REVIEW AND UPDATE

BIO-PHYSICAL AND SOCIO-ECONOMIC DATA

ON GIAM SIAK KECIL BUKIT BATU (GSK-BB) BIOSPHERE RESERVE IN RIAU PROVINCE, INDONESIA

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KERJASAMA KEGIATAN ITTO PD 712/13 REV.3 (F)

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ABSTRACT

The establishment of the Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR) in 2009 was the outcome of collaboration among various entities including the Riau Provincial Government, the Ministry of Environment and Forestry through BBKSDA Riau, the BRIN, the private sector, and NGOs. Recognized as a biosphere reserve under UNESCO's Man and Biosphere (MAB) Program on May 26, 2009, it encompasses a total area of 705,270 hectares, comprising a core area (conservation area) spanning 178,722 hectares, a buffer zone (plantation forest) of 222,426 hectares, and a transitional area (settlement and cultivation areas) of 304,123 hectares. However, information updates are still required to formulate an integrated biosphere reserve management plan for the next 5-10 years. The objective of this desk study is to update more comprehensive biophysical and socio-economic data and provide extensive input for the GSK-BB BR management plan, down to the site level. The desk study yielded additional information from the past 2-3 years concerning basic research findings related to socio-economic and biophysical aspects of peatland ecosystems, which possess a degree of complexity. Two key species in the GSK-BB BR, the Sumatran elephant and tiger, require serious efforts to ensure their survival and population sustainability. Continuous collaboration among all stakeholders is essential to improve the well-being of communities in the transition areas and to successfully establish wildlife corridors. Successfully protecting these two species signifies the successful and sustainable management of the biosphere reserve. Nevertheless, this data serves as crucial considerations for shaping the phases of the GSK-BB BR management plan. Research and innovation are pivotal logistical components to support the implementation of sustainable development in the GSK-BB BR in Riau province. However, management coordination encountered setbacks in reaffirming commitment after the GSK-BB BR was renewed for the next 5-10 years. Coordination of the GSK-BB BR management movement should be led by the provincial government, agreeing to collaborate in line with the integrated biosphere reserve management plan for GSK-BB BR (2022-2027).

Keywords: the MAB-UNESCO, Biosphere Reserve, Giam Siak Kecil Bukit Batu, Biophysics

FOREWORD

This book is the result of a desk study, providing a review and the latest updates on the biophysical and socio-economic aspects of the Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR) in Riau Province. The complexities faced by this UNESCO biosphere reserve, established in 2009, demand sustained attention and commitment from stakeholders at the provincial level in Riau. A comprehensive biophysical and socio-economic database is crucial for designing effective biosphere reserve management.

The data and information collected from research conducted by the University of Riau, the National Research and Innovation Agency (BRIN), international research collaborations, and site-level activities by NGOs funded by international sponsors reveal that existing knowledge is still fragmented with significant gaps. Bridging these gaps requires robust and long-term research logistics. The biosphere reserve, predominantly consisting of peatland ecosystems, necessitates a specialized management strategy to avoid mismanagement.

The role of industrial forest plantation companies within the biosphere reserve area is vital in drivig biosphere reserve management and research logistics, in collaboration with both national and international research institutions. The provincial government, responsible for the nomination process and post-designation management of the GSK-BB BR by UNESCO, must remain committed to ensuring its sustainability. The Regional Development Planning Agency (BAPPEDA) of Riau Province plays a crucial role in managing baseline data and information in collaboration with the Natural Resources Conservation Agency, under the Ministry of Environment and Forestry.

There are limited references available from the management activities of the biosphere reserve, but we aim to synthesize and recommend necessary steps for the sustainable management of the GSK-BB BR. Finally, this review and update book on the biophysical and socio-economic aspects of the GSK-BB BR acknowledges its current limitations, striving to create a complete and updatable database for the biosphere reserve. We hope this book provides valuable insights and knowledge for the effective management of the GSK-BB BR in Riau Province, Indonesia.

Bogor, 30 June 2024

Maman Turjaman

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I. INTRODUCTION

1.1. Background

The Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR) is among the 20 biosphere reserves in Indonesia. Its establishment in 2009 resulted from collaboration between the National Research and Innovation Agency (BRIN), the Ministry of Environment and Forestry through BBKSDA Riau, the Riau Provincial Government, and the private sector, notably PT. Sinar Mas Forestry under Asia Paper Plantation (APP) Group (Zulkarnaini *et al.* 2022). Designated as a biosphere reserve under the Man and Biosphere (MAB) Program of UNESCO on May 26, 2009, it was officially inaugurated by the Minister of Environment Forestry on July 1, 2009. Covering a total area of 705,270 hectares, it comprises a core areas (conservation area) spanning 178,722 hectares, a buffer zone (plantation forest) of 222,426 hectares, and transitional areas (cultivation area) of 304,123 hectares (Purwanto *et al.*, 2022). As a tropical peat swamp forest ecosystem, this reserve plays a vital role in regulating the ecological systems of peat swamps. Various elements within the ecosystem interact to form life cycle processes, including biogeochemical cycles, food chains, hydrological dynamics, water quality, and habitat areas for diverse flora and fauna species (Barchia, 2017). Consequently, the presence of peatlands and their ecosystems in the Biosphere Reserve positively impacts the socio-economic conditions of local communities. The GSK-BB BR in Riau Province, Indonesia, holds biosphere status due to its critical role in biodiversity conservation and ecosystem service provision, primarily owing to its extensive peat swamp forest areas. However, the GSK-BB BR landscape faces threats from various anthropogenic activities exploiting peatland resources, often conducted in exploitative and destructive manners (Mizuno *et al.*, 2022).

The Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR) presents complexities beyond its vulnerable peat swamp ecosystem. GSK-BB BR also hosts diverse flora, fauna, and potentially forest microbes with numerous key species requiring protection (Zulkarnaini *et al.*, 2022; Fujita *et al.*, 2022). The complexity and inefficiency in organizing the GSK-BB BR management organization in the past five years have hindered the execution of integrated management programs effectively. Situated within the administrative areas of two districts, Siak Raya and Bengkalis, GSK-BB BR's management coordination, led by the Riau governor, has faced significant daily coordination challenges. These responsibilities could ideally be delegated to village secretary officials or mandated to the Head of the Regional Development Planning Agency of Riau Province. Coordination bottlenecks have led to numerous issues at the field level, including illegal logging and forest encroachment in production forest areas. The proliferation of Non-Governmental Organizations (NGOs) empowering local communities with foreign funding should be coordinated and monitored by the Biosphere Reserve Management Agency in Riau Province. The frequent turnover of officials in Indonesian biosphere reserve areas often leads to program stagnation during transitions, posing a significant challenge to sustainability principles. Vacancies of 1-2 years disrupt biosphere reserve management activities, especially in Transition Areas. Conversely, the management of Core Areas and Buffer Zones, mostly comprising National Parks, Wildlife Reserves, Nature Reserves, and Conservation Forests, usually benefits from clear legal frameworks provided by Indonesian laws, establishing a robust governmental legacy for both zones (Dudley, 2008).Top of Form

This study is scoped within defined boundaries to obtain the latest biophysical data updates from documents resulting from periodic reviews and integrated biosphere reserve management established and accepted by the MAB-UNESCO Secretary in Paris last year, 2023. Additionally, it aims to update relevant additional reference sources for discussion in this review document and to outline the subsequent actions for GSK-BB BR managers to implement integrated programs as they enter the year 2024. This year also marks simultaneous local election events, suspected to disrupt the formation of a biosphere reserve coordination Board that could promptly collaborate with awaiting partners. Analysis and synthesis utilizing foundational biosphere reserve data from both international publications and available internal reports can provide recommendations on how this biosphere reserve can be effectively and efficiently managed.

1.2. Objectives

This desk study aimed to comprehensively review and update the bio-physical and socio-economic aspects of the biosphere reserve. In the context of bio-physical elements, the report will delve into the ecological and environmental components of the reserve. This includes an in-depth examination of the flora and fauna, biodiversity, ecosystems, and any changes or developments that may have occurred over time. The analysis will incorporate factors such as climate, topography, and land use patterns to provide a holistic understanding of the reserve's bio-physical dynamics. Simultaneously, the report addressed the socio-economic dimensions of the biosphere reserve. This involves assessing the human activities, communities, and societal interactions within and around the reserve. Factors such as population dynamics, livelihoods, cultural practices, and the impact of human activities on the environment will be scrutinized. Additionally, the report examined any socio-economic changes, challenges, or opportunities that have emerged since the last assessment.

The output of this activity is a comprehensive review and update of bio-physical and socio-economic aspects in the GSK-BB BR to support developing the Integrated Strategic Management Plan of the GSK-BB BR in the form of a technical report.

II. METHODOLOGY

2.1. Time and location

The review study was conducted in the Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR), located in Riau Province, Sumatra, from middle of March to middle of June 2024, spanning a duration of three months. The GSK-BB BR is located along the Strait of Malacca, covering an area of 7,053 km². Established by a private-sector initiative, it was registered by UNESCO's Man and Biosphere (MAB) program in 2009. GSK-BB consists of three zones: a core areas (1,787 km²), a buffer zone (2,224 km²), and a transition areas (3,041 km²). The core areas includes natural peat swamp forests, primarily located in the Giam Siak Kecil Wildlife Reserve and the Bukit Batu Wildlife Reserve. The buffer zone comprises planted forests of fast-growing tree species, such as *Acacia crassicarpa* and *A. mangium,* within four industrial tree plantations in Indonesia. These plantations also contain natural forests adjacent to the Wildlife Reserves, which are part of the core areas. The preservation of natural forests is in accordance with Ministry of Forestry Decrees No. 70/Kpts-II/1995 and No. 246/Kpts-II/1996, which mandate that 10% of a concession area be protected as "Kawasan Lindung." The outermost transition area of GSK-BB includes agricultural fields of smallholders and some oil palm plantations.

2.2. Collection data

The activity phases commence with formulating all necessary steps to ensure that the target plan can be executed within approximately 3 months (start in the middle of March until middle of June 2024). The research used both primary and secondary data. The collection of secondary data through literature sources, primarily through biosphere reserve-related materials on websites, were be carried out to the fullest extent possible. This compilation of references serves as the main foundation for the Desk Study phase. Additionally, the team plans to visit the management offices of the GSK-BB BR in Riau for validation, interview the local community, and in-depth discussions with stakeholders. The respondents for local community interview were be selected randomly from the nearest neighborhood with the biosphere reserve. The determination of respondent for in-depth discussion with stakeholders was determined purposively, namely the parties involved in managing the biosphere reserve. This step aimed to ensure the accuracy of data obtained from the involved parties.

Table 1. Timeline of Planed Activity

Activity	March				April				May				June			**Remarks**
Research Design and Preparation																Administration
Collecting data and information related to bio-physical and socio-economic aspects of GSK-BB BR																Desk study
Reviewing and analyzing the comprehensive data																Desk study
Analyzing and writing report																Desk study
Submit report																Technical report

2.3. Synthesis and Analysis

The synthesis of bio-physical and socio-economic assessments informed an in-depth analysis of the interplay between conservation and human activities. The report identifies synergies and potential conflicts, laying the foundation for an integrated approach to biosphere reserve management.

2.3.1. Approach: A Socio-Ecological System Framework

Biosphere reserves aimed to reconciliate social and economic development with biodiversity conservation through complex spatial and governance arrangements. To study how these aspects interaction we will use the Socio-Ecological System Approach (SES). 'Social-ecological systems' (SES) is an emerging concept for understanding the intertwined nature of human and natural systems in this new, interconnected and interdependent way. The SES concept developed in the early to mid-1990s through collaboration of scholars working in the interdisciplinary areas of ecological economics and common-pool resource systems (e.g. Berkes 1989; Ostrom 1990; Costanza 1991). Social-ecological systems research to address pressing sustainability issues facing society, and is framed by an approach grounded in an understanding of SES as complex adaptive systems, where people and nature are intertwined and coevolve.

