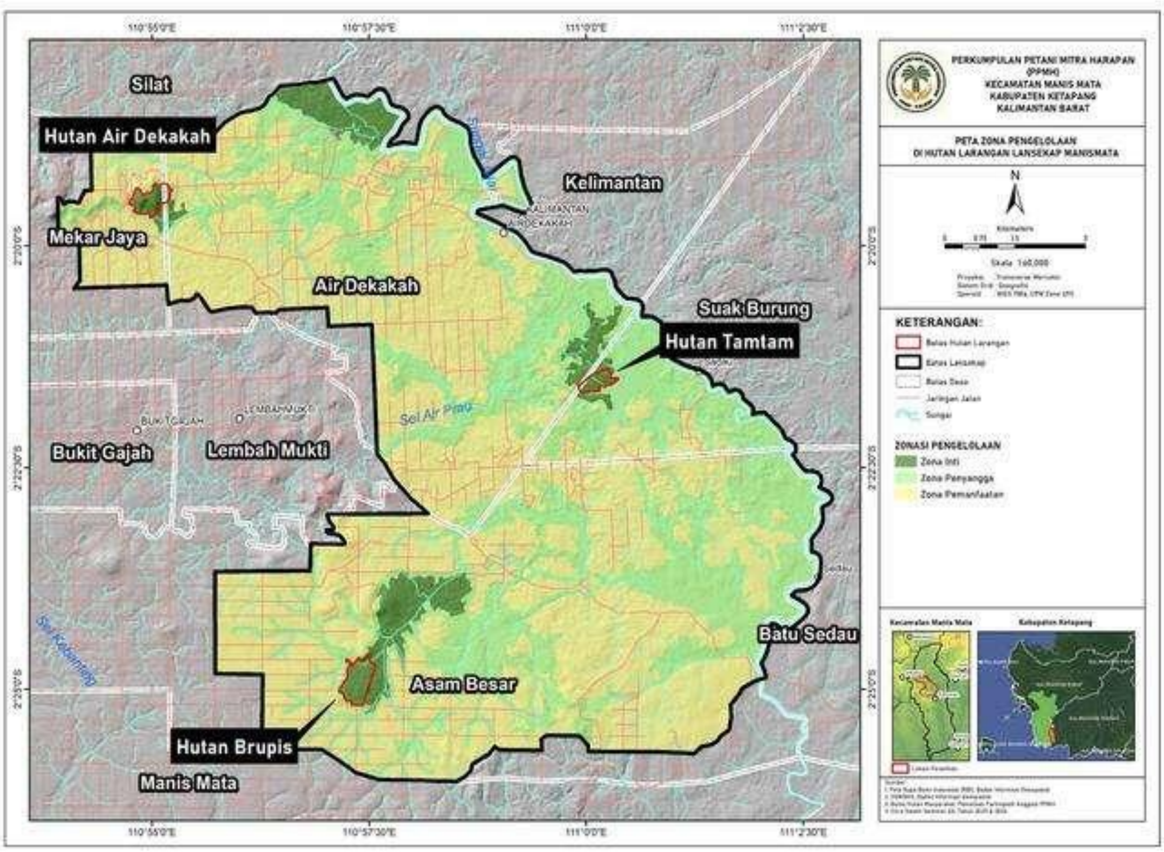


Figure 61. Map of Landscape Management Zones

Table 34. Area of Landscape Management Zones

NO	ZONA PENGELOLAAN	LUAS
1	Zona Inti	658
2	Zona Pemanfaatan	7,483
3	Zona Penyangga	4,589
	TOTAL	**12,730**

Management zoning was established as the basis for landscape management that integrates conservation objectives, the protection of ecosystem services, and the sustainable use of natural resources. Zone delineation took into account the presence of Sacred Forests, natural habitats, river and swamp buffer zones, habitat connectivity levels, and existing land use dominated by oil palm plantations.

Based on the analysis results, the total area of the managed landscape is 12,730 ha, divided into a Core Zone covering 658 ha (5.2%), a Buffer Zone covering 4,589 ha (36.0%), and a Utilization Zone covering 7,483 ha (58.8%).

Core Zone

The Core Zone covers an area of approximately 658 ha and is the area with the highest conservation value within the landscape. This zone includes the Air Dekakah, Brupis, and Tantam Sacred Forests, along with blocks of secondary forest directly adjacent to these areas. The Core Zone serves as the primary habitat for various species of flora and fauna, a carbon sink, a provider of ecosystem services, and an area of high cultural and traditional significance.

Ecologically, the core zone serves as a hub for biodiversity conservation within a landscape that has been fragmented by the expansion of oil palm plantations. The existence of this zone is crucial for sustaining wildlife populations, maintaining natural ecological processes, and protecting areas with High Conservation Value (HCV), particularly HCV 1, HCV 3, HCV 4, and HCV 6.

Buffer Zone

The buffer zone covers an area of 4,589 ha, or approximately 36% of the total landscape, making it a vital component in supporting the sustainable functioning of the core zone. This zone includes riverbanks, swamp edges, habitat corridors, old-growth thickets, and oil palm plantation areas directly bordering natural habitats.

The primary functions of the buffer zone are to reduce pressure on the core zone, maintain habitat connectivity, and preserve the landscape's hydrological functions. Additionally, this zone serves as a transition area that allows community activities to continue while adhering to environmentally friendly management principles. In the context of landscape conservation, the buffer zone is a priority area for habitat restoration, river and swamp riparian rehabilitation, agroforestry development, and the implementation of sustainable oil palm plantation practices.

The relatively large size of the buffer zone indicates that the success of conservation efforts in the Manismata Sacred Forest depends not only on the protection of the core area but also on the management of transition areas capable of maintaining ecological connectivity and reducing the risk of habitat fragmentation.

Utilization Zone

The utilization zone is the largest zone, covering approximately 7,483 ha or 58.8% of the total landscape. This zone is dominated by oil palm plantations, settlements, community farmland, and other land uses that serve as the primary sources of livelihood for local communities.

Although oriented toward economic activities, the utilization zone still plays a crucial role in supporting landscape sustainability. Management in this zone is directed toward applying the principles of sustainable production, reducing pressure on conservation areas, protecting water bodies, and increasing vegetation cover through agroforestry systems and the enrichment of native tree species. Given that the majority of the landscape falls within the utilization zone, the success of managing this area will be critical to the success of conservation efforts and the enhancement of the landscape's overall carbon stock.

Implications for Landscape Management

The zoning composition indicates that although core habitats cover only about 5% of the landscape's total area, these areas are supported by sufficiently extensive buffer zones, so the prospects for maintaining ecological functions and habitat connectivity remain relatively good. This approach reflects a landscape-based conservation strategy, in which the protection of core areas is combined with sustainable management of buffer and utilization zones.

Given this composition, landscape management priorities can be directed toward:

1. Protection of core zones to preserve natural habitats, carbon stocks, and cultural values.
2. Strengthening buffer zones through habitat restoration, rehabilitation of riverbanks and wetlands, and sustainable oil palm management.
3. Implementing sustainable production practices in the utilization zones to reduce pressure on conservation areas and enhance the landscape's contribution to biodiversity conservation and climate change mitigation.

Overall, this zoning indicates that the Manismata Landscape still has good potential to integrate conservation goals, carbon sequestration, the protection of ecosystem services, and community economic development within a single framework for sustainable landscape management.

5.1. Area Protection Strategy

As a follow-up to the biodiversity analysis in the Dekakah, Tamtam, and Brupis Waterforests, this chapter will outline an adaptive, zoning-based Area Protection Strategy. This strategy is designed to integrate the protection of sensitive habitats, law enforcement against poaching, and the restoration of wildlife migration corridors to maintain long-term ecosystem stability

Strategy in the Brupis Forest Area:

Zoning of Agroforestry Communities and Protection of Refugia for Endangered Species. Ecological Status of the Area: It has the highest vegetation diversity (H' = 3.23; S = 54; n = 197) but faces pressure from the dominance of rubber trees (*Hevea brasiliensis*—50 individuals).

Priority List for Key Species Conservation:

- *Tarsius bancanus* (Tarsier) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Helarctos malayanus* (Sun Bear) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Rusa unicolor* (Deer) & *Sus barbatus* (Wild Boar) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Tragulus javanicus* (Mouse Deer), *Muntiacus muntjak* (Muntjac), *Viverra tangalunga* (Tenggalung), *Ratufa affinis* (Jelarang) — Status: *Least Concern* (LC).

List of Conservation Action Programs:

- Tarsier Microhabitat Zoning: Protecting understory vegetation and small- to medium-diameter trees as insect-hunting areas and perching sites for *Tarsius bancanus,* which is sensitive to land clearing.
- Enforcement of Agroforestry Stand Limits: Halting further conversion of natural forests into monoculture rubber plantations to preserve tree species that serve as secondary food sources for arboreal wildlife (such as the Jelarang and Tarsier).
- Mapping Large Mammal Movement Corridors: Mapping the daily movement routes of Sun Bears, Muntjacs, Deer, and Wild Boars within rubber plantation areas to avoid direct conflict with the activities of rubber farmers and harvesters.
- Protection of Rare Parent Trees: Enforcing a total logging ban within a 50-meter radius around the locations where Ulin (*Eusideroxylon zwageri*—3 individuals) and Pantung (*Dyera lowii*—2 individuals) trees grow.

Strategies in the Tamtam Forest Area:

Protection of Core Habitats and Food Abundance Corridors. Ecological Status of the Area: The most stable natural forest conditions, a very healthy vegetation structure, and the highest evenness index (E = 0.84) without any single dominant species.

Priority List for Key Species Conservation:

- *Manis javanica* (Pangolin) — IUCN Status: Critically Endangered (CR) / Protected.
- *Helarctos malayanus* (Sun Bear), *Rusa unicolor* (Sambar Deer), *Sus barbatus* (Wild Boar) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Tragulus javanicus* (Mouse Deer) & *Muntiacus muntjak* (Muntjac) — IUCN Status: *Least Concern* (LC) / Protected.

List of Conservation Action Programs:

- Designation of Core Habitat Status: Recommend Tamtam Forest as an area where human extractive activities are prohibited (Forest Sanctuary) because it is home to a globally critically endangered species (*Manis javanica*).
- Absolute Protection of Forage Trees (*Keystone Resources*): Strictly prohibit the commercial harvesting of fruit within the forest from Cempedak (*Artocarpus* integer—10 individuals), Pekawai (*Durio kutejensis*), and Kerantungan (*Durio oxleyanus*) trees to ensure food availability for Sun Bears and other fruit-foraging mammals.
- Protection of the Forest Floor and Soil Structure: Restricting human access to the forest floor to protect the microhabitat of the Javan pangolin (*Manis javanica*) as it searches for ant/termite colonies beneath the root systems of large trees such as Manggungan (*Elaeocarpus microphyllus*) and Punaga.
- Anti-Poaching Patrols: Given the high economic value of the Javan pangolin and the abundance of game animals (deer, muntjacs, and mouse-deer), this area must be a primary focus of regular forest security patrols.

Strategies in the Air Dekakah Forest Area:

Restoration of Critical Habitats and Recovery of Range Areas. Ecological Status of the Area: The ecosystem is highly vulnerable and degraded. The number of tree stands is very low (n = 59) and exhibits imbalance due to the dominance of Punaga trees (18 individuals) and the invasion of pioneer/exotic species.

Priority List for Key Species Conservation:

- *Rusa unicolor* (Rusa) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Helarctos malayanus* (Malayan Sun Bear) — IUCN Status: *Vulnerable* (VU) / Protected.
- *Exilisciurus exilis* (Dwarf Squirrel) — IUCN Status: *Data Deficient* (DD) / Not Protected.

List of Conservation Action Programs:

- *Canopy Gap Rehabilitation*: Conducting *enrichment planting* of broad-canopied trees to reconnect arboreal movement corridors, aiding the movement of small fauna such as *Exilisciurus exilis* (Dwarf Squirrel) that require canopy continuity.
- Eradication of Invasive Alien Species: Gradually eliminating *Acacia mangium* trees to prevent them from competing for soil nutrients, thereby allowing for the succession of local vegetation preferred by wildlife.
- Enrichment of Primary Food Sources for Bears and Deer: Intensively planting saplings of wild fruit trees (genera *Durio* and *Artocarpus*), as the native food trees in Air Dekakah are currently on the brink of local extinction (with only one individual remaining of each species). Restoring these food sources will encourage the return of Sun Bears and Deer to this area.
- Riparian Barrier: Protecting the 18 remaining Punaga trees along the water's edge to prevent erosion and provide shelter for large mammals (deer and sun bears) when they access drinking water sources.

Landscape-Scale Integrated Management *Strategy*:

- *Green Corridor* Development: Developing a connecting vegetation corridor that links Tamtam Forest (as the primary foraging area/sanctuary) with Brupis Forest (as a biodiversity hotspot), using the Air Dekakah restoration area as a transitional bridge.
- Community-Based Monitoring System: Involving local communities in protecting ecosystem buffer zones, particularly in Brupis Forest, which borders agricultural activities, to mitigate potential *human-wildlife* conflicts.

5.2 Strengthening Community-Based Management

Community empowerment strategies are no longer theoretical but are based on spatial-ecological principles. Communities in the Brupis Forest are focused on wildlife-tolerant rubber management; communities in the Tamtam Forest are encouraged to serve as a protective bastion for critical species (pangolins); while communities in the Air Dekakah Forest are positioned as active agents in the restoration of riparian vegetation.

Table 35. Strengthening Community-Based Management (CBM)

No	Focus Location	Main Program	Key Species Reference	Community Action	Success Targets
1	Brupis Forest	Wildlife-Friendly Rubber Plantation Partnership	*Tarsius bancanus* & Sun Bear	• Outreach on the ban on snares for wild boars. • Zoning for the protection of Ulin mother trees.	• *Zero poaching* (no active snares). • Ulin trees are safe from logging.
2	Tamtam Forest	*Community Rangers* (Indigenous Tribal Task Force)	Pangolin (*Manis javanica*—CR)	• Routine patrols to prevent poaching. • Customary prohibition on the commercial harvesting of wild cempedak fruit.	• Core forest floor habitat is secure. • Animal food supply remains intact.
3	Air Dekakah Forest	Adoption of Riparian Zones & Community-Led Nurseries	Deer & Sun Bears	• Independent propagation of local fruit trees (Durian, Pudu). • Community cleanup (*eradication*) of Acacia.	• Rapid natural succession of riparian trees. • Removal of 2 invasive Acacia trees.
4	All Locations	*Citizen Science* & Educational Ecotourism	Gibbons, Tarsiers, & Pangolins	• Training residents to become educational tour guides. • Reporting wildlife sightings via a smartphone app.	• Alternative economic opportunities for residents. • Real-time, up-to-date spatial wildlife database.

5.3 Rehabilitation and Restoration Plan

Landscape Rehabilitation and Restoration Plan

A conservation action plan has been developed to maintain the ecological, social, and economic sustainability of the Manismata Landscape through three main approaches: protection, restoration, and environmentally friendly management. These approaches take into account land cover conditions, habitat fragmentation levels, ecological connectivity, the presence of Sacred Forests, and the dominance of smallholder oil palm plantations as the primary land use.

Based on the results of spatial analysis, the recommended area for environmentally friendly management totals 8,405 ha, or approximately 66.0% of the total landscape area. This area is still utilized for community production and livelihood activities, primarily oil palm plantations, agricultural land, and other land uses. Given that the majority of the landscape falls into this category, the success of long-term conservation depends heavily on the implementation of sustainable management practices. Recommended activities include sustainable oil palm management, protection of river and swamp buffer zones, development of agroforestry , reduction in the use of agricultural chemicals, and increased vegetation cover on production lands.

Table 36. Area Covered by the Conservation Action Plan

Rencana Aksi Konservasi	Luas (Ha)
Pengelolaan ramah lingkungan	8,405
Proteksi	3,397
Restorasi	929
Grand Total	**12,730**

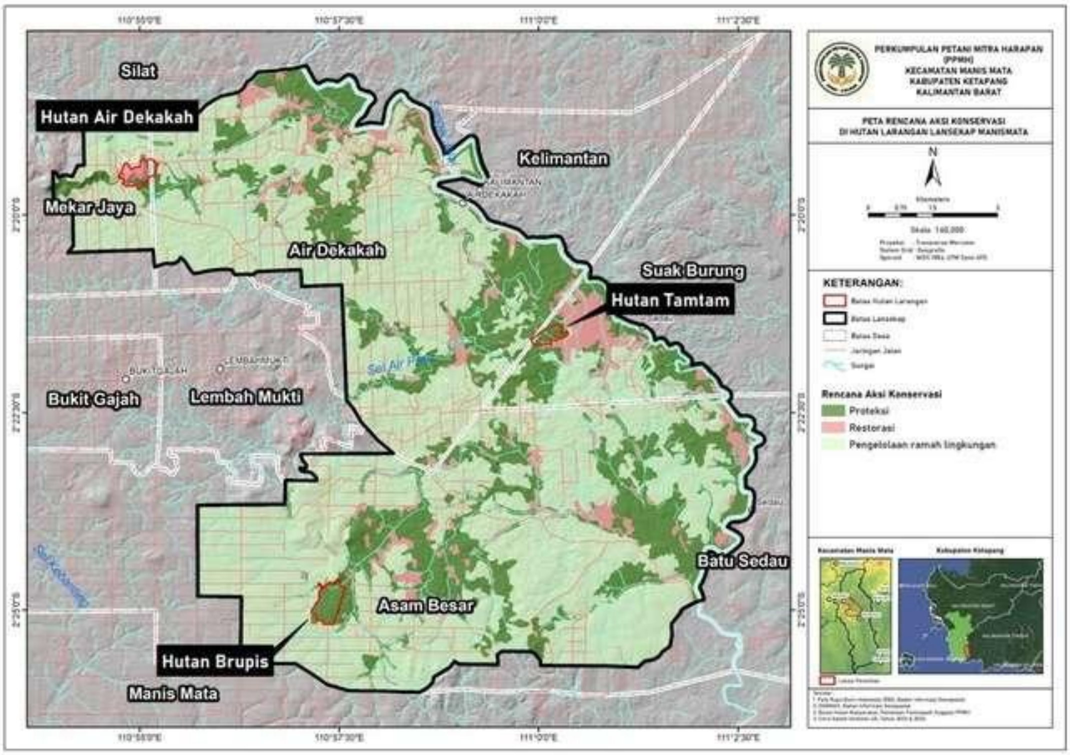


Figure 62. Map of the Conservation Action Plan

The area recommended for protection covers approximately 3,397 ha, or 26.7% of the total landscape. This area includes natural habitats that are still in relatively good condition, Sacred Forest areas, important ecological corridors, and areas of high conservation value. The primary functions of the protection zone are to preserve wildlife habitats, maintain carbon stocks, safeguard ecosystem services, and maintain connectivity among remaining habitats. The existence of these protected areas is crucial, given that the landscape has become fragmented due to the expansion of oil palm plantations over the past few decades.