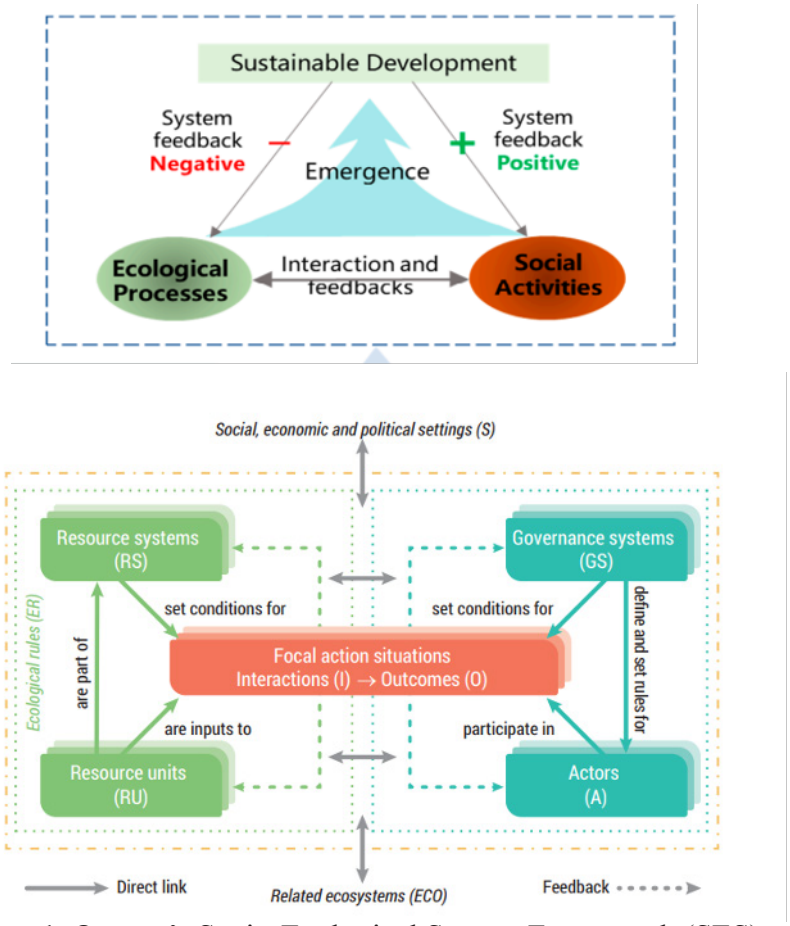

Figure 1. Ostrom's Socio-Ecological System Framework (SES).

2.3.2. Bio-Physical Assessment:

a. Ecological Dynamics:

The assessment of ecological dynamics reveals the robustness of the reserve's tropical rainforests, wetlands, and river systems. It consists of mapping the ecological structure and landscape patterns of the area, analyzing habitat fragmentation, identification of important ecological corridors, study of ecosystem dynamics and land use changes. Strategies will be developed to enhance habitat health and biodiversity conservation.

To effectively manage the GSK-BB BR, a landscape approach can be instrumental. This approach ensures that conservation efforts are comprehensive, addressing both ecological and social dimensions. By promoting best practices in production, planning, and local decision-making processes, it ensures the healthy provision of ecosystem services and the improvement of human well-being. The landscape approach facilitates land use planning and management for multiple stakeholders within a defined landscape. This method integrates the needs and interests of various groups, including local communities, government agencies, and private sectors, promoting collaboration and sustainable land management practices. By adopting a landscape approach, the biosphere reserve can better protect biodiversity, preserve essential ecosystem services, and promote sustainable development. This holistic strategy not only conserves the natural environment but also supports the livelihoods and well-being of the local communities, ensuring a balanced and sustainable future for the region

b. Biodiversity:

Building on the biodiversity assessment, the plan outlines measures to protect and restore the diverse flora and fauna, focusing identification of flora and fauna species that exist in the area particularly the endangered and endemic species, mapping the distribution of species and their populations, evaluation of the conservation status of these species, and analysis of genetic diversity in certain populations. Conservation initiatives will aim to maintain a balanced and resilient ecosystem.

c. Environmental Changes:

Strategies for mitigating environmental changes, such as deforestation and climate change impacts, will be implemented. This includes sustainable land-use planning and monitoring of water bodies.

2.3.3. Socio-Economic Assessment:

a. Population Dynamics:

Taking into account population dynamics, the plan addresses community engagement strategies that align with the biosphere reserve's conservation goals. Population growth and migration patterns will be considered for sustainable development.

b. Livelihoods and Economic Activities:

The plan supports local livelihoods by promoting sustainable economic activities, such as eco-friendly agriculture and responsible fishing practices. Economic development initiatives will be tailored to harmonize with conservation objectives.

c. Cultural Practices:

Cultural heritage preservation strategies will be integrated, recognizing the importance of traditional practices in fostering environmental stewardship. Community-based approaches will be encouraged to protect cultural values.

d. Human Impact on the Environment:

Mitigation measures will be implemented to address the impact of human activities on the environment, emphasizing conservation education and sustainable practices. Legal frameworks will be strengthened to deter illegal activities.

2.3.4. Integrated Strategic Management Plan:

The plan introduces a holistic approach that integrates conservation initiatives with community development. Key components include:

a. Zoning and Land Use:

Establishment of clear zones within the reserve, balancing conservation areas with sustainable land-use practices to accommodate human activities.

b. Community Engagement:

Implementation of community-based conservation programs, fostering partnerships that empower local communities to become active stewards of the biosphere reserve.

c. Sustainable Tourism:

Promotion of eco-friendly tourism initiatives that generate income for local communities while minimizing environmental impact.

d. Monitoring and Enforcement:

Development of a robust monitoring and enforcement system to ensure adherence to conservation guidelines and laws, deterring any activities that pose a threat to the reserve.

III. RESULTS AND DISCUSSION

3.1. Bio-physical Assessment

3.1.1. Ecological Dynamics

The ecological dynamics occur in tandem with the harmonization of human behavior interacting with the forest environment inhabiting the GSK-BB BR for their daily needs. Therefore, biosphere reserve managers must possess multidisciplinary knowledge for sustainable development in the GSK-BB BR. In conducting the assessment of the GSK-BB BR, it is crucial to understand the zoning system established by referring to the nomination documents of the biosphere reserve, as designated by UNESCO in 2009 (Purwanto *et al.*, 2022). The delineation of three zones with clear boundaries and extents includes the core area, buffer zone, and transition areas. Subsequently, the assessment involves examining the ecological dynamics based on the dominant ecosystem type within the GSK-BB BR, which is found to be peat swamp forests. The biophysical assessment delves deeper into the existence of flora such as native forest plant species, fauna, insects, and microbes, each playing a role in the ecological dynamics within the interacting ecosystems present in the GSK-BB biosphere reserve.

The Indo-Malayan region encompasses 62% of the world's tropical peatlands (Page *et al.*, 2006). These peatlands have long been recognized as biodiversity hotspots, hosting many endemic species of flora, fauna, and microbes (Yule, 2010). Additionally, peatland ecosystems have historically supported local community livelihoods through their coexistence with peatland forests. However, from an ecological dynamics perspective in the GSK-BB biosphere reserve, as well as in the context of political policies, urbanization, and intensified agriculture driven by global demands for food and fuel, approximately 80% of Southeast Asian peat swamp forests have been cleared to make way for agro-industrial plantations (Mishra *et al.*, 2021).

Based on the land cover map presented in the periodic document of the GSK-BB (Figure 2.) (Purwanto *et al.*, 2022), an analysis of the biophysical data of ecosystem types and landscapes presented in the Table was conducted. The GSK-BB biosphere reserve features terrestrial ecosystems predominantly characterized by "tropical peat swamp forest vegetation communities" within the Sumatra bioregion. These ecosystems consistently exhibit specific combinations of geology, landforms, and soil types. Moreover, the tropical peat swamp forest ecosystem is highly influenced by the area's ecological condition, particularly by human activities and climate change. Despite referencing the Millennium Ecosystem Assessment Framework and Ecosystem and Biodiversity Economics, there has been no comprehensive assessment to economically quantify the value of each ecosystem type in the GSK-BB Biosphere Reserve. The latest biodiversity assessment report, the Biodiversity Assessment Report of the GSK-BB biosphere reserve, prepared by LIPI (now BRIN) in collaboration with Riau BBKSDA and APP SMF in 2007, 2014, and 2017, underscores the ecological significance of the GSK-BB biosphere reserve area in balancing the peat swamp forest ecosystem, particularly concerning water management. Changes in this ecosystem will impact its value, notably during the dry season (water scarcity) and the rainy season (flooding). Therefore, effective management of this area is crucial for ecosystem services, especially regarding water management and conservation of peat swamp forest areas, constituting a vital consideration in assessing the overall biodiversity value of the region.

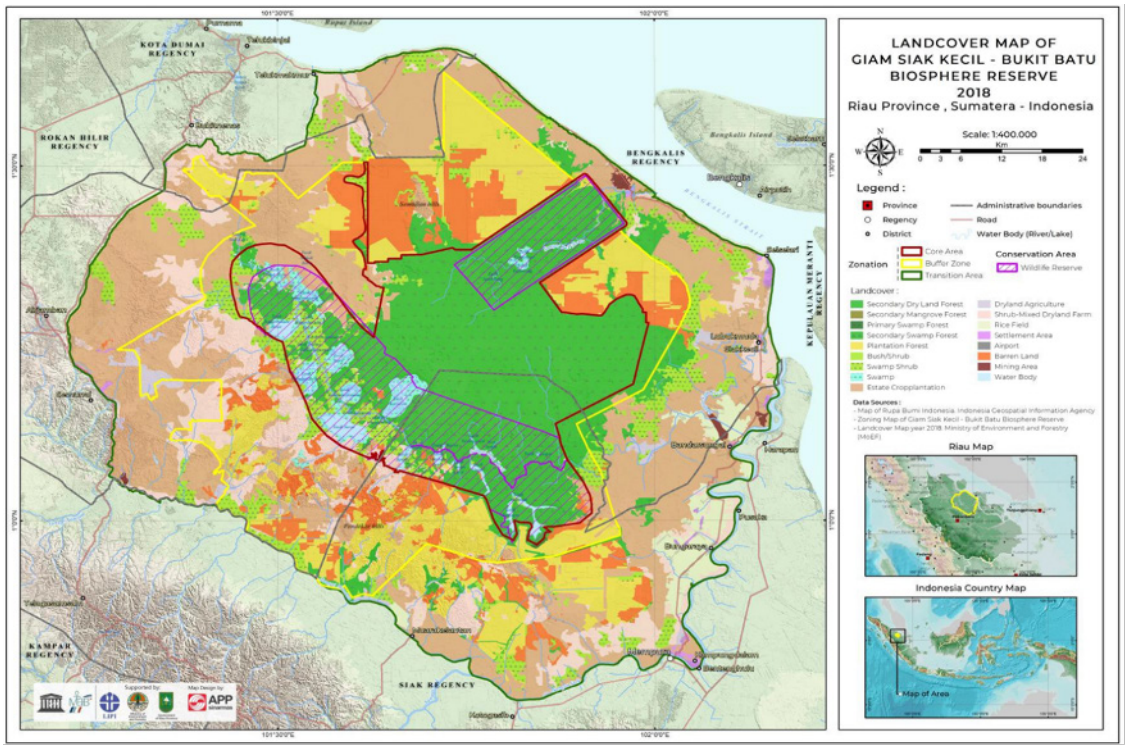

Figure 2. Map depicting the land cover of the Giam Siak Kecil-Bukit Batu Biosphere Reserve, Riau Province, Indonesia.

Table 2. Landscape and ecosystem services of GSK-BB BR as the basis for current conditions to implement management and monitoring activities in more detail

No	Ecosystem Services	Provisioning		Regulating			Supporting		Cultural			
		Food	Water	Flood	Drought	Land Degradation	Soil	Nutrient Cycling	Recreation	Spiritual	Religious	Non-Material e.g., Visual amenity
1	Tropical peat swamp forest	√	√	√	√	√	√	√	√			√
2	Tropical rain forest	√	√	√	√	√	√	v	v	v		v
3	Secondary Forest	√	√	√	√	√	√	√				√
4	Small Lake (*Tasik*)	√	√	√	√	√	√	√	√	√	√	√
5	Sacred site	√	√	√	√	√	√	√	√			√
6	*Acacia* spp.	√	√	√	√	√	√	√	√			√
7	*Eucalyptus* spp.	√	√	√	√	√	√	√	√	√		√
8	Palm oil plantation	√	√	√	√	√	√	√	√	√		√
9	Rubber plantation	√	√	√	√	√	√	√	√	√		√
10	Coffee plantation	√	√	√	√	√	√	√	√	√		√
11	Caco plantation	√	√	√	√	√	√	√	√	√		√
12	Traditional agroforestry	√	√	√	√	√	√	√	√	√		√
13	Dry field	√	√	√	√	√	√	√	√	√		√
14	Rice field	√	√	√	√	√	√	√	√	√	√	√

Based on Table 2, which details the biosphere reserve landscape with information on forest and plantation commodities crucial to the economy of stakeholders in the Core Area, Buffer Zone, and Transition Area, it is clear that all these commodities are present within the GSK-BB BR. This biosphere reserve is unique, with production activities involving workers that contribute to a sustainable economy within the core area, a condition that has persisted for almost 15 years since its designation as a biosphere reserve by UNESCO. Naturally, the Core Areas and Buffer Zone contain protected flora and fauna, including endemic fauna with specific home ranges. However, there are crucial points requiring in-depth research: has the shift to monoculture vegetation in forest and plantation areas altered the original habitat, leading to a drastic decline in key species populations? Additionally, conflicts between fauna and humans working in these areas exacerbate this issue. These critical points necessitate specific research and problem-solving, such as reconfiguring the biosphere reserve's zoning or creating wildlife corridors to facilitate the movement of animals within designated pathways managed by the biosphere reserve authorities.