Meanwhile, the areas recommended for restoration cover approximately 929 ha, or 7.3% of the total landscape. These areas are generally located in sites experiencing habitat degradation, loss of vegetation cover, or serving as critical “ ” that disrupt connectivity between natural habitats. Restoration efforts are aimed at restoring the area’s ecological functions through the planting of native vegetation, the rehabilitation of habitat corridors, the restoration of riverbanks and wetlands, and the enrichment of vegetation in areas with high potential for enhancing landscape connectivity. Restoration sites are primarily focused on areas that can strengthen the ecological links between the Air Dekakah, Brupis, and Tantam Sacred Forests and the surrounding natural habitats.

Spatially, the Tantam Sacred Forest and its surrounding natural habitats are largely classified as protected areas because they still possess relatively good levels of connectivity and habitat quality. In contrast, several areas around Air Dekakah and the central to eastern parts of the landscape are prioritized for restoration because they experience higher levels of fragmentation and require the restoration of habitat corridors. Meanwhile, most of the areas dominated by oil palm plantations fall under the environmentally friendly management category, indicating that conservation in the Manismata Landscape cannot be achieved solely through a protected-area approach but also requires active community involvement in implementing sustainable land-use practices.

The composition of this conservation action plan demonstrates that the conservation approach adopted is landscape-based, integrating the protection of natural habitats, the restoration of degraded areas, and the sustainable management of production areas. With a composition of approximately 26.7% protection area, 7.3% restoration area, and 66.0% environmentally friendly management area, this strategy strikes a balance between the need for biodiversity conservation, increased carbon stocks, the protection of ecosystem services, and the economic sustainability of local communities.

Table 37. Summary of Management Priorities

Action Plan	Area (Ha)	Percentage (%)	Main Objective
Environmentally Friendly Management (Regenerative Agriculture)	8,405	66.0	Sustainable production and reduced pressure on natural habitats
Protection	3,397	26.7	Habitat protection, carbon, and high conservation value
Restoration	929	7.3	Habitat restoration and improved ecological connectivity
Total	**12,730**	**100**	**Sustainable landscape management**

One of the sites recommended as a very high restoration priority is located on the southwest side of the Tamtam Sacred Forest, on land that is currently not being managed productively and is situated near an area owned by PT Cargill (Figure 63). Based on the results of spatial analysis, this location is in a highly strategic position because it directly borders the natural habitat blocks of the Tamtam Sacred Forest and serves as a key connecting point between the core habitat and the surrounding secondary forest areas.

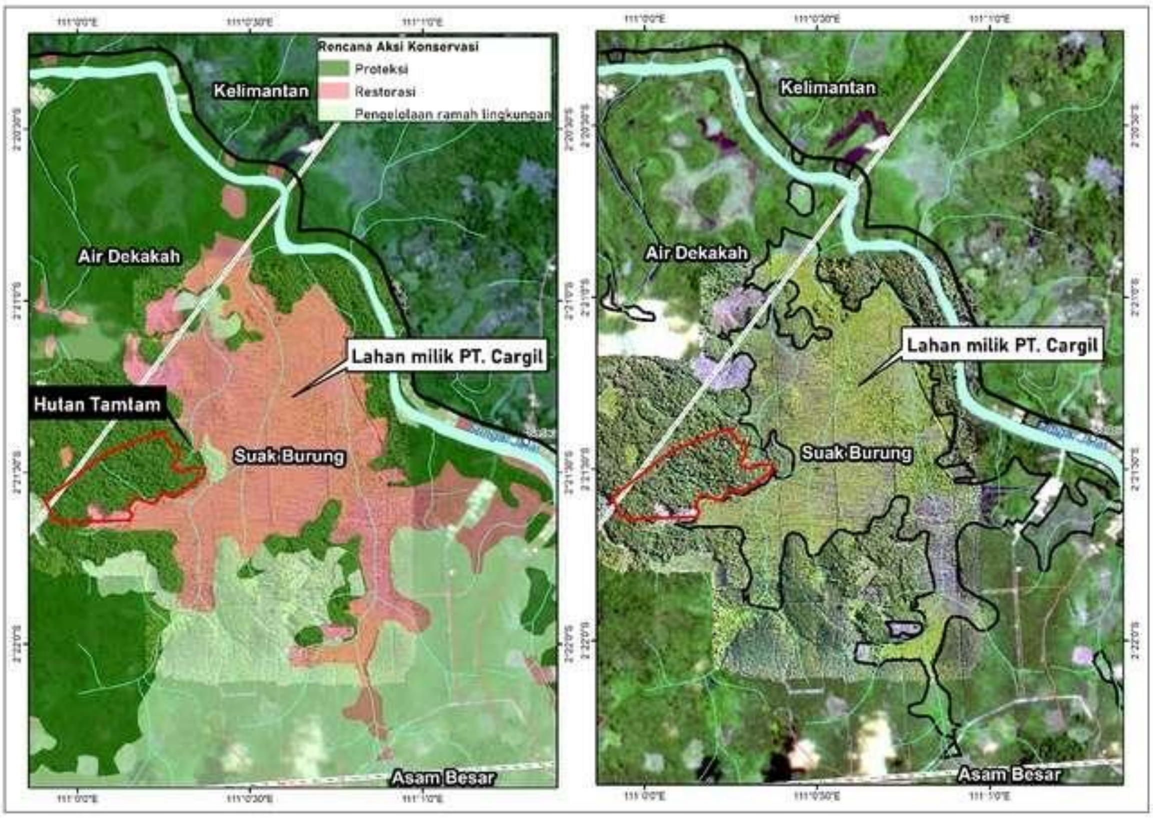


Figure 63. Planned rehabilitation site on unmanaged land owned by PT Cargill

Ecologically, the rehabilitation of this area has the potential to provide significant benefits, namely increasing carbon stocks through the planting of native woody vegetation, expanding effective habitat for wildlife, reducing the edge effect, and strengthening the connectivity of ecological corridors that support wildlife movement within the Manismata Landscape. In addition, vegetation restoration at this site will also improve hydrological functions, reduce the risk of erosion, and enhance the microclimate around the Sacred Forest area.

The restoration program at this site is recommended to employ a Regenerative Agriculture approach and Nature-based Solutions (NbS) through the planting of native Kalimantan tree species with high conservation value and carbon storage capacity, such as Meranti (Shorea spp.), Balangeran (Shorea balangeran), Medang (Dehaasia spp. and Alseodaphne spp.), Nyatuh (Palaquium rostratum), Ulin (Eusideroxylon zwageri), as well as several Multi-Purpose Tree Species (MPTS) such as Durian, Petai, Jengkol, Cempedak, and Tengkawang in appropriate buffer zones. This approach is expected to integrate carbon stock enhancement, biodiversity conservation, and economic benefits for the surrounding communities.

Figure 64. Aerial photo of unmanaged land owned by PT. Cargill adjacent to the Tamtam Forest

Given its strategic location relative to the Tamtam Sacred Forest, the underutilized condition of the land, and its potential to enhance habitat connectivity and carbon sequestration, this site is recommended as a pilot project for landscape-scale carbon restoration that can be developed through collaboration between PPMH Manismata, FORTASBI, PT Cargill, and other stakeholders.

Overall, this conservation action plan provides a realistic and adaptive management framework, in which areas of high conservation value remain protected, degraded areas are restored, and production areas can continue to be utilized sustainably to support the well-being of communities in the Manismata Landscape.

Forest Rehabilitation Plan

This rehabilitation and restoration plan was developed to restore hydrological functions, biodiversity, and wildlife habitat connectivity in areas that have experienced land degradation or modification. Ecological interventions are tailored to each location based on the extent of vegetation damage and the specific needs of target fauna.

1. Brupis Forest: *Enrichment Planting and Succession Control in Rubber Plantations*

Degradation Assessment: The high population of rubber trees (*Hevea brasiliensis*—50 individuals) threatens the long-term diversity of local tree species and has the potential to trigger micro-droughts on the forest floor. Target Fauna for Restoration: *Tarsius bancanus* (Tarsier) and *Helarctos malayanus* (Sun Bear).

Action Plan:

- Introduction of Food Trees and Vertical Climbing Structures: Planting saplings from the genera *Artocarpus* (Cempedak/Mentawa) and Lauraceae (Medang) among community-managed rubber stands. This measure aims to restore the seasonal food supply for the Sun Bear while providing vertical climbing structures for *Tarsius bancanus*.

- *Understory Management*: Allowing native shrubs and understory plants to grow (rather than completely clearing them) around rubber trees to encourage the colonization of nocturnal insects (the primary food source of the Tarsier).
- Ulin Population Rehabilitation: Conducting seedling propagation and reintroduction of Ulin (*Eusideroxylon zwageri*) saplings in areas far from human cultivation activities to ensure the future sustainability of nest trees.

2. Tamtam Forest: *Preventive Rehabilitation (Maintenance Restoration)* and Protection of Core Habitat

Degradation Assessment: Very minimal (healthy primary-secondary natural forest, E = 0.84), but vulnerable to threats from poaching of high-value wildlife and encroachment by plantations. Target Species for Recovery: *Manis javanica* (Pangolin—Status: Critically Endangered/CR) and *Tragulus javanicus* (Mouse Deer).

Action Plan:

- Forest Floor Habitat Restoration: Preserve natural decaying wood piles and thick litter from Manggungan trees (*Elaeocarpus microphyllus*). This decaying wood and litter serve as microhabitats for ants and termites, which are the sole food source for the Javan pangolin (*Manis javanica*).
- Planting a Green *Buffer* Belt: Planting thorny or sap-producing tree species along the outer boundary of the Tamtam Forest to prevent encroachers or poachers from entering the core habitat of protected wildlife.
- Increasing Forest Floor Forage Vegetation: Planting *groundcover crops* preferred by the Javan mouse-deer (*Tragulus javanicus*) and deer under the canopy of forest fruit trees.

3. Air Dekakah Forest: *Total Restoration of Critical Ecosystems (Hard Restoration)*

Degradation Assessment: Severe degradation, characterized by a deficit in the number of standing trees (n = 59), numerous gaps in the canopy, and the invasion of the introduced alien species *Acacia mangium*. Target Fauna for Restoration: *Rusa* (Rusa), *Helarctos malayanus* (Malayan Sun Bear), and *Exilisciurus exilis* (Pygmy Squirrel).

Action Plan:

- Eradication of Acacia and Closure of Canopy Gaps: Completely eliminate 2 commercial Acacia trees because they disrupt the succession of native vegetation through allelopathy. The clear-cut area will be immediately planted with fast-growing, dense-canopied local pioneer trees to restore the canopy corridor for *Exilisciurus exilis*.

- Massive Intervention with Critical Food Plants: Given that only one individual of each forage-providing forest fruit tree (such as Durian, Kalimantan Tamarind, and Pudu) remains (critical), restoration efforts must include mass planting of at least 50 saplings per hectare of these fruit tree species to encourage Honey Bears to return to this area.
- Riparian Rehabilitation for Wildlife Water Sources: Increase the planting of Punaga trees (*Calophyllum inophyllum L.*) along the riverbanks. The Punaga's root system will purify river water and prevent landslides, creating pools and safe drinking spots for herds of deer (*Rusa unicolor*) without the risk of riverbank erosion.

Table 38. Summary of the Rehabilitation & Restoration Plan Matrix

Location	Main Issues	Target Fauna	Restoration Methods	Recommended Tree Species
Brupis Forest	Dominance of Rubber Trees, Threat of Monoculture	Tarsiers & Sun Bears	*Enrichment Planting* & Understory Management	Medang, Ulin, Pantung, Mentawa
Forest Tamtam	Potential boundary disturbances & wildlife poaching	Pangolin (CR) & Muntjac	*Core* habitat protection, management of decaying wood and litter	Manggungan, Cempedak, Durian Forest
Air Dekakah Forest	Stand deficit (n=59), Acacia invasion, open canopy	Deer, Bears, & Pygmy Squirrels	Eradication of invasive species, riparian rehabilitation, canopy closure	Punaga, Mahang, Durian, Kalimantan Tamarind

5.4 Landscape Carbon Enhancement Strategy

The carbon enhancement strategy for the Manismata Landscape was developed based on land cover conditions, existing carbon stocks, deforestation rates, habitat fragmentation, and the results of habitat connectivity analysis. The approach developed is not only oriented toward increasing carbon stocks but also supports biodiversity conservation, the restoration of the landscape's ecological functions, and the improvement of the well-being of communities whose livelihoods largely depend on the plantation sector.

One of the key strategies is the protection of remaining natural habitats, particularly secondary forests, which are the largest carbon sinks within the landscape. Analysis results show that secondary forests contribute the highest carbon stock compared to other land covers, making the protection of these areas a top priority to prevent further carbon loss. Efforts that can be undertaken include strengthening the protection of the Dekakah, Brupis, and Tantam Sacred Forests, preventing new land clearing, and controlling activities that could potentially cause forest degradation.

In addition to habitat protection, landscape carbon enhancement can also be achieved through the restoration of degraded areas identified as habitat connectivity priorities. Based on the analysis, there are approximately 929 ha of priority restoration areas with the potential to be developed as ecological corridors or new natural habitats. Restoration is carried out through the planting of native tree species, vegetation enrichment in shrubland and open areas, riverbank rehabilitation, and the restoration of areas degraded by human activities. These activities not only increase carbon stocks but also improve habitat connectivity and support wildlife movement between areas.

The next strategy is the implementation of sustainable oil palm management in a 921-hectare priority area surrounding natural habitats and ecological corridors. Given that oil palm plantations are the dominant land use in the Manismata Landscape, carbon sequestration cannot be achieved solely through conservation approaches but must also involve improvements in production land management practices. Sustainable oil palm management can be achieved by preserving remaining natural vegetation, protecting riverbanks and wetlands, reducing excessive use of chemicals, and planting economically valuable native tree species in specific areas. This approach is expected to increase carbon stocks without reducing the productivity of community lands.

Landscape carbon sequestration can also be enhanced through the development of community-based agroforestry systems. These systems integrate plantation crops with timber trees or local fruit trees such as durian, petai, jengkol, tengkawang, cempedak, and matoa. In addition to contributing to increased biomass and carbon stocks, agroforestry also provides more diverse economic benefits to communities, thereby reducing pressure on remaining forest areas.

Furthermore, the protection and rehabilitation of river and wetland riparian zones are critical components of the carbon enhancement strategy. Riparian zones and wetlands serve vital ecological functions as carbon sinks, water regulators, and habitats for diverse flora and fauna. Therefore, efforts to restore vegetation along river and wetland riparian zones must be prioritized, particularly in areas that have been converted to agricultural land.

Overall, the carbon enhancement strategy in the Manismata Landscape is guided by a combination of natural habitat protection, restoration of degraded areas, sustainable oil palm management, agroforestry development, and the rehabilitation of riparian zones and wetlands. This approach is expected to gradually increase the landscape's carbon stock, reduce emission rates resulting from land-cover changes, strengthen habitat connectivity, and support the long-term sustainability of the landscape's ecological and economic functions.

No	Strategy	Priority Location	Area (Ha)	Main Objective	Benefits	Priority Level
1	Protection of Natural Habitats	The Dekakah, Brupis, and Tantam Sacred Forests and the surrounding secondary forests	3,886	Preventing carbon stock loss and deforestation	Preserving carbon stocks, wildlife habitats, and ecological functions	Very High
2	Restoration of Degraded Habitats	Habitat corridors and priority restoration areas	929	Increasing carbon stocks and habitat connectivity	Carbon sequestration, habitat restoration, and reduction of fragmentation	Very High
3	Sustainable Palm Oil Management	Palm oil areas bordering natural habitats, rivers, and wetlands	921	Reducing pressure on natural habitats and increasing carbon stocks on production lands	Enhancing ecosystem services and sustainable productivity	High
4	Agroforestry Development	Community gardens and buffer zones	Identifying potential locations	Increasing biomass and diversifying the community's economy	Increased carbon stocks and higher community income	High
5	Riverbank and Swamp Rehabilitation	River corridors and wetland areas	Adjusting the delineation results	Restoring hydrological functions and increasing vegetation cover	Carbon sequestration, water body protection, and wildlife habitat	In progress
6	Institutional Strengthening and Community-Based Management	Entire landscape	Entire region	Ensuring long-term sustainability of carbon management	Reducing the risk of deforestation and increasing community participation	Moderate

Table 39. Strategy for Increasing Landscape Carbon in the Manismata Sacred Forest

5.5 Biodiversity Monitoring Strategy for the Larangan Forest

Periodic monitoring is essential as an evaluation tool (*feedback mechanism*) to ensure that restoration interventions are proceeding in accordance with ecological targets. The monitoring program is divided into two main pillars: Vegetation Structure (Flora) Monitoring and Key Species Fauna Population Monitoring.

1. Methods and Indicators for Flora (Vegetation) Monitoring

Vegetation monitoring is conducted to assess canopy cover development, growth rates, and the success of native plant enrichment.

A. Establishment of *Permanent Sampling Plots* (PSP):

Establish at least 3 permanent plots measuring 20 x 20 m at each location (Brupis, Tamtam, Air Dekakah) to monitor tree growth periodically every 6 months. Success Indicators to Be Monitored:

- *Canopy Cover Rate*: Specifically in the Air Dekakah Forest to ensure that open gaps in the canopy begin to close through the succession of Mahang and Punaga.
- *Survival Rate* of Rare Species: Calculating the survival *rate* of Ulin and Pantung seedlings planted in the Brupis Forest.
- Species Richness (S) and Evenness (E): Ensuring that evenness values in the Tamtam Forest remain high and detecting any decline in biodiversity at other locations.

2. Methods and Protocols for Monitoring Key Fauna Species

Wildlife monitoring is aimed at detecting the presence, movement, and population trends of protected or endangered species based on wildlife data records.

A. Camera Trap Protocol

- Target Species: Large, shy terrestrial mammals, such as the Javan pangolin (*Manis javanica*), Malayan sun bear (*Helarctos malayanus*), sambar deer (*Rusa unicolor*), muntjac, mouse deer, and wild boar.

Implementation Details:

- Camera trap installation is prioritized in Tamtam Forest (a core zone with critical status for the Javan pangolin) and along the Air Dekakah riparian corridor where sika deer and Malayan sun bears access drinking water. Cameras are checked and data downloaded once a month.

B. Nocturnal Line Transect Protocol

- Target Species: Small nocturnal animals, primarily the Tarsier (*Tarsius bancanus*) and the Tangalung (*Viverra tangalunga*).

Implementation Details:

- Conducted exclusively in the Brupis Forest along the boundary between rubber plantations and natural forest. The monitoring team walks slowly from 7:00 PM to 11:00 PM using red headlamps (to avoid blinding the animals) to count direct sightings or *eye*-shines of Tarsiers.

C. Transect Protocol for Nest Counts & Vocal Encounters (Bioacoustic/Vocal Monitoring)

- Target Species: Diurnal arboreal species such as the Jelarang (*Ratufa affinis*) and the Dwarf Squirrel (*Exilisciurus exilis*), as well as Honey Bear claw marks on trees.

Implementation Procedures:

- Recording indirect traces (Honey Bear scratch marks on the bark of Laban or Medang trees) and counting the frequency of tree-dwelling mammal vocalizations in the morning (5:30–8:30 a.m.) in the Tamtam and Air Dekakah Forests.

3. Matrix of Schedule and Focus Locations for Biodiversity Monitoring

Table 40. Matrix of Biodiversity Monitoring Schedule and Locations

Monitoring Object	Method	Frequency	Focus Location	Animals/Vegetation Indicators
Core Ecosystem Health	Permanent Plot Vegetation Analysis	Every 6 Months	Tamtam Forest	Abundance of forage trees (Cempedak, Manggungan)
Critically Endangered (CR) Mammals	*Camera Traps* & Litter Analysis	Every 1 Month	Tamtam Forest	*Manis javanica* (Pangolin)
Nocturnal Mammals (VU)	*Night Survey* / Flashlight Transect	Every 3 Months	Brupis Forest	*Tarsius bancanus* (Tarsier)
Effectiveness of Green Corridors	*Camera Traps* & Scratch Marks	Every 1 Month	Dekakah Wetland Forest	*Helarctos malayanus* (Sun Bear) & *Rusa unicolor*
Micro-Arboreal Fauna	*Canopy* Census	Every 3 Months	Dekakah & Brupis	*Exilisciurus exilis* (Dwarf Squirrel) & *Ratufa affinis* (Jelarang)

4. Reporting and *Early* Warning System

- Conflict and Threat Data Log: All field findings (e.g., signs of illegal logging, wildlife snares, or the illegal expansion of rubber plantations into protected zones) must be immediately reported via the spatial data system (SMART Patrol).
- Annual Evaluation Review: If, for two consecutive years, camera traps fail to capture images of pangolins in Tamtam or tarsiers in Brupis, the area's conservation strategy must undergo a comprehensive evaluation, as this indicates either a gap in protection or undetected habitat degradation.

5.6 Short-Term Intervention Priorities for the Sacred Forest

Short-term interventions (1–2 years) focus on *emergency actions* to mitigate immediate threats, secure remaining critical habitats, and lay the physical groundwork for long-term restoration. Based on the critical status of each area, the following actions must be implemented immediately:

1. Tamtam Forest: Securing the Pangolin's Core Habitat (Status: *Crucial-Urgent*)

The Tamtam Forest has the highest priority for immediate protection measures because it is the only location where the Javan pangolin (*Manis javanica*), classified as Critically Endangered (CR) in wildlife records, has been documented.

Action 1: *Camera Trap Deployment*

- Action: Permanently install at least 5–10 camera traps in the root zones of the giant Manggungan (*Elaeocarpus microphyllus*) and Punaga trees. Objective: To map active burrows, daily foraging routes, and detect the presence of armed poachers or sling snare setter.

Action 2: Total Ban on the Harvesting of Wild Forest Fruits

- Action: Issue a joint proclamation with customary institutions and the village government to prohibit the harvesting of Cempedak (*Artocarpus integer*), Pekawai, and Kerantungan fruits by the community. Objective: To secure the daily food supply for the Malayan Sun Bear (*Helarctos malayanus*), which is classified as *Vulnerable* (VU), so that it does not leave the forest to forage in residents' gardens

2. Dekakah Wetland Forest: Riparian Zone Conservation (Status: *Rehabilitation—Urgent*)

The Dekakah Wetland Forest is experiencing a vegetation crisis; these open areas threaten the water availability for the Sambar Deer (*Rusa unicolor*) and the Sun Bear.

Action 1: Rapid Propagation (*Rescue Nursery*) for Critical Food Species

- Action: Search for and collect seeds or wild seedlings from the remaining 1 Durian tree, 1 Kalimantan Tamarind tree, and 1 Pudu tree—all on the brink of local extinction in Air Dekakah. Objective: Conduct mass propagation in an emergency nursery before these parent trees die or fall, to ensure long-term food availability.

3. Brupis Forest: Mapping Nocturnal Wildlife Corridors in the Agroforestry Area

Brupis Forest has high biodiversity, with a particularly high abundance of nocturnal wildlife such as the Tarsier (*Tarsius bancanus*) and the Tenggalung (*Viverra tangalunga*)

Action 1: Campaign to Eliminate Traps That Cause the Death of Terrestrial Wildlife

- Action: Removing wild boar snares that are often illegally set among rubber and laban trees. Objective: To protect sun bears, mouse deer, sambar deer, and deer, which are vulnerable to injury or death from becoming trapped in hunters' snares

Action 2: Physical *Tagging* of Ulin and Pantung Trees

- Action: Installing permanent metal protective signs on 3 Ulin trees and 2 Pantung trees. Objective: To provide a visual warning to the public against damaging, cutting down, or burning litter around the bases of these valuable trees.

5.7 Medium-Term Intervention Priorities for the Sacred Forest

Medium-term interventions are aimed at *ecosystem enrichment*, habitat manipulation to support wildlife population stability, and the establishment of physical connectivity between areas. At this stage, the focus shifts from emergency measures to measured structural restoration.

1. Air Dekakah Forest: Restoration of Vegetation Structure and Arboreal Connectivity

Following the primary and secondary succession phases, the Air Dekakah Forest has entered a phase of landscape architecture restoration.

Canopy Bridge Re-establishment:

- Action: Conducting large-scale planting of fast-growing, locally native pioneer tree species with broad canopies, such as Mahang (*Macaranga pearsonii*) and Laban (*Vitex pinnata*). Wildlife Objective: Providing continuous canopy bridges to facilitate safe movement for wildlife, allowing them to expand their ranges without having to descend to the open forest floor.

Mass Enrichment of Key Bear Food Species:

- Action: Integrate forest fruit saplings (durian and Kalimantan tamarind) that have been propagated in the short-term phase into the riparian buffer zone. Fauna Objective: Redirect the movement of Sun Bears (*Helarctos malayanus*) so that Air Dekakah becomes a permanent habitat rather than merely a daily transit route.

2. Brupis Forest: Transformation of Rubber Agroforestry Structures into Forest Gardens

The medium-term focus in the Brupis Forest is to break the dominance of 50 rubber trees (*Hevea brasiliensis*) through the enrichment of native rainforest vegetation.

Introduction of Lower and Middle Vegetation Strata:

- Action: Planting clusters of trees from the Lauraceae family (Medang Bulan, Medang Sandak, Medang Pulut) among rubber trees whose latex productivity is beginning to decline. Fauna Objective: To provide vertical microhabitats (with ideal trunk diameters and dense canopies) that are critically needed by the Tarsier (*Tarsius bancanus*) as daytime refuge from predatory attacks.

Large Mammal Terrestrial Corridor Release:

- Action: Design *a* 20–30-meter-wide *green corridor* cutting through the rubber plantation area by planting native local tree species such as Kepayang (*Dipterocarpus sp.*). Fauna Objective: To provide a safe space for the Sambar Deer (*Rusa unicolor*), Muntjac (*Muntiacus muntjak*), and Tangalunga Civet (*Viverra tangalunga*) to move from the core zone to the outer zone without being hindered by human activities.

3. Tamtam Forest: Enhancing Forage Quality and Securing the *Core Habitat*

Although the tree community is considered healthy, medium-term interventions are needed to address seasonal food scarcity (*mast fruiting*).

Keystone Species Enrichment:

- Action: Enrich the area with tree seedlings from the Moraceae family (*Artocarpus* genus, such as wild cempedak) and Fagaceae in zones with sparse tree density. Wildlife Objective: Ensure a stable year-round food supply for Sun Bears and Wild Boars (*Sus barbatus*), thereby reducing fertility decline in these species caused by energy deficits.

Intensive Protection of Termite and Ground Ant Colonies:

- Action: Prohibit the removal of litter and the dismantling of naturally decayed wood from the remnants of Manggungan (*Elaeocarpus microphyllus*) stands. Fauna Objective: To maintain the availability of the primary food source for the Javan Pangolin (*Manis javanica*), which is listed as Critically Endangered (CR) by the , as the survival of this species is highly dependent on the abundance of soil insects under the canopy of large trees.

Table 41. Medium-Term Work Program Matrix (Years 3-5)

Focus Locations	Key Work Programs	Ecological Methods	Final Success Indicators
Air Dekakah Forest	Restoration of upper corridors & enrichment of foraging zones	Dense planting of Mahang, Laban, and *Durio* genus trees	• Increase in the number of stands (n > 100) • Detection of wildlife activity in the new canopy
Brupis Forest	Diversification of rubber plantations into *Forest Gardens*	Introduction of local non-rubber commodity species (family Dipterocarpaceae)	• Increase in the percentage of meranti dominance • Stabilization of the *Tarsius bancanus* population
Tamtam Forest	Management of wildlife food stability & microhabitat protection	Conservation of decaying Manggungan tree litter and planting of Cempedak	• Maintenance of equity • Confirmation of the Presence of *Manis javanica*

5.8 Opportunities for Multi-Stakeholder Collaboration

Collaboration on the Management of the Larangan Forest

The complexity of ecological challenges at the three sites—ranging from high pressure from rubber agroforestry in the Brupis Forest, the protection of *critically endangered* wildlife habitats in the Tamtam Forest, to severe degradation in the Air Dekakah Forest—demonstrates that management cannot be carried out by a single agency alone. A collaborative governance model (*pentahelix*) is needed, involving various stakeholders, each with their own strategic roles.

Through this multi-stakeholder consortium, the Tamtam Forest will preserve its integrity through a strict protection scheme, the Brupis Forest will be managed adaptively through human-wildlife partnerships, and the Air Dekakah Forest can recover from its critical condition through environmental restoration funding from the private sector. This harmonious collaboration ensures the long-term conservation of biodiversity across the entire integrated forest landscape.

1. Government Collaboration (BKSDA / Department of Environment and Forestry)

As the regulatory authority, government agencies serve as the primary driving force behind legal protection.

- Collaborative Action in the Tamtam Forest: Given the discovery of the Javan pangolin (*Manis javanica*), which is classified as *Critically Endangered* (CR), the BKSDA needs to initiate the designation of this area as *an Essential Ecosystem Area (KEE)* or a High Conservation Value Forest (ANKT/HCVF).
- Collaborative Action in the Brupis Forest: Facilitating the legal framework for the Social Forestry (Forestry Partnership) scheme so that communities can utilize rubber plantations without disturbing protected wildlife such as *Tarsius bancanus*.

2. Collaboration with Local Communities and Agroforestry Farmers

Communities are *grassroots* actors who interact directly with the forest ecosystem on a daily basis.

- Collaborative Action in the Brupis Forest: Entering into partnership agreements with rubber farmers who own 50 commercial rubber stands. Farmers were trained to implement the "Wildlife-Friendly Rubber" method, under which they are prohibited from setting ground snares to protect the Sun Bear (*Helarctos malayanus*) and the Sambar Deer (*Rusa unicolor*), which frequently cross through the gaps between rubber trees.
- Collaborative Action in the Tamtam Forest: Formation of a Tribal/Indigenous Village Patrol Team (*Community Rangers*) to safeguard the abundance of forest fruit trees (Cempedak and Manggungan) from external looting, in order to protect the wildlife food chain.

3. Private Sector/Industrial Collaboration (CSR Schemes and Carbon Offsets)

Private companies operating in the surrounding area can contribute through corporate social and environmental responsibility (CSR) funding.

- Collaborative Action in the Air Dekakah Forest: Partnering with the private sector to fund the Total Restoration of Critical Ecosystems program. Since Air Dekakah has only 59 tree stands and has lost many trees that serve as animal food sources, the private sector can fund the procurement of local fruit seedlings (Durian, Kalimantan Tamarind, Pudu) as well as the eradication of commercial Acacia trees. This funding is also claimed by companies as a *carbon offset* investment.

4. Collaboration with Academics and Research Institutions (NGOs / Universities)

Academics play a role in providing a scientific database, innovative monitoring technologies, and evaluating restoration results.

- Landscape-Level Collaborative Actions: Universities or conservation NGOs facilitate the implementation of the Biodiversity Monitoring Strategy by providing technological tools such as *camera traps* to detect wildlife movement in the

Tamtam Forest and bioacoustic recording devices in Air Dekakah. Universities can also involve students through Thematic Community Service (KKN) programs or thesis/dissertation research related to the development of permanent observation plots (PSP).

Landscape Partnership-Based Management Collaboration

The success of conservation efforts in the PPMH Manismata Sacred Forest depends not only on the protection of the core area but also on integrated landscape management that involves all stakeholders surrounding the area. Given that most of the natural habitat is located within a landscape of smallholder and corporate oil palm plantations, the Landscape Partnership approach is the most effective strategy for maintaining the sustainability of ecological functions while supporting land productivity.

As the organization managing the area, PPMH Manismata, together with FORTASBI, plays a key role in developing the Sustainable Sacred Forest and Landscape Management Plan as part of the organization's work plan. This document serves as a guideline for implementing area protection, habitat restoration, carbon stock enhancement, biodiversity monitoring, and the development of conservation-based community livelihoods.

Implementation of this management plan can be advanced through collaboration with various stakeholders within the landscape, including PT Cargill, whose operational area borders the Tamtam Sacred Forest. This spatial proximity opens opportunities to develop joint programs such as habitat restoration, strengthening ecological corridors, rehabilitating unmanaged land, protecting riverbanks, increasing carbon stocks, and monitoring biodiversity—all as part of the company's commitment to Regenerative Agriculture, No Deforestation, No Peat, No Exploitation (NDPE), and its sustainability targets.

This collaboration can also be expanded to include local governments, the BKSDA, universities, non-governmental organizations, donors, and other companies operating within the Manismata Landscape, thereby establishing a collaborative landscape management model capable of sustainably integrating biodiversity conservation, carbon stock enhancement, protection of ecosystem services, and community well-being.

Table 42. Strategic Partnership Matrix Based on Location and Key Issues

Focus Location	Key Ecological Issues	Key Wildlife/Vegetation Involved	Key Partners	Specific Forms of Cooperation
Brupis Forest	Pressure from rubber cultivation on the forest ecosystem	*Tarsius bancanus* & *Hevea brasiliensis*	Forest Farmers' Group (KTH) & BKSDA	Sustainable Agroforestry Certification & Protection of Nocturnal Wildlife Corridors.
Tamtam Forest	Protection of Critically Endangered Species Threatened with Global Extinction	*Manis javanica* (Pangolin—CR)	Indigenous Institutions, Conservation NGOs, & Police	Anti-Poaching Task Force (*Smart Patrol*) & Protection of Core Forest Floor Habitats.
Air Dekakah Forest	Severe vegetation degradation & open canopy gaps	*Rusa unicolor*, *Exilisciurus exilis*, & *Acacia mangium*	Private Sector (CSR), Universities, & DLHK	*Enrichment Planting* Program (Forage Enrichment) & Invasive Species Eradication.
Sacred Forest Landscape	Integrated landscape management, carbon sequestration, and biodiversity conservation	*Overall*	*PPMH, FORTASBI, PT Cargill, DLHK, BKSDA, Universities, NGOs, Local Government*	Development and implementation of a Landscape Management Plan, restoration of habitat corridors, rehabilitation of unmanaged land around the Tamtam Forest, monitoring of biodiversity and carbon, development of regenerative agriculture, and collaborative funding through CSR, sustainable investments, and carbon programs.