Current biophysical data is essential for designing the implementation of activities and sharing responsibilities led by the Riau Provincial Government and BBKSDA-KLHK, which legally hold the mandate to manage the three designated zones set by MAB-UNESCO. There have been no territorial legal changes established by the Republic of Indonesia, so this should not be a matter of contention in carrying out tasks at the site level. Private sector partners, NGOs, indigenous community groups, and farming associations play a crucial role in supporting and participating in activities, particularly in the transitional areas. Local and central government authorities lead and manage daily biosphere reserve activities based on the agreed integrated management plan document. All activities conducted by partners must be coordinated by the GSK-BB BR Coordination Board, and their activities, including the source of funding, must be monitored for accountability by all parties involved.

Ideally, the three zoning areas of the GSK-BB Biosphere Reserve should be sterile and free from activities that jeopardize the existence of its ecosystem, such as changes in forest area, unknown or unauthorized illegal activities sanctioned by central or local governments. Not only from a landscape perspective, but the biodiversity of flora, fauna, and forest microbes within it are integral parts inseparable from the management of the GSK-BB Biosphere Reserve. Research logistics are crucial for establishing a sustainable biosphere. How we monitor the populations of key species in the GSK-BB Biosphere Reserve, such as the tiger, elephant, tapir, and endemic species whose existence must be preserved, is essential. The reduction of their home range due to illegal land conversion will inevitably lead to a decrease in the populations of wildlife and native trees in the peatland ecosystem. It is the shared responsibility of biosphere reserve managers to take decisive action and address these issues (Figure 3.)

The basic research program to save key species of flora, fauna, and forest microbes must be discussed with stakeholders. Priority research programs involve inviting and discussing with experts in the breeding of forest plants and endemic wildlife, research strategies, and their roadmap, including the necessary long-term infrastructure and financial support. Efforts to restore forests by increasing forest cover in the three zones of the GSK-BB biosphere reserve are a serious and prioritized endeavor to mitigate climate change, considering that peatland ecosystems have very high carbon reserves compared to tropical mineral soil ecosystems.

The assessment of ecological sustainability in peatland management policies within the GSK-BB Biosphere Reserve encompasses five attributes: land conversion, land conservation, soil fertility level, land use, and utilization of the area for tourism. The ecological sustainability analysis (RAPPEAT) yielded a sustainability index of 46.5%, classifying it as less sustainable (<50) (Figure 4). This indicates significant pressure on the peatland ecosystem from an ecological perspective, corroborated by field observations revealing disturbances such as land degradation, illegal logging, and land conversion.

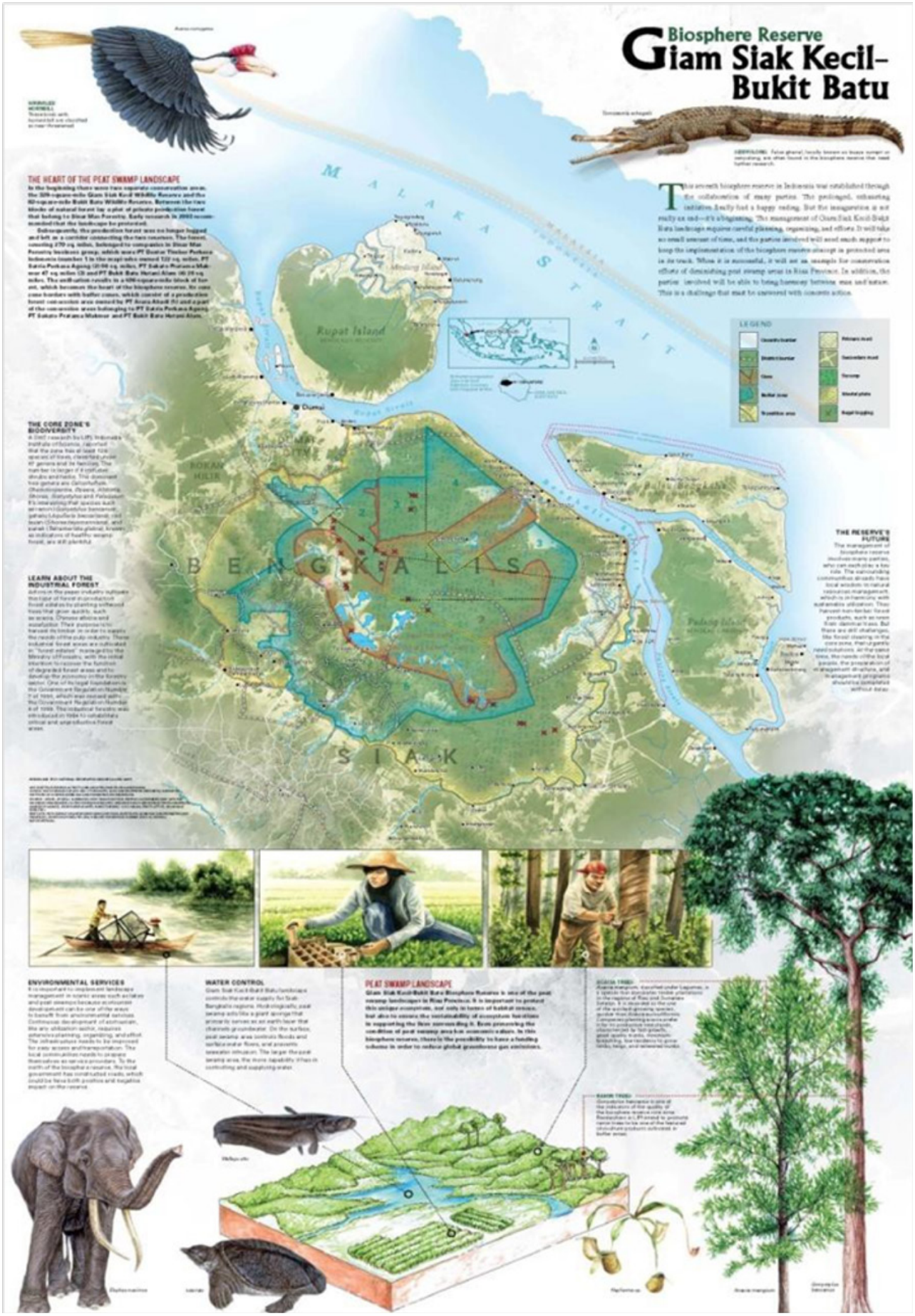

Figure 3. Achieving sustainability in the development of the GSK-BB Biosphere Reserve through its zonation system and production activities, as highlighted by @nationalgeographic.