CHAPTER VI. CONCLUSION

6.1 Key Conclusions

The study results indicate that the Dekakah Sacred Forest, the Brupis Sacred Forest, and the Tamtam Sacred Forest hold significant ecological value within the Manismata Landscape, which is dominated by smallholder oil palm plantations. Although officially classified as “Other Land Use Areas” (APL), these three areas still function as natural habitats, providers of ecosystem services, carbon sinks, and pillars of landscape sustainability.

The biodiversity found indicates that these three areas continue to support a variety of important flora and fauna species, including protected species and those of high conservation value such as the pangolin, sun bear, tarsier, and deer, as well as various important plant species such as the pitcher plant. These findings suggest that the three areas serve as critical habitats for biodiversity within a landscape that has undergone land-use transformation.

Based on habitat quality assessments, the Brupis Sacred Forest received a “good” rating with a score of 39, the Tamtam Sacred Forest a “moderate” rating with a score of 29, and the Air Dekakah Sacred Forest a “moderate” rating with a score of 24. Differences in habitat quality are influenced by vegetation cover conditions, fragmentation levels, habitat connectivity, and varying anthropogenic pressures at each location.

Landscape connectivity analysis shows that the Tamtam Sacred Forest has the highest level of connectivity because it remains connected to relatively large blocks of natural habitat and functioning riparian corridors. The Brupis Sacred Forest has moderate connectivity and has the potential to serve as a habitat connector in the southern part of the landscape, while the Air Dekakah Sacred Forest is the most isolated area and requires efforts to improve connectivity through habitat restoration and the strengthening of vegetation corridors.

A carbon stock assessment shows that the three Sacred Forests store a total of 13,958.11 tC, equivalent to 51,180.53 tCO_2eq. The Tamtam Sacred Forest has the highest carbon stock, followed by Brupis and Air Dekakah. These findings indicate that all three areas make a significant contribution to climate change mitigation at the landscape level.

The High Conservation Value (HCV) analysis identified the presence of HCV 1, HCV 3, HCV 4, HCV 5, and HCV 6 within the study area. These conservation values are related to the presence of important species, remaining natural habitats, hydrological functions, carbon storage, clean water supply, as well as the cultural and historical values inherent in the Larangan Forest.

Based on the management zoning analysis, the landscape is divided into a Core Zone covering 658 ha, a Buffer Zone covering 4,589 ha, and a Utilization Zone covering 7,483 ha. In addition, conservation action needs have been identified, including a 3,397-ha protection area, a 929-ha restoration area, and an 8,405-ha environmentally friendly management area. This division provides a clear spatial basis to support conservation management and sustainable development in the Manismata Landscape.

6.2 Management Implications

The study results indicate that the sustainability of the Manismata Landscape is highly dependent on the ability to maintain the ecological functions of the three Sacred Forests as biodiversity hotspots amidst the dominance of smallholder oil palm plantations. Therefore, area management must be directed toward an integrated landscape approach that combines biodiversity conservation, carbon stock enhancement, protection of ecosystem services, and the implementation of Regenerative Agriculture as part of a sustainable production system.

The first priority is to strengthen the protection of core areas, particularly the Brupis Sacred Forest and the Tamtam Sacred Forest, through institutional strengthening of local communities, area patrols, control of encroachment, prevention of land conversion, and protection of species and habitats of high conservation value. These areas must be preserved as core habitats, primary carbon sinks, and sources of ecosystem services for the landscape as a whole.

The second priority is to improve habitat connectivity through the restoration of 929 ha of identified critical areas, particularly along vegetation corridors, riverbanks, swamp edges, and areas connecting patches of natural habitat. One location recommended as a very high restoration priority is the unmanaged land surrounding the Tamtam Sacred Forest, which borders PT Cargill’s operational area. Restoration at this site has the potential to increase carbon stocks, strengthen ecological corridors, reduce habitat fragmentation, and support wildlife movement at the landscape level.

The third priority is the implementation of environmentally friendly management practices across 8,405 ha of production areas through sustainable oil palm practices and the application of Regenerative Agriculture principles. This strategy includes protecting riverbanks and wetlands, reducing chemical use, enriching local vegetation, developing agroforestry, protecting High Conservation Value (HCV) areas, and strengthening the implementation of RSPO and ISPO principles, as well as the No Deforestation, No Peat, No Exploitation (NDPE) commitment.

From a climate change mitigation perspective, the three Sacred Forests and their remaining natural habitats must be preserved as the landscape's primary carbon sinks. Restoration activities, vegetation rehabilitation, and increased tree cover on degraded lands are expected to boost carbon stocks, reduce greenhouse gas emissions, and simultaneously improve habitat quality and ecosystem services.

Successful landscape management requires strong multi-stakeholder collaboration. PPMH Manismata, together with FORTASBI, is expected to serve as the primary driving force in developing and implementing the Sacred Forest and Sustainable Landscape Management Plan as part of the organizations' work plans. Program implementation can be carried out through partnerships with the government, universities, non-governmental organizations, and the private sector—including PT Cargill and other companies within the landscape—via technical support, funding, restoration programs, biodiversity monitoring, carbon stock enhancement, and the development of conservation-based community livelihoods.

With this approach, the Manismata Landscape has great potential to become a model for community-based oil palm landscape management rooted in multi-stakeholder partnerships—one capable of integrating biodiversity conservation goals, carbon stock enhancement, the protection of ecosystem services, the implementation of Regenerative Agriculture, and the sustainable improvement of community well-being. This model is expected to serve as a best practice example for sustainable oil palm landscape management in Indonesia.

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APPENDIX

Appendix 1. List of Fauna Species

List of Bird Species at Three Locations

No	Local Name	Scientific Name
1	Elang ular bido	*Spilornis cheela*
2	Elang ikan kepala kelabu	*Icthyophaga ichthyaetus*
3	Cipoh kacat	*Aegithina tiphia*
4	Cekakak belukar	*Halcyon smyrnensis*
5	Pekaka emas	*Pelargopsis capensis*
6	Raja udang meninting	*Meninting Kingfisher*
7	Walet-sapi jari-bulu	*Collocalia affinis*
8	Cinenen kelabu	*Ruficeps Orthotomus*
9	Cinenen sp.	*Orthotomus sp.*
10	Perenjak rawa	*Yellow-bellied prinia*
11	Tekukur biasa	*Spilopelia chinensis*
12	Punai hijau	*(Treron capellei)*
13	Punai gading	*Treron vernas*
14	Gagak kampung	*Corvus macrorhynchos*
15	Bubut Besar	*Centropus sinensis*
16	Bubut biru	*Centropus sp.*
17	Cabai gunung	*Dicaeum sanguinolantum*
18	Cabai sp.	*Dicaeum sp.*
19	Srigunting hitam	*Dicrurus macrocercus*
20	Srigunting bukit	*Dicrurus remifer*
21	Bondol haji	*Maja Bunting*
22	Layang-layang batu	*Hirundo javanica*
23	Layang-layang rumah	*Delichon dasypus*
24	Sikatan	*Rufigastric Flycatcher*
25	Sikatan bubik	*Daurian Flycatcher*
26	Burung-madu Kelapa	*Anthreptes malacensis*
27	Burung-madu Sriganti	*Cinnyris ornatus*
28	Ayam hutan merah	*Gallus gallus*
29	Betet ekor panjang	*Psittacula longicauda*
30	Pelatuk tunggir emas	*Chrysocolaptes lucidus*
31	Pelatuk merah	*Chrysophlegma miniaceum*
32	Cucak kutilang	*Pycnonotus aurigaster*
33	Merbah belukar	*Pycnonotus plumosus*
34	Merbah cerucuk	*Goiavier Pycnonotus*
35	Kareo padi	*Amaurornis phoenicurus*
36	Kipasan belang	*Javan White-eye*
37	Tiong emas	*Gracula religiosa*
38	Kerak Kerbau	*Javan Starling*
39	Perling kumbang	*Panayan White-eye*

List of Herpetofauna Species at Three Locations

No.	Local Name	Scientific Name
1	Katak tegalan	*Fejervarya limnocharis*
2	Ular cobra	*Naja sumatrana*
3	Katak Kongkang	*Chalcorana raniceps*
4	Biawak sungai	*Varanus salvator*
5	Katak Kongkang Gading	*Hylarana erythraea*
6	Kadal kebun	*Eutropis multifasciata*

Appendix 2. Species Conservation Status (IUCN, CITES, Ministry of Environment and Forestry Regulation)

No	Species Name		Family	Status		Method Observation
	Local	Latin		National	IUCN	
1	Tarsius	*Tarsius bancanus*	Tarsiidae	D	Vu	Direct Observation
2	Kera Ekor Panjang	*Macaca fascicularis*	Cercopithecidae	TD	LC	Calls
3	Pelanduk Napu	*Tragulus napu*	Tragulidae	D	LC	Footprints
4	Rusa Sambar	*Unicolor Deer*	Cervidae	D	Vu	Tracks
5	Kijang Muncak	*Muntiacus muntjak*	Cervidae	D	LC	Traces
6	Babi Berjenggot	*Sus barbatus*	Suidae	TD	Vu	Footprints and wallows
7	Pelanduk kancil	*Tragulus javanicus*	Tragulidae	D	DD	Footprints
8	Jelarang	*Ratufa affinis*	Sciuridae	TD	NT	Direct Observation
9	Bajing Kerdil	*Exilisciurus exilis*	Sciuridae	TD	DD	Direct Observation
10	Beruang Madu	*Helarctos malayanus*	Ursidae	D	Vu	Direct observation, claw marks
11	Trenggiling	*Manis javanica*	Manidae	D	En	Nest, Claw marks
12	Tenggalung Malaya	*Viverra tangalunga*	Viverridae	D	LC	Tracks, Claw Marks

Appendix 3. Vegetation Analysis Results

Results of Tree Vegetation Analysis (Brupis Forest)

No	Latin Name	KR (%)	DR (%)	FR (%)	INP (%)
1	*Hevea brasiliensis*	25.38	22.94	12.70	61.02
2	*Polyalthia sumatrana*	6.09	7.67	5.56	19.31
3	*Vitex pinnata*	7.11	3.99	4.76	15.86
4	*Macaranga gigantea*	5.08	3.88	3.97	12.93
5	*Artocarpus anisophyllus*	3.55	5.09	3.97	12.61
6	*Santiria griffithii*	3.55	3.81	4.76	12.13
7	*Archidendron clypearia*	3.05	5.79	3.17	12.01
8	*Dillenia borneensis*	3.55	3.37	4.76	11.69
9	*Alstonia spatulata Blume*	3.05	4.42	3.97	11.43
10	*Dipterocarpus sp*	3.05	2.41	3.17	8.63
11	*Artocarpus integer*	2.54	2.83	3.17	8.54
12	*Calophyllum inophyllum L.*	2.03	1.65	2.38	6.06
13	*Dyera lowii Hook.f.*	1.02	3.22	1.59	5.82
14	*Nephelium mangayi Hiern.*	2.03	0.98	2.38	5.39
15	*Beilschmiedia sp.*	1.52	0.70	2.38	4.60
16	*Durio zibethinus*	1.02	1.91	1.59	4.52
17	*Cananga odorata*	1.02	1.58	1.59	4.19
18	*Nothaphoebe coriacea*	1.02	1.19	1.59	3.79
19	*Eusideroxylon zwageri*	1.52	0.68	1.59	3.79
20	*Madhuca motleyana*	0.51	2.26	0.79	3.56
21	*Aglaia macrocarpa*	1.02	0.86	1.59	3.47
22	*Flacourtia rukam*	1.02	0.80	1.59	3.40
23	*Mangifera laurina Blume*	1.02	1.53	0.79	3.34
24	*Artocarpus elasticus Blume*	1.52	0.70	0.79	3.01
25	*Koordersiodendron pinnatum*	1.02	0.38	1.59	2.98
26	*Durio kutejensis (Hassk.) Becc.*	1.02	0.36	1.59	2.96
27	*Memecylon edule*	0.51	1.46	0.79	2.76
28	*Sterculia cordata*	1.02	0.90	0.79	2.71
29	*Artocarpus sp*	1.02	0.79	0.79	2.60
30	*Syzygium laxiflorum*	0.51	1.21	0.79	2.51
31	*Sandoricum borneense Miq.*	0.51	1.12	0.79	2.42
32	*Gymnacranthera spp.*	0.51	1.12	0.79	2.42
33	*Licania splendens (Korth.) Prance*	1.02	0.52	0.79	2.33
34	*Diospyros spp.*	0.51	0.79	0.79	2.09
35	*Dehaasia sp.*	0.51	0.72	0.79	2.02
36	*Callophyllum sp.*	0.51	0.68	0.79	1.98
37	*Elaeocarpus microphyllus*	0.51	0.55	0.79	1.85
38	*Campnosperma coreacum*	0.51	0.46	0.79	1.76
39	*Popowia bancana*	0.51	0.46	0.79	1.76
40	*Garcinia parvifolia (Miq.) Miq.*	0.51	0.43	0.79	1.73

41	*Pternandra galeata*	0.51	0.40	0.79	1.70
42	*Stemonurus secundiflorus Blume*	0.51	0.40	0.79	1.70
43	*Macaranga pearsonii Merr.*	0.51	0.40	0.79	1.70
44	*Sandoricum borneense Miq.*	0.51	0.33	0.79	1.63
45	*Vernonia arborea Buch.-Ham.*	0.51	0.33	0.79	1.63
46	*Lithocarpus conocarpus*	0.51	0.30	0.79	1.60
47	*Lithocarpus sp*	0.51	0.22	0.79	1.52
48	*Campnosperma coriaceum*	0.51	0.22	0.79	1.52
49	*Dracontomelon dao (Blanco) Merr.*	0.51	0.22	0.79	1.52
50	*Fordia splendidissima*	0.51	0.22	0.79	1.52
51	*Ficus sp*	0.51	0.22	0.79	1.52
52	*Cratoxylum sumatranum*	0.51	0.18	0.79	1.48
53	*Artocarpus heterophyllus*	0.51	0.18	0.79	1.48
54	*Nephelium erectum*	0.51	0.18	0.79	1.48

Results of Vegetation Analysis in Tihang (Brupis Forest)

No	Latin Name	KR (%)	DR (%)	FR (%)	INP (%)
1	*Hevea brasiliensis*	14.05	16.58	10.87	41.50
2	*Vitex pinnata*	7.44	7.29	7.61	22.33
3	*Dipterocarpus sp*	5.79	6.19	4.35	16.32
4	*Macaranga gigantea*	4.96	7.45	3.26	15.67
5	*Dehaasia sp.*	4.96	4.71	5.43	15.10
6	*Calophyllum inophyllum L.*	5.79	4.12	4.35	14.25
7	*Flacourtia rukam Zoll. & Moritzi*	4.96	2.84	3.26	11.06
8	*Eusideroxylon zwageri*	3.31	2.34	4.35	10.00
9	*Myristica sp.*	3.31	4.15	1.09	8.54
10	*Dillenia borneensis*	2.48	2.43	3.26	8.17
11	*Vernonia arborea Buch.-Ham.*	2.48	3.15	2.17	7.80
12	*Aglaia macrocarpa*	2.48	3.12	2.17	7.77
13	*Palaquium rostratum*	2.48	1.97	3.26	7.71
14	*Artocarpus anisophyllus*	2.48	2.72	2.17	7.37
15	*Cananga odorata*	2.48	2.17	2.17	6.82
16	*Archidendron clypearia*	1.65	2.24	2.17	6.07
17	*Garcinia sp.*	1.65	1.71	2.17	5.53
18	*Pternandra galeata*	1.65	1.57	2.17	5.39
19	*Sandoricum koetjape*	1.65	1.57	2.17	5.39
20	*Ochanostachys amentacea*	1.65	1.57	2.17	5.39
21	*Macaranga pearsonii Merr.*	1.65	1.43	2.17	5.26
22	*Sandoricum sp.*	1.65	1.28	2.17	5.10
23	*Syzygium Sp*	1.65	0.81	2.17	4.63
24	*Santiria laevigata Bl.*	0.83	1.45	1.09	3.37
25	*Cantleya corniculata*	0.83	1.31	1.09	3.22
26	*Garcinia parvifolia*	0.83	1.16	1.09	3.08
27	*Artocarpus elasticus Blume*	0.83	1.16	1.09	3.08
28	*Syzygium laxiflorum*	0.83	1.03	1.09	2.94
29	*Campnosperma coreacum*	0.83	0.91	1.09	2.82
30	*Artocarpus lanceifolius Roxb.*	0.83	0.91	1.09	2.82
31	*Cinnamomum sintok*	0.83	0.91	1.09	2.82
32	*Durio kutejensis (Hassk.) Becc.*	0.83	0.91	1.09	2.82
33	*Aquilaria malaccensis Lamk.*	0.83	0.91	1.09	2.82
34	*Cratoxylum sumatranum*	0.83	0.79	1.09	2.70
35	*Polyalthia spp.*	0.83	0.58	1.09	2.49

36	*Adinandra dumosa Jack*	0.83	0.58	1.09	2.49
37	*Madhuca motleyana*	0.83	0.58	1.09	2.49
38	*Tetractomia obovata Merrill.*	0.83	0.58	1.09	2.49
39	*Xylopia fusca*	0.83	0.58	1.09	2.49
40	*Dialium platysepalum*	0.83	0.49	1.09	2.40
41	*Popowia bancana*	0.83	0.49	1.09	2.40
42	*Nephelium uncinatum*	0.83	0.49	1.09	2.40
43	*Parkia speciosa Hassk.*	0.83	0.40	1.09	2.32
44	*Elaeocarpus microphyllus*	0.83	0.40	1.09	2.32

Table of Vegetation Analysis at Pancang (Brupis Forest)

No	Latin Name	KR (%)	DR (%)	FR (%)	INP (%)
1	*Dehaasia sp.*	8.70	0.0	5.56	14.25
2	*Palaquium rostratum*	5.59	0.0	5.56	11.15
3	*Popowia bancana*	4.97	0.0	5.56	10.52
4	*Sandoricum sp.*	3.73	0.0	5.56	9.28
5	*Dialium platysepalum Baker*	4.35	0.0	4.63	8.98
6	*Garcinia parvifolia*	4.35	0.0	4.63	8.98
7	*Artocarpus elasticus Blume*	6.83	0.0	1.85	8.68
8	*Pternandra galeata*	3.73	0.0	3.70	7.43
9	*Campnosperma coreacum*	4.35	0.0	1.85	6.20
10	*Hevea brasiliensis*	3.11	0.0	2.78	5.88
11	*Aglaia macrocarpa*	3.11	0.0	2.78	5.88
12	*Macaranga pearsonii Merr.*	2.48	0.0	2.78	5.26
13	*Calophyllum inophyllum L.*	3.11	0.0	1.85	4.96
14	*Dipterocarpus sp*	1.86	0.0	2.78	4.64
15	*Aquilaria malaccensis*	2.48	0.0	1.85	4.34
16	*Syzygium laxiflorum*	1.86	0.0	1.85	3.72
17	*Polyalthia spp.*	1.86	0.0	1.85	3.72
18	*Myristica sp.*	1.86	0.0	1.85	3.72
19	*Dillenia borneensis*	2.48	0.0	0.93	3.41
20	*Eurycoma longifolia*	1.24	0.0	1.85	3.09
21	*Leathery Antidesma*	1.24	0.0	1.85	3.09
22	*Artocarpus lanceifolius*	1.24	0.0	1.85	3.09
23	*Combretocarpus rotundatus*	1.24	0.0	1.85	3.09
24	*Vernonia arborea*	1.24	0.0	1.85	3.09
25	*Ochanostachys amentacea*	1.24	0.0	1.85	3.09
26	*Ilex cymosa Blume.*	1.24	0.0	1.85	3.09
27	*Melaleuca leucadendra*	1.24	0.0	1.85	3.09
28	*Macaranga trichocarpa*	1.24	0.0	0.93	2.17
29	*Bhesa paniculata Arn.*	1.24	0.0	0.93	2.17
30	*Tetramerista glabra Miq.*	1.24	0.0	0.93	2.17
31	*Alstonia spatulata Blume*	1.24	0.0	0.93	2.17
32	*Areca catechu*	0.62	0.0	0.93	1.55
33	*Mangifera pajang*	0.62	0.0	0.93	1.55
34	*Santiria laevigata Bl.*	0.62	0.0	0.93	1.55

35	*Elaeocarpus sp*	0.62	0.0	0.93	1.55
36	*Nephelium Sp*	0.62	0.0	0.93	1.55
37	*Syzygium Sp*	0.62	0.0	0.93	1.55
38	*Tristaniopsis sp.*	0.62	0.0	0.93	1.55
39	*Alseodaphne sp.*	0.62	0.0	0.93	1.55
40	*Cinnamomum sintok*	0.62	0.0	0.93	1.55
41	*Pternandra azurea*	0.62	0.0	0.93	1.55
42	*Durio kutejensis.*	0.62	0.0	0.93	1.55
43	*Artocarpus integer*	0.62	0.0	0.93	1.55
44	*Artocarpus lanceifolius*	0.62	0.0	0.93	1.55
45	*Litsea sp*	0.62	0.0	0.93	1.55
46	*Neonauclea gigantea Merr.*	0.62	0.0	0.93	1.55
47	*Ficus aurata*	0.62	0.0	0.93	1.55
48	*Macaranga Sp*	0.62	0.0	0.93	1.55
49	*Koompassia malaccensis*	0.62	0.0	0.93	1.55
50	*Adinandra dumosa Jack*	0.62	0.0	0.93	1.55
51	*Garcinia sp*	0.62	0.0	0.93	1.55
52	*Tetractomia obovata Merrill.*	0.62	0.0	0.93	1.55
53	*Xylopia fusca Maingay*	0.62	0.0	0.93	1.55
54	*Eusideroxylon zwageri*	0.62	0.0	0.93	1.55

Table of Seedling Vegetation Analysis (Brupis Forest)

No	Latin Name	(KR)	(FR)	INP (%)
1	*Hevea brasiliensis*	0.2100	0.0603	0.2703
2	*Alseodaphne sp.*	0.1566	0.1034	0.2600
3	*Dialium platysepalum*	0.0641	0.0603	0.1244
4	*Combretocarpus rotundatus*	0.0605	0.0345	0.0950
5	*Palaquium rostratum*	0.0285	0.0431	0.0716
6	*Aquilaria malaccensis*	0.0178	0.0431	0.0609
7	*Ochanostachys amentacea*	0.0249	0.0345	0.0594
8	*Santiria laevigata*	0.0285	0.0259	0.0543
9	*Sandoricum sp.*	0.0178	0.0345	0.0523
10	*Archidendron clypearia*	0.0249	0.0259	0.0508
11	*Artocarpus* sp.	0.0214	0.0259	0.0472
12	*Macaranga gigantea*	0.0285	0.0172	0.0457
13	*Cinnamomum sintok*	0.0142	0.0259	0.0401
14	*Artocarpus anisophyllus*	0.0142	0.0259	0.0401
15	*Cananga odorata*	0.0214	0.0172	0.0386
16	*Pternandra galeata*	0.0107	0.0259	0.0365
17	*Flacourtia rukam*	0.0107	0.0259	0.0365
18	*Artocarpus lanceifolius*	0.0178	0.0172	0.0350
19	*Calophyllum inophyllum*	0.0178	0.0172	0.0350
20	*Aglaia macrocarpa*	0.0107	0.0172	0.0279
21	*Cratoxylum sumatranum*	0.0178	0.0086	0.0264
22	*Dehaasia sp.*	0.0178	0.0086	0.0264
23	*Myristica sp.*	0.0071	0.0172	0.0244
24	*Artocarpus integer*	0.0071	0.0172	0.0244
25	*Artocarpus elasticus*	0.0142	0.0086	0.0229
26	*Nephelium uncinatum*	0.0107	0.0086	0.0193
27	*Popowia bancana*	0.0071	0.0086	0.0157
28	*Syzygium* sp.	0.0071	0.0086	0.0157
29	*Polyalthia* spp.	0.0071	0.0086	0.0157
30	*Alstonia spatulata*	0.0071	0.0086	0.0157
31	*Ochanostachys amentacea*	0.0071	0.0086	0.0157
32	*Mangifera pajang* Kosterm.	0.0071	0.0086	0.0157
33	*Glochidion sp.*	0.0036	0.0086	0.0122
34	*Garcinia parvifolia*	0.0036	0.0086	0.0122
35	*Gymnacranthera* spp.	0.0036	0.0086	0.0122

36	*Cantleya corniculata*	0.0036	0.0086	0.0122
37	*Bambusa vulgaris*	0.0036	0.0086	0.0122
38	*Durio oxleyanus*	0.0036	0.0086	0.0122
39	*Ficus spathulifolia*	0.0036	0.0086	0.0122
40	*Dipterocarpus sp*	0.0036	0.0086	0.0122
41	*Artocarpus sp*	0.0036	0.0086	0.0122
42	*Garcinia sp.*	0.0036	0.0086	0.0122
43	*Tetractomia obovata*	0.0036	0.0086	0.0122
44	*Elaeocarpus microphyllus*	0.0036	0.0086	0.0122
45	*Vitex pinnata*	0.0036	0.0086	0.0122
46	*Shorea platycarpa*	0.0036	0.0086	0.0122
47	*Eurycoma longifolia*	0.0036	0.0086	0.0122
48	*Melastoma malabathricum*	0.0036	0.0086	0.0122
49	*Dipterocarpus sp*	0.0036	0.0086	0.0122
50	*Adinandra dumosa* Jack	0.0036	0.0086	0.0122
51	*Campnosperma coreacum*	0.0036	0.0086	0.0122
52	*Macaranga pearsonii*	0.0036	0.0086	0.0122
53	*Nephelium* sp.	0.0036	0.0086	0.0122
54	*Dialium sp.*	0.0036	0.0086	0.0122
55	*Syzygium tawahense*	0.0036	0.0086	0.0122

Tamtam Forest

Tree Vegetation Analysis Table (Tamtam Forest)

No	Scientific Name	(Kr)	(Dr)	(Fr)	INP (%)
1	*Elaeocarpus microphyllus*	0.1981	0.4434	0.1148	75.62%
2	*Artocarpus integer*	0.0943	0.1164	0.0656	27.63%
3	*Dehaasia sp.*	0.0660	0.0489	0.0984	21.33%
4	*Calophyllum inophyllum*	0.1038	0.0187	0.0492	17.17%
5	*Artocarpus anisophyllus*	0.0472	0.0253	0.0656	13.81%
6	*Hevea brasiliensis*	0.0660	0.0125	0.0492	12.77%
7	*Cananga odorata*	0.0472	0.0252	0.0492	12.15%
8	*Syzygium leptostemon*	0.0189	0.0839	0.0164	11.92%
9	*Shorea leprosula Miq.*	0.0094	0.0903	0.0164	11.61%
10	*Flacourtia rukam*	0.0566	0.0084	0.0492	11.42%
11	*Durio kutejensis*	0.0283	0.0058	0.0492	8.33%
12	*Diospyros sp.*	0.0283	0.0053	0.0328	6.64%
13	*Palaquium obtusifolium*	0.0094	0.0401	0.0164	6.59%
14	*Durio oxleyanus*	0.0189	0.0033	0.0328	5.50%
15	*Macaranga gigantea*	0.0283	0.0045	0.0164	4.92%
16	*Tetractomia obovata Merrill.*	0.0094	0.0178	0.0164	4.37%
17	*Alstonia spatulata Blume*	0.0189	0.0039	0.0164	3.91%
18	*Xylopia fusca*	0.0189	0.0022	0.0164	3.75%
19	*Campnosperma auriculatum*	0.0094	0.0070	0.0164	3.28%
20	*Nephelium uncinatum*	0.0094	0.0054	0.0164	3.12%
21	*Shorea parvifolia*	0.0094	0.0052	0.0164	3.10%
22	*Myristica sp.*	0.0094	0.0045	0.0164	3.03%
23	*Durio zibethinus*	0.0094	0.0040	0.0164	2.99%
24	*Syzygium sp.*	0.0094	0.0034	0.0164	2.92%
25	*Archidendron clypearia*	0.0094	0.0025	0.0164	2.83%
26	*Nephelium lappaceum*	0.0094	0.0025	0.0164	2.83%
27	*Eusideroxylon zwageri*	0.0094	0.0025	0.0164	2.83%
28	*Campnosperma coreacum*	0.0094	0.0019	0.0164	2.77%
29	*Tristaniopsis obovata*	0.0094	0.0015	0.0164	2.73%
30	*Vitex pinnata*	0.0094	0.0012	0.0164	2.71%
31	*Vernonia arborea*	0.0094	0.0012	0.0164	2.71%
32	*Aglaia rubiginosa*	0.0094	0.0012	0.0164	2.71%

Tihang Vegetation Analysis Table (Tamtam Forest)

No	Scientific Name	(KR)	(DR)	(FR)	INP (%)
1	*Elaeocarpus microphyllus*	0.1981	0.4434	0.1148	75.62%
2	*Artocarpus integer*	0.0943	0.1164	0.0656	27.63%
3	*Dehaasia sp.*	0.0660	0.0489	0.0984	21.33%
4	*Calophyllum inophyllum L.*	0.1038	0.0187	0.0492	17.17%
5	*Artocarpus anisophyllus*	0.0472	0.0253	0.0656	13.81%
6	*Hevea brasiliensis*	0.0660	0.0125	0.0492	12.77%
7	*Cananga odorata*	0.0472	0.0252	0.0492	12.15%
8	*Syzygium leptostemon*	0.0189	0.0839	0.0164	11.92%
9	*Shorea leprosula*	0.0094	0.0903	0.0164	11.61%
10	*Flacourtia rukam*	0.0566	0.0084	0.0492	11.42%
11	*Durio kutejensis*	0.0283	0.0058	0.0492	8.33%
12	*Diospyros sp.*	0.0283	0.0053	0.0328	6.64%
13	*Palaquium obtusifolium*	0.0094	0.0401	0.0164	6.59%
14	*Durio oxleyanus Griff.*	0.0189	0.0033	0.0328	5.50%
15	*Macaranga gigantea*	0.0283	0.0045	0.0164	4.92%
16	*Tetractomia obovata*	0.0094	0.0178	0.0164	4.37%
17	*Alstonia spatulata Blume*	0.0189	0.0039	0.0164	3.91%
18	*Xylopia fusca*	0.0189	0.0022	0.0164	3.75%
19	*Campnosperma auriculatum*	0.0094	0.0070	0.0164	3.28%
20	*Nephelium uncinatum*	0.0094	0.0054	0.0164	3.12%
21	*Shorea parvifolia Dyer*	0.0094	0.0052	0.0164	3.10%
22	*Myristica sp.*	0.0094	0.0045	0.0164	3.03%
23	*Durio zibethinus*	0.0094	0.0040	0.0164	2.99%
24	*Syzygium sp.*	0.0094	0.0034	0.0164	2.92%
25	*Archidendron clypearia*	0.0094	0.0025	0.0164	2.83%

26	*Nephelium lappaceum*	0.0094	0.0025	0.0164	2.83%
27	*Eusideroxylon zwageri*	0.0094	0.0025	0.0164	2.83%
28	*Campnosperma coreacum*	0.0094	0.0019	0.0164	2.77%
29	*Tristaniopsis obovata*	0.0094	0.0015	0.0164	2.73%
30	*Vitex pinnata*	0.0094	0.0012	0.0164	2.71%
31	*Vernonia arborea*	0.0094	0.0012	0.0164	2.71%
32	*Aglaia rubiginosa*	0.0094	0.0012	0.0164	2.71%

Vegetation Analysis Table for Pancang (Tamtam Forest)

No	Scientific Name	(KR)	(FR)	INP (%)
1	*Elaeocarpus microphyllus*	0.1981	0.1148	31.29%
2	*Artocarpus integer*	0.0943	0.0656	15.99%
3	*Dehaasia sp.*	0.0660	0.0984	16.44%
4	*Calophyllum inophyllum L.*	0.1038	0.0492	15.30%
5	*Artocarpus anisophyllus*	0.0472	0.0656	11.27%
6	*Hevea brasiliensis*	0.0660	0.0492	11.52%
7	*Cananga odorata*	0.0472	0.0492	9.64%
8	*Syzygium leptostemon*	0.0189	0.0164	3.53%
9	*Shorea leprosula Miq.*	0.0094	0.0164	2.58%
10	*Flacourtia rukam*	0.0566	0.0492	10.58%
11	*Durio kutejensis*	0.0283	0.0492	7.75%
12	*Diospyros sp.*	0.0283	0.0328	6.11%
13	*Palaquium obtusifolium*	0.0094	0.0164	2.58%
14	*Durio oxleyanus Griff.*	0.0189	0.0328	5.17%
15	*Macaranga gigantea*	0.0283	0.0164	4.47%
16	*Tetractomia obovata Merrill.*	0.0094	0.0164	2.58%
17	*Alstonia spatulata Blume*	0.0189	0.0164	3.53%
18	*Xylopia fusca*	0.0189	0.0164	3.53%
19	*Campnosperma auriculatum*	0.0094	0.0164	2.58%
20	*Nephelium uncinatum*	0.0094	0.0164	2.58%
21	*Shorea parvifolia Dyer*	0.0094	0.0164	2.58%
22	*Myristica sp.*	0.0094	0.0164	2.58%
23	*Durio zibethinus*	0.0094	0.0164	2.58%
24	*Syzygium sp.*	0.0094	0.0164	2.58%
25	*Archidendron clypearia*	0.0094	0.0164	2.58%
26	*Nephelium lappaceum*	0.0094	0.0164	2.58%
27	*Eusideroxylon zwageri*	0.0094	0.0164	2.58%
28	*Campnosperma coreacum*	0.0094	0.0164	2.58%
29	*Tristaniopsis obovata*	0.0094	0.0164	2.58%
30	*Vitex pinnata*	0.0094	0.0164	2.58%
31	*Vernonia arborea*	0.0094	0.0164	2.58%
32	*Aglaia rubiginosa*	0.0094	0.0164	2.58%

Vegetation Analysis Table for Seedlings (Tamtam Forest)