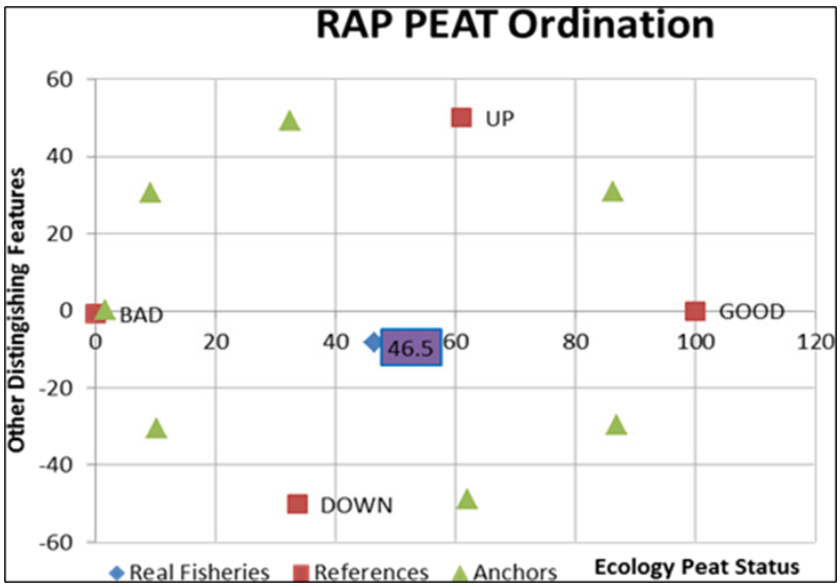

Figure 4. Ecological Sustainability Index of the Giam Siak Kecil Bukit Batu (GSK-BB) BR, Riau, Indonesia (Zulkarnaini *et al.*, 2022).

In addition to the sustainability index, RAPPEAT analysis highlights attribute leverage, aiming to identify attributes significantly influencing the ecological dimension's sustainability index. The analysis identified two sensitive attributes: land use (RMS = 3.84) and land conversion (RMS = 3.11). These findings suggest that plantation activities strongly impact the peat swamp ecosystem's condition. Kavanagh and Pitcher (2004) explain that the RMS value signifies each attribute's role in sustainability sensitivity, with higher values indicating greater influence.

Figure 5 illustrates that land use and land conversion attributes exhibit high sensitivity to the ecological dimension's sustainability in the GSK-BB Biosphere Reserve. The destruction of peatlands due to land use and conversion for plantation activities drives this sensitivity. Peatlands in Riau Province, particularly in the GSK-BB Landscape, have emerged as a global environmental concern due to various forms of degradation or destruction, impacting locally and globally over the short and long term. Peatland degradation diminishes the land's ability to regulate water and store carbon, altering its ecological functions (Bassi *et al.* 2020).

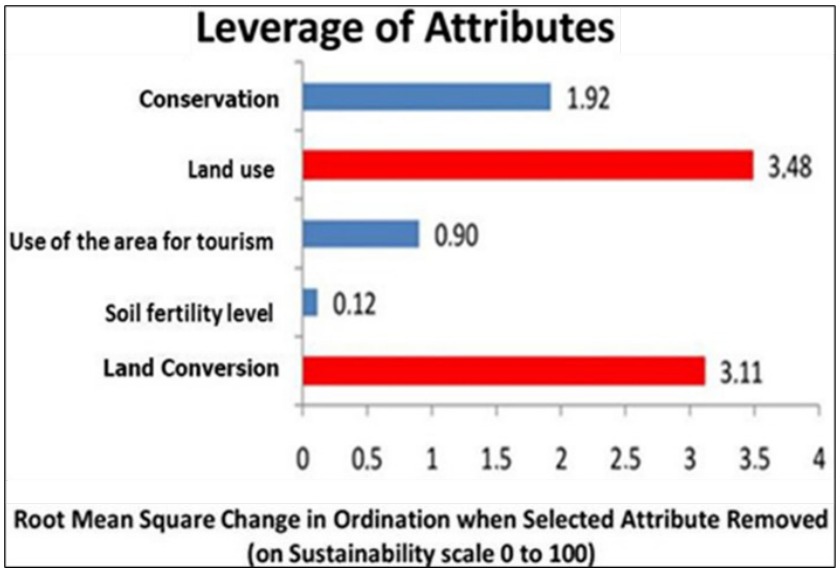

Figure 5. The impact of each attribute within the ecological dimension of the Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR) represented by RMS Value (Zulkarnaini *et al.*, 2022).

Current peat fires stem from abundant fuels and fire sources. Landscape-scale forest clearing, combined with widespread fire usage and peat drainage, escalates the risk of uncontrolled fires (Wildayana 2017). Deforested and drained peatlands are highly susceptible to fire due to their dry, flammable surfaces, posing significant risks from both intentional and unintentional burning.

While fire can rapidly clear large forest areas, it can also perpetuate in peat swamp forests. Subsequent fires hinder forest recovery, as deadwood from the initial fire increases the likelihood of subsequent blazes. These dynamics underscore that peat fires are no longer occasional events but regular occurrences exacerbated by rapid land-use changes rather than climate variability.

Despite severe fires often attributed to climate anomalies, such as El Niño (Page 2016), abnormal weather conditions are not necessary for peat fires. Instead, they are routine during dry seasons, driven by land-use changes (Guha and Chakrabarti 2019). These fires pose significant environmental concerns, impacting greenhouse gas emissions, air quality, human health, livelihoods, and regional economies each fire season (Tanneberger *et al.* 2020).