No	Scientific Name	(KR)	(FR)	INP (%)
1	*Elaeocarpus microphyllus*	0.1981	0.1148	31.29%
2	*Artocarpus integer*	0.0943	0.0656	15.99%
3	*Dehaasia sp.*	0.0660	0.0984	16.44%
4	*Calophyllum inophyllum L.*	0.1038	0.0492	15.30%
5	*Artocarpus anisophyllus*	0.0472	0.0656	11.27%
6	*Hevea brasiliensis*	0.0660	0.0492	11.52%
7	*Cananga odorata*	0.0472	0.0492	9.64%
8	*Syzygium leptostemon*	0.0189	0.0164	3.53%
9	*Shorea leprosula Miq.*	0.0094	0.0164	2.58%
10	*Flacourtia rukam*	0.0566	0.0492	10.58%
11	*Durio kutejensis*	0.0283	0.0492	7.75%
12	*Diospyros sp.*	0.0283	0.0328	6.11%
13	*Palaquium obtusifolium*	0.0094	0.0164	2.58%
14	*Durio oxleyanus Griff.*	0.0189	0.0328	5.17%
15	*Macaranga gigantea*	0.0283	0.0164	4.47%
16	*Tetractomia obovata*	0.0094	0.0164	2.58%
17	*Alstonia spatulata*	0.0189	0.0164	3.53%
18	*Xylopia fusca*	0.0189	0.0164	3.53%
19	*Campnosperma auriculatum*	0.0094	0.0164	2.58%
20	*Nephelium uncinatum*	0.0094	0.0164	2.58%
21	*Shorea parvifolia Dyer*	0.0094	0.0164	2.58%
22	*Myristica sp.*	0.0094	0.0164	2.58%
23	*Durio zibethinus*	0.0094	0.0164	2.58%
24	*Syzygium sp.*	0.0094	0.0164	2.58%
25	*Archidendron clypearia*	0.0094	0.0164	2.58%
26	*Nephelium lappaceum*	0.0094	0.0164	2.58%
27	*Eusideroxylon zwageri*	0.0094	0.0164	2.58%
28	*Campnosperma coreacum*	0.0094	0.0164	2.58%
29	*Tristaniopsis obovata*	0.0094	0.0164	2.58%
30	*Vitex pinnata*	0.0094	0.0164	2.58%
31	*Vernonia arborea*	0.0094	0.0164	2.58%
32	*Aglaia rubiginosa*	0.0094	0.0164	2.58%

Air Dekakah Forest

Tree Vegetation Analysis Table (Air Dekakah Forest)

No	Scientific Name	(KR)	(DR)	(FR)	INP (%)
1	*Gynotroches axillaris*	0.3810	0.4428	0.1667	99.04%
2	*Archidendron clypearia*	0.0952	0.0760	0.1111	28.24%
3	*Palaquium obtusifolium*	0.0476	0.1468	0.0833	27.77%
4	*Campnosperma coreacum*	0.0714	0.0393	0.1111	22.18%
5	*Durio oxleyanus Griff.*	0.0238	0.0749	0.0556	15.42%
6	*Macaranga gigantea*	0.0476	0.0273	0.0556	13.04%
7	*Artocarpus integer*	0.0476	0.0145	0.0556	11.76%
8	*Artocarpus anisophyllus*	0.0238	0.0235	0.0556	10.29%
9	*Laurina knema*	0.0238	0.0221	0.0556	10.15%
10	*Nephelium uncinatum*	0.0238	0.0204	0.0556	9.98%
11	*Dacryodes rostrata*	0.0238	0.0196	0.0556	9.90%
12	*Durio zibethinus*	0.0238	0.0170	0.0556	9.64%
13	*Ficus grossularioides*	0.0238	0.0162	0.0556	9.56%
14	*Syzygium sp.*	0.0238	0.0130	0.0278	6.46%
15	*Calophyllum inophyllum L.*	0.0238	0.0091	0.0278	6.07%
16	*Hevea brasiliensis*	0.0119	0.0139	0.0278	5.36%
17	*Aglaia rubiginosa*	0.0119	0.0096	0.0278	4.93%
18	*Campnosperma auriculatum*	0.0119	0.0032	0.0278	4.29%
19	*Ptychopyxis caput*	0.0119	0.0022	0.0278	4.19%
20	*Diospyros sp.*	0.0119	0.0018	0.0278	4.15%
21	*Elaeocarpus microphyllus*	0.0119	0.0018	0.0278	4.15%
22	*Quercus sp.*	0.0119	0.0016	0.0278	4.13%
23	*Nauclea orientalis*	0.0119	0.0016	0.0278	4.13%
24	*Shorea parvifolia Dyer*	0.0119	0.0012	0.0278	4.09%

Appendix 4. Field Documentation

Brupis Forest

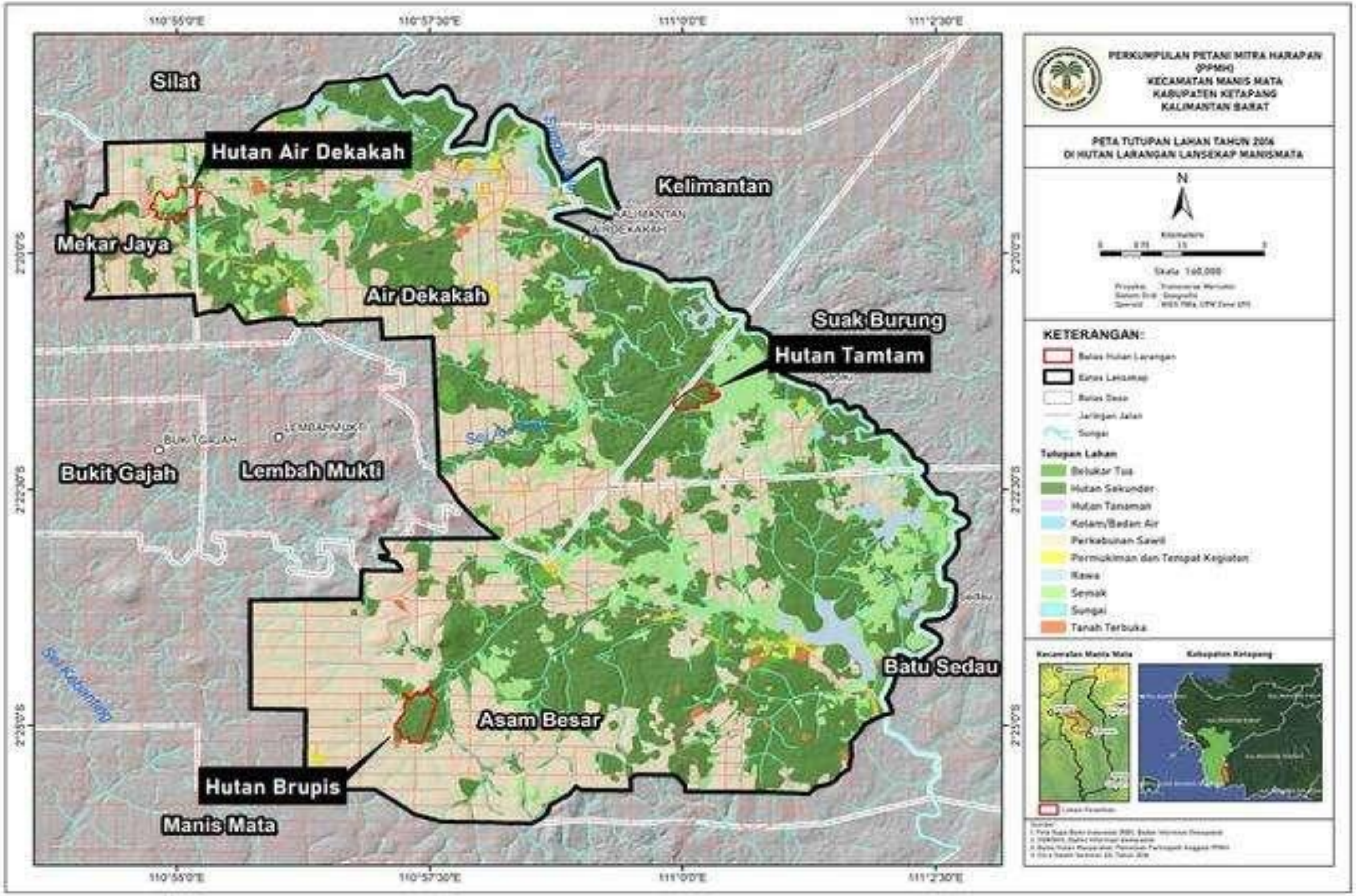
Tamtam

Air Dekakah

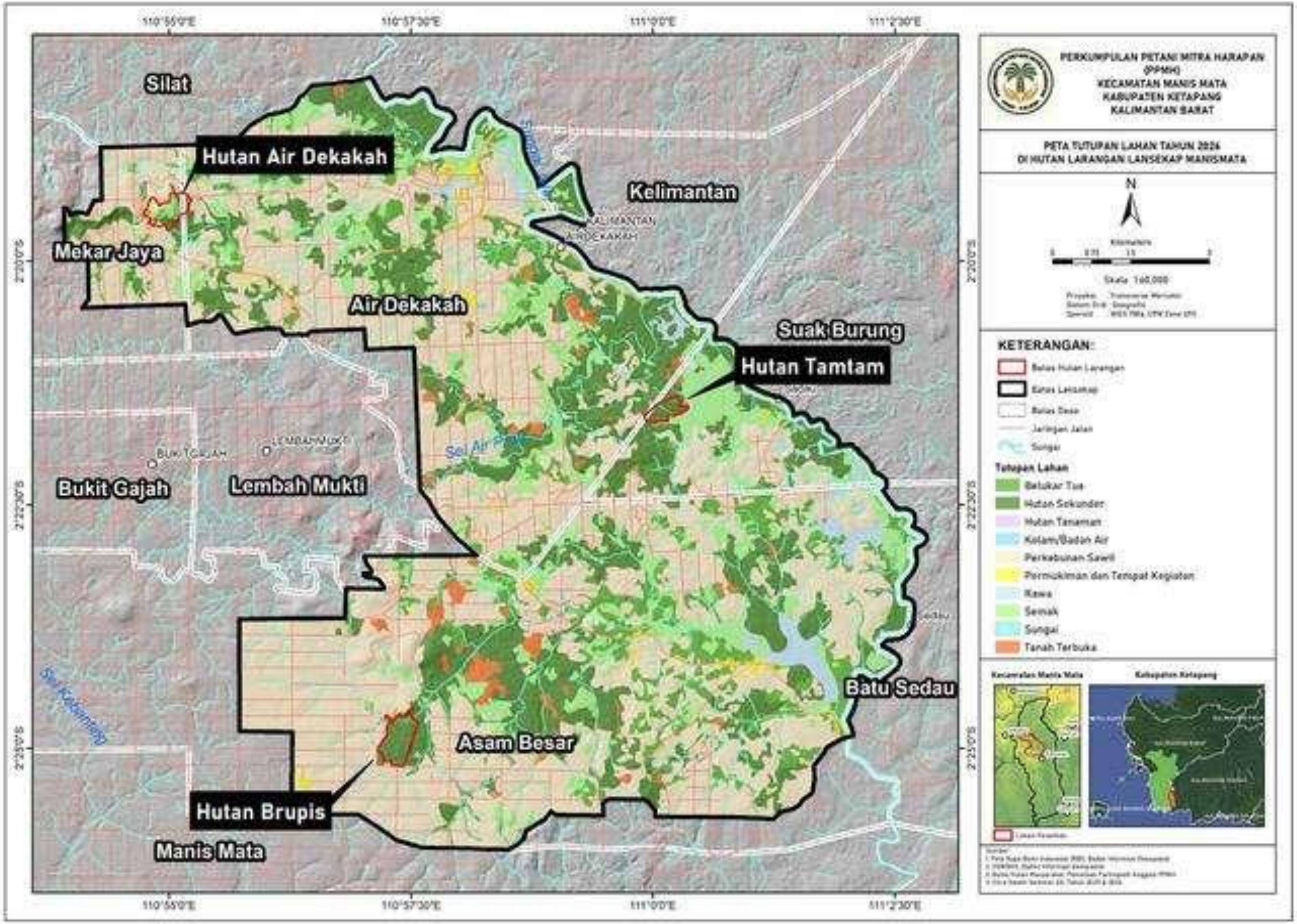
Appendix 5. Thematic Map


PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA TUTUPAN LAHAN TAHUN 2024
DI HUTAN LARANGAN BRUPIS
N
KETERANGAN:
Batas Hutan Larangan
Batas Lanskap
Batas Desa
Jaringan Jalan
Sungai
TUTUPAN LAHAN
Belukar Tua
Hutan Sekunder
Hutan Tanaman
Kolam/Badan Air
Perkebunan Sawit
Permukiman dan Tempat Kegiatan
Rawa
Semak
Sungai
Tanah Terbuka
Kecamatan Manis Mata
Kabupaten Ketapang
Asam Besar
Sm
Bt
Swt
Hs
Ht

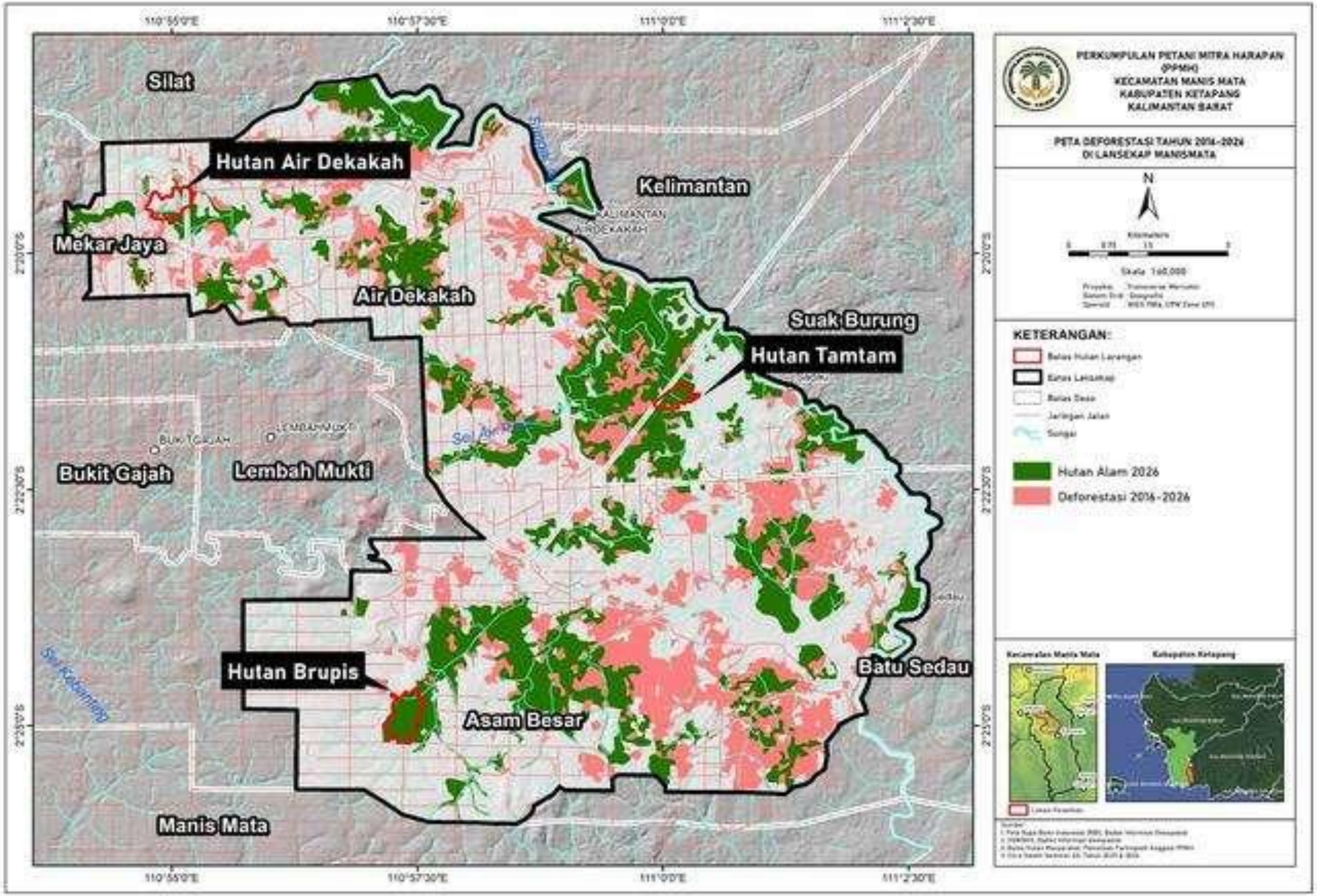
PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA TUTUPAN LAHAN TAHUN 2024
DI HUTAN LARANGAN TAMTAM
N
KETERANGAN:
Batas Hutan Larangan
Batas Lanskap
Batas Desa
Jaringan Jalan
Sungai
TUTUPAN LAHAN
Belukar Tua
Hutan Sekunder
Hutan Tanaman
Kolam/Badan Air
Perkebunan Sawit
Permukiman dan Tempat Kegiatan
Rawa
Semak
Sungai
Tanah Terbuka
Kecamatan Manis Mata
Kabupaten Ketapang
Air Dekakah
Suak Burung
Swt
Sm
Hs
Bt
Tk



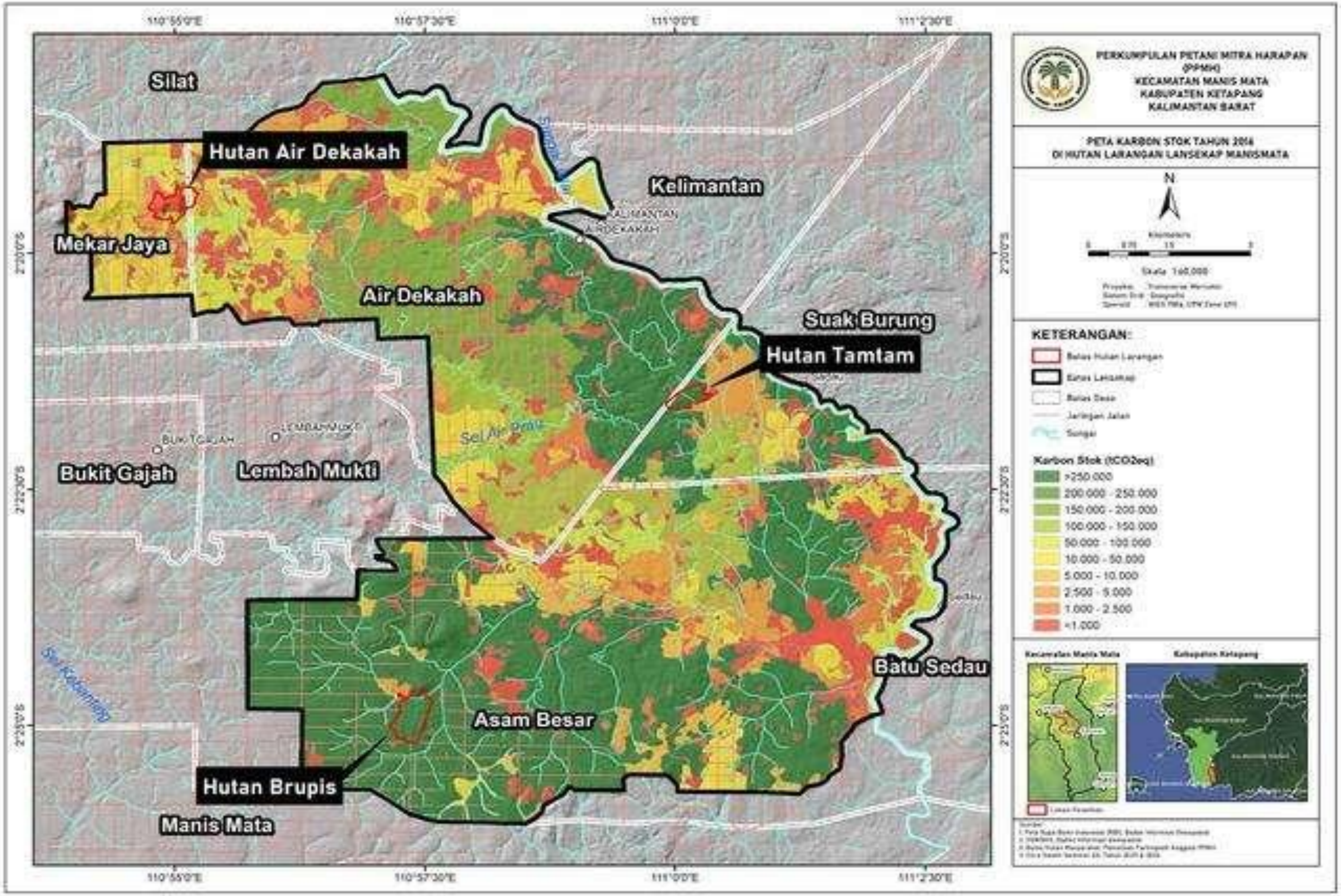
PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA TUTUPAN LAHAN TAHUN 2016
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
Skala 1:60,000
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Tutupan Lahan
Belukar Tua
Hutan Sekunder
Hutan Tanaman
Kolam/Badan Air
Perkebunan Sawit
Permukiman dan Tempat Kegiatan
Rawa
Semak
Sungai
Tanah Terbuka
Kecamatan Manis Mata
Kabupaten Ketapang
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata



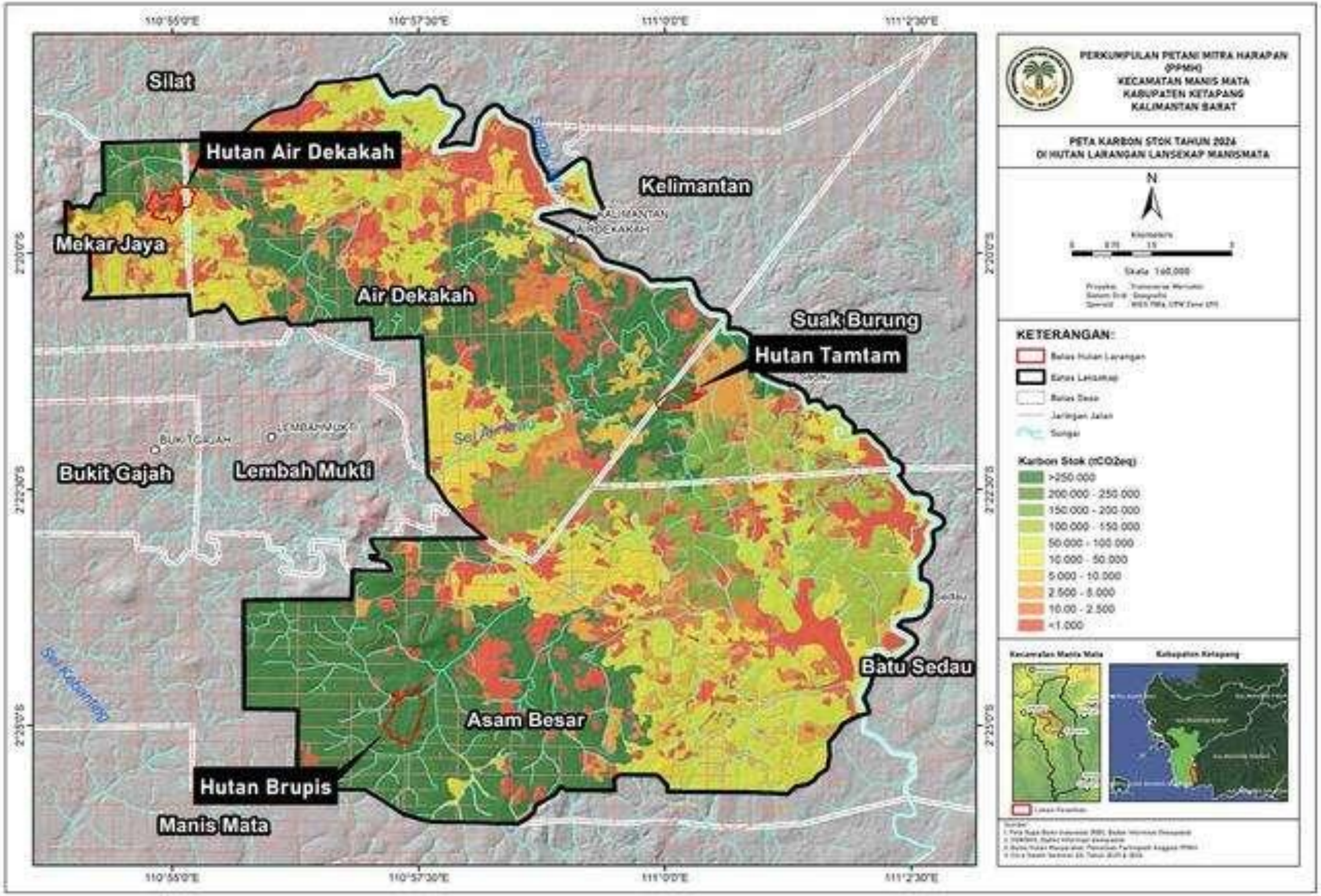
PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA TUTUPAN LAHAN TAHUN 2026
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Tutupan Lahan
Belukar Tua
Hutan Sekunder
Hutan Tanaman
Kolam/Badan Air
Perkebunan Sawit
Permukiman dan Tempat Kegiatan
Rawa
Semak
Sungai
Tanah Terbuka
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Sei Air Pinang
Batu Sedau
Sei Kelansang
Asam Besar
Hutan Brupis
Manis Mata



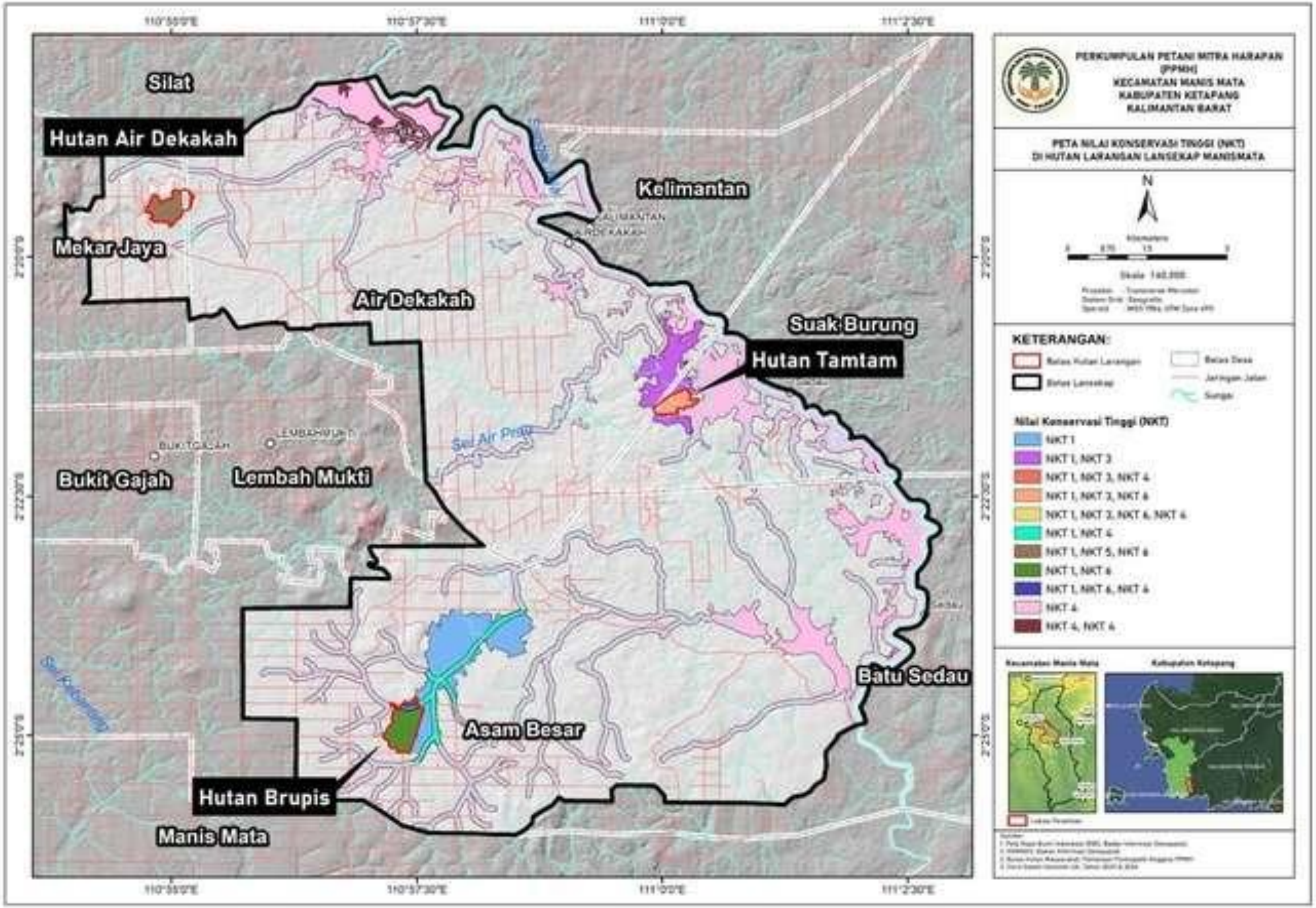
PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA DEFORESTASI TAHUN 2016-2026
DI LANSEKAP MANISMATA
KETERANGAN:
Hutan Alam 2026
Deforestasi 2016-2026
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Hutan Brupis
Asam Besar
Batu Sedau
Manis Mata
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E



PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA KARBON STOK TAHUN 2016
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Karbon Stok (tCO2eq)
>250.000
200.000 - 250.000
150.000 - 200.000
100.000 - 150.000
50.000 - 100.000
10.000 - 50.000
5.000 - 10.000
2.500 - 5.000
1.000 - 2.500
<1.000
Kecamatan Manis Mata
Kabupaten Ketapang
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Sei Air Pitas
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata

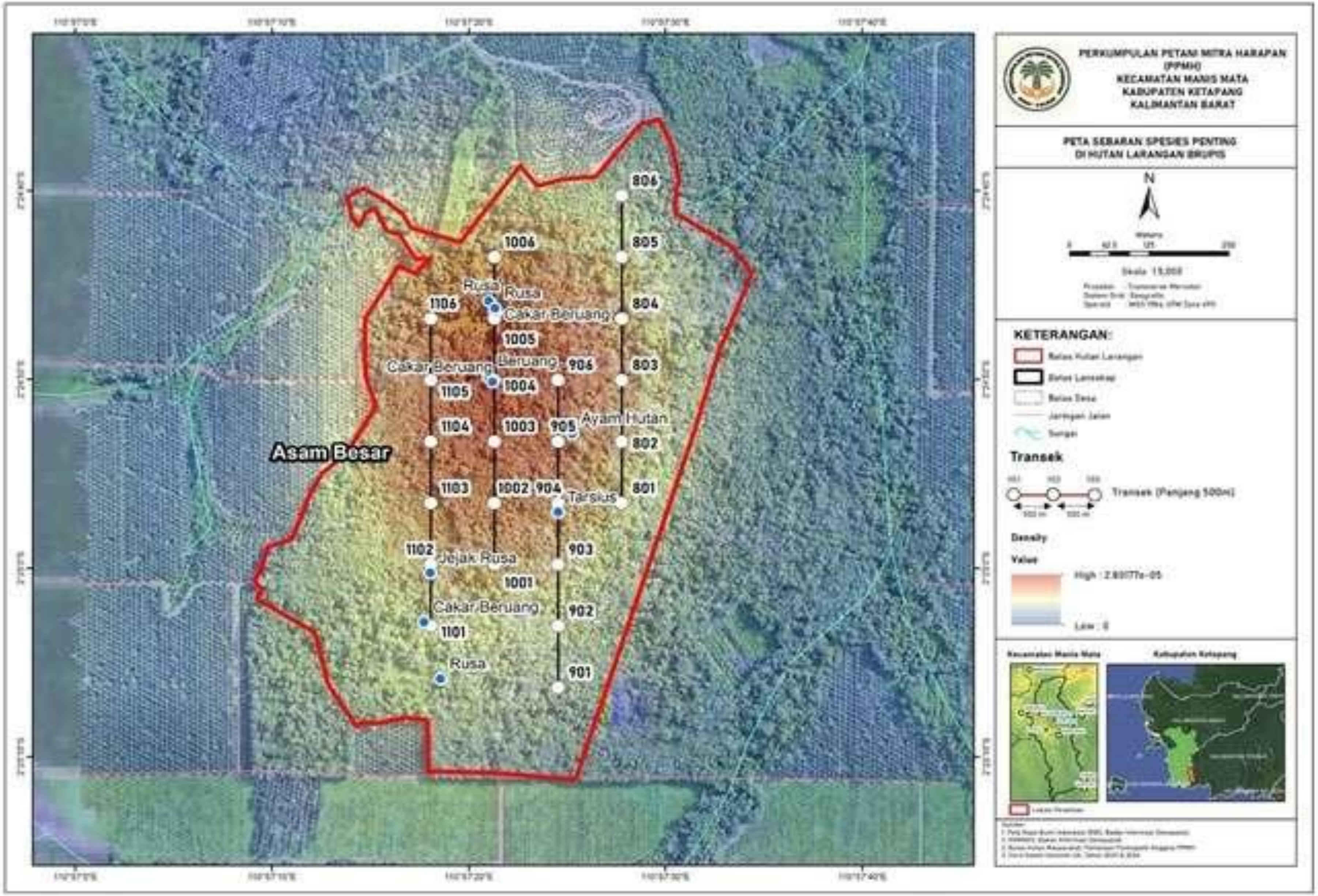


PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA KARBON STOK TAHUN 2024
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Karbon Stok (tCO2eq)
>250.000
200.000 - 250.000
150.000 - 200.000
100.000 - 150.000
50.000 - 100.000
10.000 - 50.000
5.000 - 10.000
2.500 - 5.000
10.00 - 2.500
<1.000
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E