3.1.2. Biodiversity

a. Biodiversity of flora (forest tree species)

From the periodic review of the GSK-BB BR, a list of forest vegetation has been identified. It is well known that forest vegetation is the lifeblood that generates life energy for forest communities. Forest vegetation can photosynthesize, influencing the food chain for biomass in the forest, as well as forest microbial groups capable of decomposing nutrients not obtained by vegetation, leading to an exchange of energy. Without forest vegetation, human life would undoubtedly be disrupted by the rapid climate change, as many people are unable to adapt to such extreme environments. Endemic forest plants, which are categorized as highly rare, prompt biosphere reserve managers to take strategic steps to preserve them and cultivate them on a mass scale with the mastery of advanced forestry cultivation technology. The dwindling source trees of the forest need to be protected and monitored with a geotagging system. Issues such as pollination, fertilization, and the vitality of young plants that will regenerate must be studied with sufficient mastery. Biosphere reserve managers are not only responsible for maintaining zoning based on landscapes but also need to assess the composition of forest plant communities and evaluate the potential of individual forest trees. This activity is indeed part of biosphere reserve logistics; the value of preserving rare forest plants is immeasurable, as each forest plant holds promise as a bio-prospect that generates high-value benefits not only for the environment but also for essential aspects of human life such as health, food, and environmental restoration.

The forest vegetation community is a cohesive unit with below-ground interactions, where they communicate by exchanging nutrients to sustain the life and growth of individual trees, resulting in harmony and what seems like immunity within the forest ecosystem, with no pest attacks or diseases in natural forests.

Based on Table 3, which presents approximately 200 identified forest species in the GSK-BB BR area, there is a remarkable diversity of tree species associated with the peatland ecosystem. However, this ecosystem is highly sensitive and vulnerable to damage from peatland fires, illegal logging, and forest encroachment, which have been difficult to control over the years. Strict law enforcement against environmental criminals, including any involved state officials, must be uncompromising. Effective law enforcement is essential for restoring the area's function as part of the GSK-BB BR, managed collaboratively by the provincial government, the Ministry of Environment and Forestry's conservation office, private concession holders, national NGOs, local communities within the GSK-BB, and indigenous populations. Achieving coordinated efforts for sustainable development in this biosphere reserve is challenging.

Furthermore, research logistics in the GSK-BB BR are crucial for the urgent conservation of native

forest vegetation. This can be achieved by deploying advanced silvicultural and forest propagation technologies to preserve rare forest species. National private companies, which have R&D focused on tree species for pulp and paper production, are also conducting specialized research on native tree species from the peatland ecosystem. Their capacity should be expanded with additional laboratory infrastructure and skilled human resources, involving cross-academic collaboration at the provincial and national levels. This endeavor requires significant effort and high investment to safeguard the high economic and conservation value of forest biodiversity in the GSK-BB BR's peatland ecosystem.

Table 3. Inventory Results of native forest vegetations Existing in the GSK-BB Biosphere Reserve (Puwanto *et al.*, 2022)

1	*Acronychia porteri* Hook. f.	Rutaceae	Pauh	Pk.	
2	*Acryopsis javanica*	Orchidaceae		Ae.	App. I CITES
3	*Actinodaphne glomerata* Ness.	Lauraceae		Pk.	
4	*Adina minutiflora* Valeton	Rubiaceae	Brumbung	Pk.	
5	*Aeschynanthus radicans* Jack.	Gesneriaceae		Ep.	
6	*Aglaia ignea* Valeton ex K. Heyne	Meliaceae	Pasak linggau	Pb.	EN
7	*Aglaia sp*	Meliaceae		Ps.	
8	*Aglaonema nitidum* Korth	Araceae	Aglaonema	Tr.	
9	*Alocasio longiloba* Miq.	Araceae		Tr.	
10	*Alseodaphne spp.*	Lauraceae	Medang	Ps.	
11	*Alseodaphne umbelliflora* (Blume) Hook. F.	Lauraceae	Medang lender	Ps.	EN
12	*Alstonia pneumatiphora* Back. Ex don Berger	Apocynaceae	Pule rawa	Pb.	EN
13	*Alstonia spathulate* Blume	Apocynaceae	Pule rawa	Ps	
14	*Anisoptera costata* Korth.	Dipterocarpaceae	Mersawa	Pb.	EN
15	*Antidesma coriceae* Blume	Euphorbiaceae	Buni hutan	Pr.	
16	*Antidesma montanum* Blume	Euphorbiaceae	Buni hutan	Pr.	
17	*Antidesma puncticulatum* Miq.	Euphorbiaceae	Buni rawa	Pk.	
18	*Antidesma tetrandrum*	Euphorbiaceae	Buni rawa	Pr.	
19	*Archidendron borneense* (Bth.) Nielsen	Mimosaceae		Pk.	
20	*Ardisia sp.*	Myrsinaceae		Tr.	
21	*Aromadendron nutans* Dandy	Magnoliaceae		Pk.	
22	*Artabotrys sp.*	Annonaceae		Ln.	
23	*Artocarpus sp.*	Moraeae		Ps.	
24	*Asplenium nidus* L.	Aspleniaceae	Kadaka	PE.	
25	*Austrobuxus nitidus* Miq.	Euphorbiaceae		Pk.	
26	*Baccaurea bracteate*	Euphorbiaceae	Rambe paya	Pk.	
27	*Baccaurea sumatrana*	Euphorbiaceae		Pk.	
28	*Barringtonia reticulata*	Lecythidaceae		Ps.	
29	*Blumeodendron elateriospermum* J. J. Smith	Euphorbiaceae			
30	*Blumeodendron tokbrai* (Blume) J. J. Smith	Euphorbiaceae		Ps.	
31	*Brackenridgea hookeri* (Planch.) A. Gray	Orchnaceae	Kelat merah	Pk.	
32	*Calophyllum pulcherrimum* Wallich ex Choisy	Clusiaceae	Bintangur	Pb.	
33	*Calophyllum sclerophyllum Besque*	Clusiaceae	Bintangur	Ps.	
34	*Calophyllum soulatri*	Clusiaceae	Bintangur	Pb.	
35	*Camnosperma coriaceum* Hallier f. ex v. Steenis	Anacardiaceae	Terentang	Pb.	