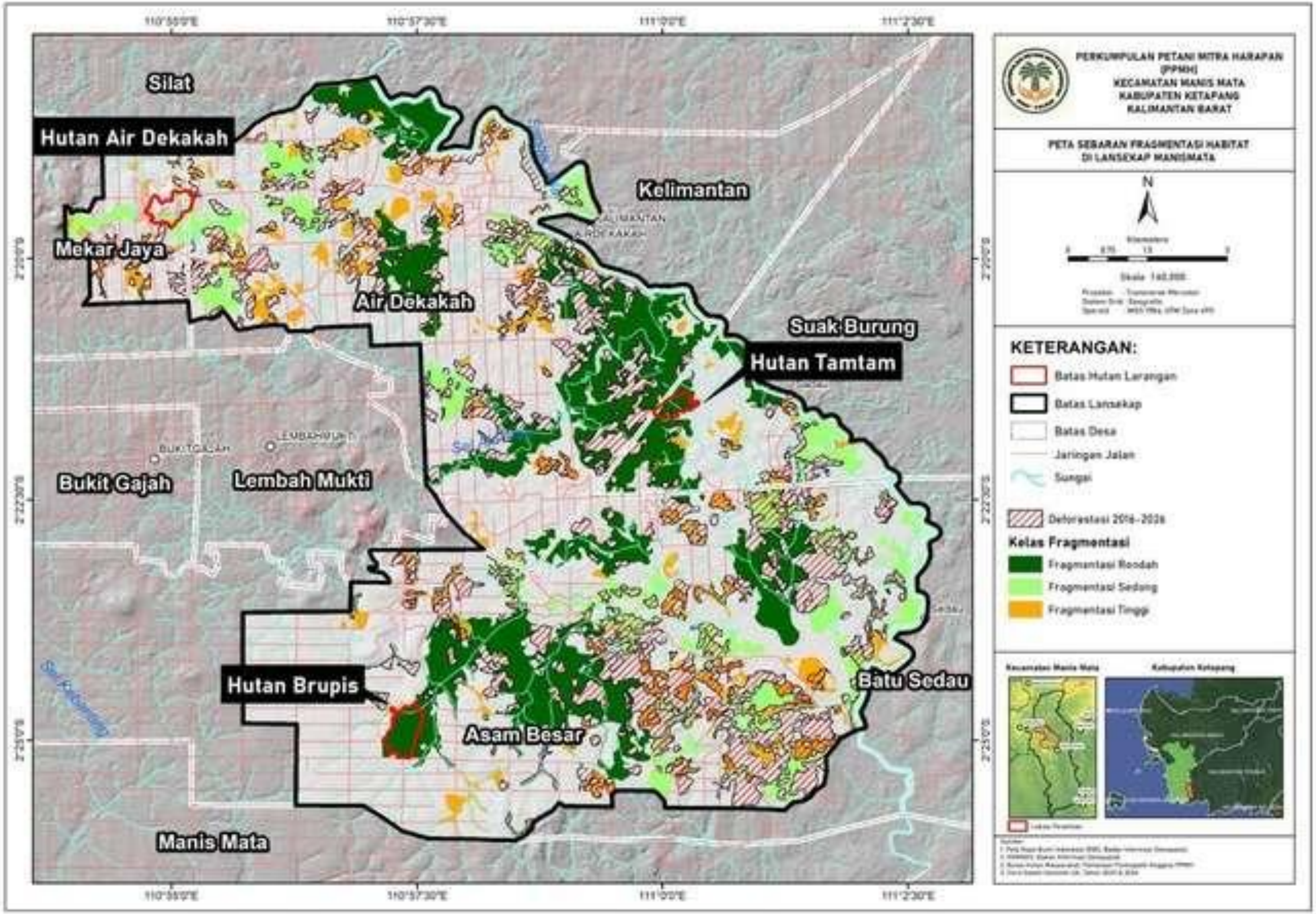


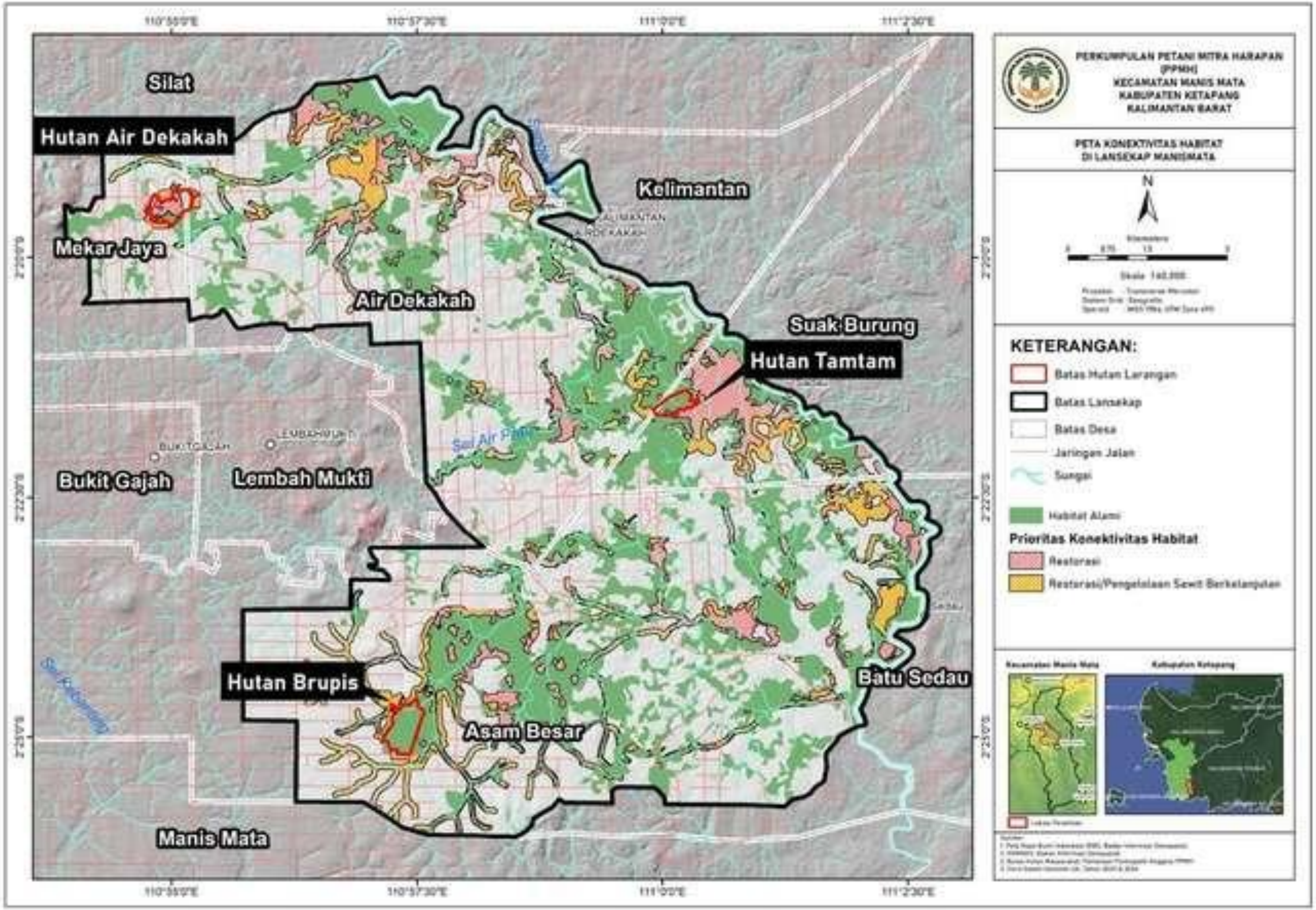
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
2°20'0"S
2°22'30"S
2°25'0"S
Silat
Hutan Air Dekakah
Mekar Jaya
Air Dekakah
Kelimantan
Suak Burung
Hutan Tamtam
Sei Air Pras
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata
PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA NILAI KONSERVASI TINGGI (NKT)
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Nilai Konservasi Tinggi (NKT)
NKT 1
NKT 1, NKT 3
NKT 1, NKT 3, NKT 4
NKT 1, NKT 3, NKT 6
NKT 1, NKT 3, NKT 4, NKT 6
NKT 1, NKT 4
NKT 1, NKT 5, NKT 6
NKT 1, NKT 6
NKT 1, NKT 4, NKT 6
NKT 4
NKT 4, NKT 6
Kecamatan Manis Mata
Kabupaten Ketapang


PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA SEBARAN SPESIES PENTING
DI HUTAN LARANGAN AIR DEKAKAH
N
KETERANGAN:
Batas Hutan Larangan
Batas Lanskap
Batas Desa
Jaringan Jalan
Sungai
Transek
Transek (Panjang 500m)
Density
Value
High : 2.80177e-05
Low : 0
Kecamatan Manis Mata
Kabupaten Ketapang
Mekar Jaya
Air Dekakah
101
102
103
104
105
106
201
202
203
204
205
206
301
302
303
304
305
306
401
Beruang
Beruang
Beruang
Beruang

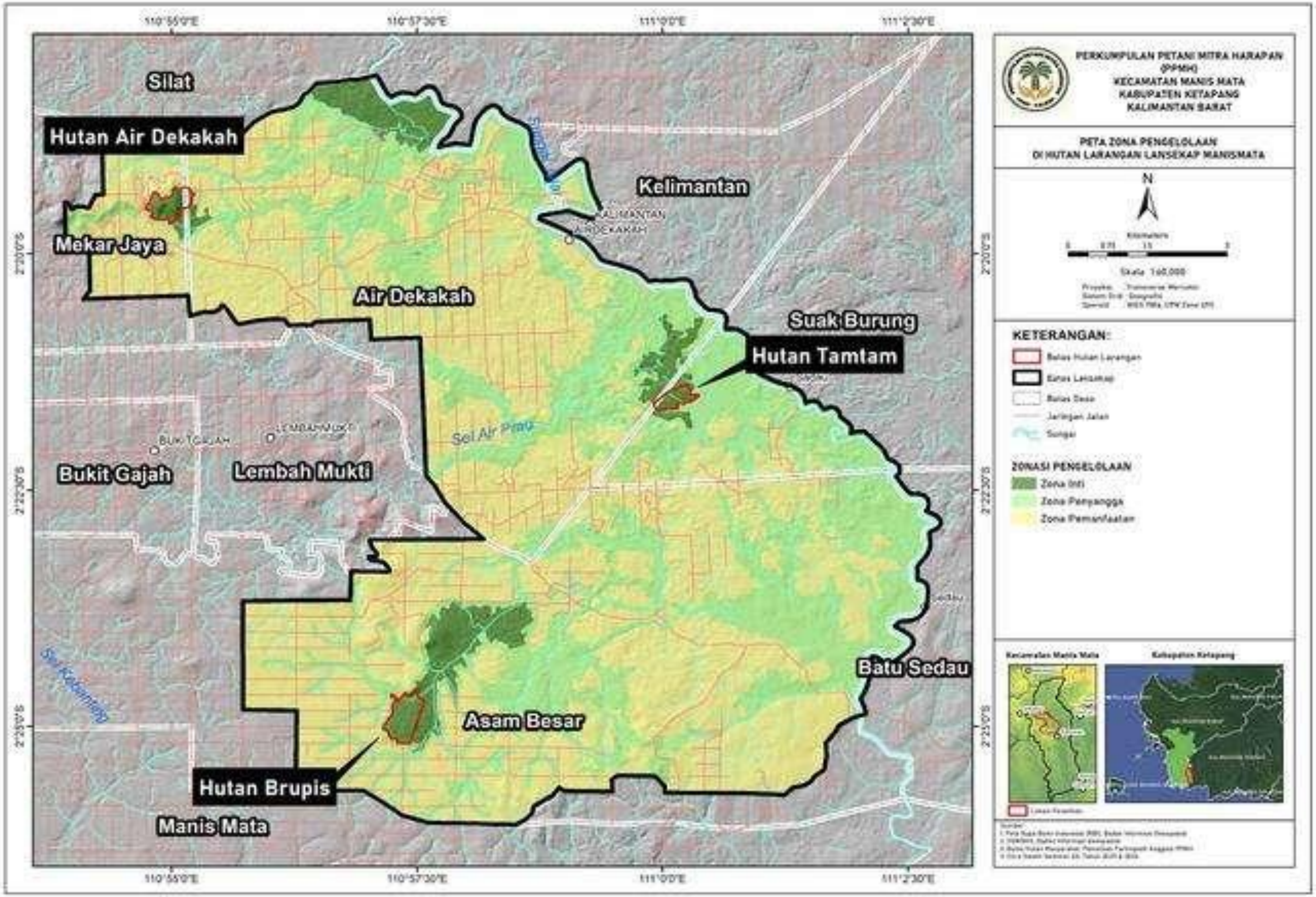

PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA SEBARAN SPESIES PENTING
DI HUTAN LARANGAN BRUPIS
N
KETERANGAN:
Batas Hutan Larangan
Batas Lanskap
Batas Desa
Jaringan Jalan
Sungai
Transek
Transek (Panjang 500m)
Density
Value
High : 2.80177e-05
Low : 0
Kecamatan Manis Mata
Kabupaten Ketapang
Asam Besar
806
805
804
803
802
801
1006
1005
1004
1003
1002
1001
1106
1105
1104
1103
1102
1101
906
905
904
903
902
901
Rusa
Cakar Beruang
Beruang
Ayam Hutan
Tarsius
Jejak Rusa


PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA SEBARAN SPESIES PENTING
DI HUTAN LARANGAN TAMTAM
N
KETERANGAN:
Batas Hutan Larangan
Batas Lanskap
Batas Desa
Jaringan Jalan
Sungai
Transek
Transek (Panjang 500m)
Density
Value
High : 2.83177e-05
Low : 0
Kecamatan Manis Mata
Kabupaten Ketapang
Air Dekakah
Suak Burung
601
Kancil
Kijang
602
Trenggiling
Rusa
605
Rusa
606
Rusa
604
Ayam Hutan
Rusa
501
502
503
504
505
506
701

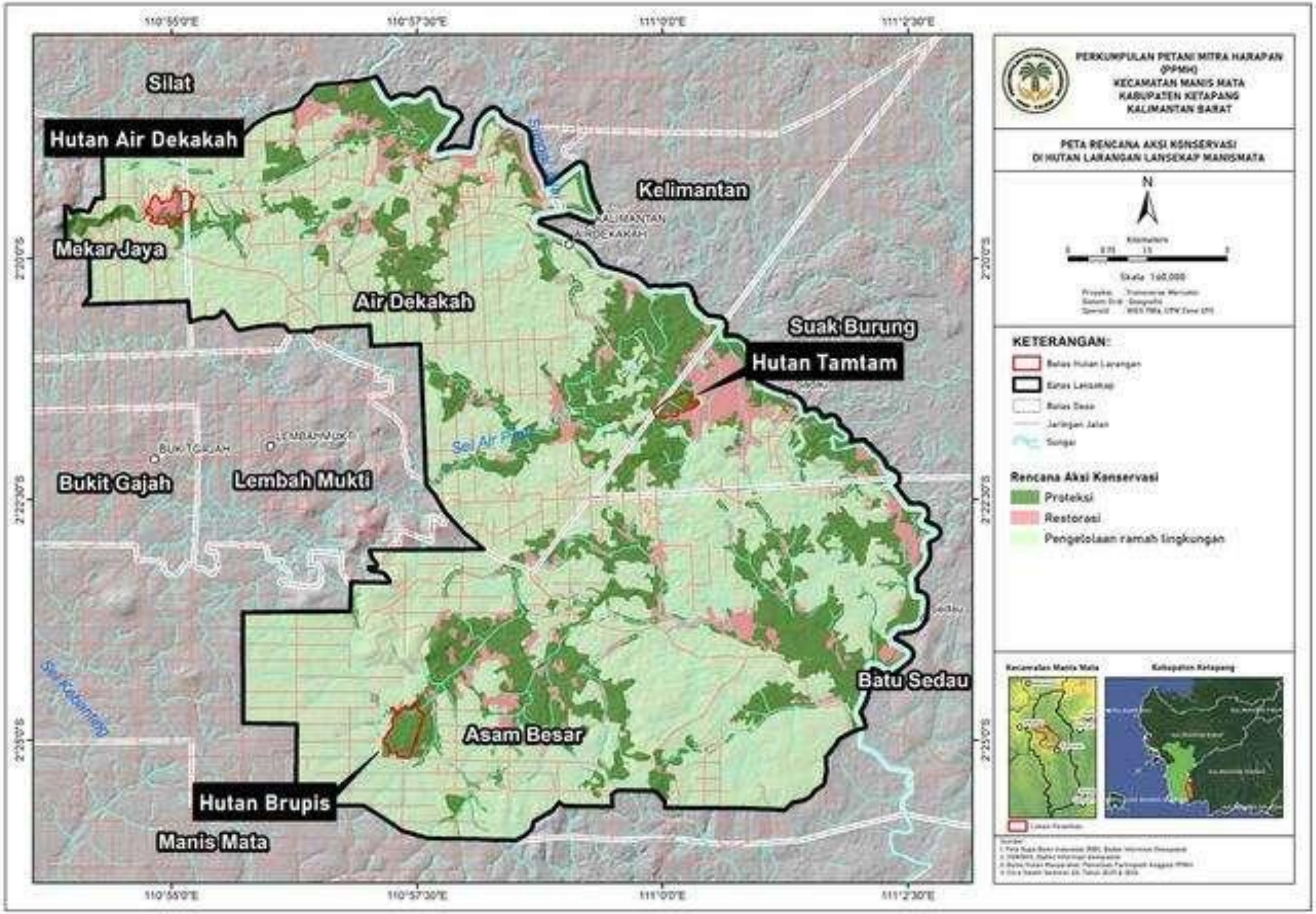

110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
Silat
Hutan Air Dekakah
Kelimantan
Mekar Jaya
Air Dekakah
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Hutan Brupis
Batu Sedau
Asam Besar
Manis Mata
PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA SEBARAN FRAGMENTASI HABITAT
DI LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Deforestasi 2016-2026
Kelas Fragmentasi
Fragmentasi Rendah
Fragmentasi Sedang
Fragmentasi Tinggi
Kecamatan Manis Mata
Kabupaten Ketapang



PERKUMPULAN PETANI MITRA HARAPAN (PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA KONEKTIVITAS HABITAT
DI LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Habitat Alami
Prioritas Konektivitas Habitat
Restorasi
Restorasi/Pengelolaan Sawit Berkelanjutan
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
Silat
Hutan Air Dekakah
Mekar Jaya
Air Dekakah
Kelimantan
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Hutan Brupis
Asam Besar
Batu Sedau
Manis Mata



110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E
2°20'0"S
2°22'30"S
2°25'0"S
Silat
Hutan Air Dekakah
Mekar Jaya
Air Dekakah
Kelimantan
Suak Burung
Hutan Tamtam
Sei Air Prau
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata
PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA ZONA PENGELOLAAN
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
ZONASI PENGELOLAAN
Zona Inti
Zona Penyangga
Zona Pemanfaatan



PERKUMPULAN PETANI MITRA HARAPAN
(PPMH)
KECAMATAN MANIS MATA
KABUPATEN KETAPANG
KALIMANTAN BARAT
PETA RENCANA AKSI KONSERVASI
DI HUTAN LARANGAN LANSEKAP MANISMATA
N
KETERANGAN:
Batas Hutan Larangan
Batas Lansekap
Batas Desa
Jaringan Jalan
Sungai
Rencana Aksi Konservasi
Proteksi
Restorasi
Pengelolaan ramah lingkungan
Silat
Hutan Air Dekakah
Mekar Jaya
Air Dekakah
Kelimantan
Suak Burung
Hutan Tamtam
Bukit Gajah
Lembah Mukti
Batu Sedau
Asam Besar
Hutan Brupis
Manis Mata
Sei Air Pinis
110°55'0"E
110°57'30"E
111°0'0"E
111°2'30"E