36	*Camnosperma squamatum* Ridl.	Anacardiaceae	Terentan man	Ps.	
37	*Canarium sumatranum* Boerl.	Burseraceae	Klako	Ps.	
38	*Cantleya corniculate* (Becc.) Howard	Icacinaceae	Daru-daru	Ps.	
39	*Capparis sp.*	Capparidaceae		Pk.	
40	*Carallia brachiate* (Lour.) Merr.	Rhizophoraceae	Ringgit dareh	Pk.	
41	*Cattleya comiculata*	Icacinaceae	Bedaru/daru-daru	Ps.	
42	*Combretocarpus rotundatus* (Miq.) Danser	Anisophylleaceae	Perepat darat	Pk.	
43	*Cratoxylum arborescent* (Vahl) Blume	Hypericaceae	Grunggang	Pb.	
44	*Crudia habilandii* Prain	Fabaceae		Pk.	
45	*Cryptocarya crassinervia* Miq.	Lauraceae	Medang	Ps.	
46	*Cryptocarya griffithiana* Wight.	Lauraceae	Medang	Ps.	
47	*Ctenolophon parvifolius* Oliv.	Linaceae		Pk.	
48	*Cyathocalyx biovulatus* Boerl.	Annonaceae		Ps.	
49	*Cymbidium sp.*	Orchidaceae		Ae.	
50	*Cyperus sp.*	Cyperaceae		Tr.	App. I CITES
51	*Cyrtostachys lakka Becc.*	Arecaceae	Pinang merah	Pk.	
52	*Dacryodes macrocarpa* (King) H. J. Lam	Burseraceae		Ps.	
53	*Dacryodes rugosa* (King) H. J. Lam	Burseraceae	Kenari rawa		
54	*Dialium indum* L.	Fabaceae		Ps.	
55	*Dillenia excelsa* (Jack) Gilg	Dilleniaceae	Simpur	Ps.	EN
56	*Diospyros bantamensis* Kds. Et Val. ex Bakh.	Ebenaceae		Pk.	
57	*Diospyros coriaceae*	Ebenaceae	Kayu arang	Ps.	
58	*Diospyros ebenum*	Ebenaceae	Kayu arang	Ps.	
59	*Diospyros hermaphroditica* (Zoll.) Back.	Ebenaceae	Kayu arang	Ps.	
60	*Diospyros lanceifolia*	Ebenaceae	Kayu arang	Ps.	
61	*Diospyros maingayi* (Hiem) Bakh.	Ebenaceae	Kayu arang	Ps.	
62	*Diospyros maritima* Blume	Ebenaceae		Pk.	
63	*Diospyros pendula* Hasselt ex Hassk.	Ebenaceae	Kayu arang	Ps.	
64	*Diospyros toposia* Buch-Ham	Ebenaceae	Kayu arang	Ps.	
65	*Durio carinatus* Masters	Bombacaeae	Durian burung	Pb.	
66	*Dyre lowii* Hook F.	Apocynaceae	Jelutong paya	Pb.	EN
67	*Elaeocarpus stipularis* Blume	Elaeocarpaceae	Ganitri	Pk	EN
68	*Elaeocarpus floribundus* Blume	Elaeocarpaceae		Ps.	
69	*Elaeocarpus mastersii* King	Elaeocarpaceae		Ps.	
70	*Elaeocarpus polystahis* Blume	Elaeocarpaceae		Pk.	
71	*Elaodoxa griffiti*	Arecaceae	Salah hutan	Sm.	
72	*Endiandra rubescens* Miq.	Lauraceae		Pk.	
73	*Fagrarea spicata*	Loganiaceae		Sm.	
74	*Ficus globosa* Blume	Moraceae		Pj.	
75	*Ficus microcarpa* L. F.	Moraceae	Beringin paya	Pc.	
76	*Ficus sundaica*	Moraceae		Pb.	
77	*Ficus sp.*	Moraceae		Pk.	
78	*Gaertnera vaginans* Merr.	Rubiaceae		Pk.	
79	*Ganua motleyana* (de Vriese) Pierre ex. Dubard	Sapotaceae	Bengku/Punak	Ps.	

80	*Garcinia bancana* L.	Clusiaceae	Manggis hutan	Pk.	EN
81	*Garcinia dasyphodum* (Miq.) Miq.	Clusiaceae	Kelat	Pk.	
82	*Garcinia celebica* L.	Clusiaceae	Manggis hutan	Pk.	
83	*Garcinia eugenifolia* (Hassk) Miq.	Clusiaceae	Gelugur	Ps.	
84	*Garcinia parvifolia* (Miq) Miq)	Clusiaceae	Manggis hutan	Pk.	
85	*Garcinia rostrata* (Hassk.) Miq.	Clusiaceae	Kandis	Ps.	
86	*Garcinia sszygiifolia* (Hassk.) Miq.	Clusiaceae	Gelugur	Pk.	
87	*Garcinia vidua* L.	Clusiaceae		Pk.	
88	*Gardenia elata* Ridley	Rubiaceae		Pk.	
89	*Gardenia forsteniana* Miq.	Rubiaceae		Pk.	
90	*Gardenia pterocalyx* Miq.	Rubiaceae		Pk.	
91	*Goniothalamus giganteus* Hook. F. & Thoms.	Annonaceae		Pk.	
92	*Gonystylus bancanus* (Miq.) Kurtz.	Thymelaeaceae	Ramin	Pb.	
93	*Gramatophyllum speciosum* Blume	Orchidaceae	Anggrek macan	Ep.	App. II CITES
94	*Gymnacranthera concreta* (A. DC.) Sincl.	Myristicaceae		Pk.	App. I CITES
95	*Gymnacranthera eugeniifolia* (A. DC.) Sincl.	Myristicaceae		Pk.	
96	*Gymnacranthera forbesii* (King) Warb.	Myristicaceae		Pk.	
97	*Hanguana malayana* (Jack) Merr.	Liliaceae		Tr.	
98	*Horsfieldia glabra* (Blume) Warb.	Myristicaceae	Dara-dara	Ps.	
99	*Horsfieldia subglobosa* (Miq.) Warb.	Myristicaceae	Dara-dara	Ps.	
100	*Hydnocarpus mrillianus* Sleum.	Flacourtiaceae		Pk.	
101	*Hydnocarpus woodii*	Flacourtiaceae		Ps.	
102	*Hyptage benghalensis* Kurtz.	Malphigiaceae		Ln.	
103	*Ilex bogoriensis* Loes.	Aquifoliaceae	Mesira	Pk.	
104	*Ilex cymose* Blume	Aquifoliaceae		Ps.	
105	*Ilex hypoglauca* (Miq.) Loes.	Aquifoliaceae		Ps.	
106	*Jackia omata* Wallich	Rubiaceae	Medang gambut	Pk.	
107	*Knema cinerea* (Poir.) Warb.	Myristicaceae	Dara-dara	Pk.	
108	*Knema converta* (Poir.) Warb.	Myristicaceae	Dara-dara	Pk.	
109	*Knema intermedia* (Blume) Warb.	Myristicaceae		Ps.	
110	*Knema sp.* (Blume) Warb.	Myristicaceae		Pk.	
111	*Kompassia malaccensis* Maingay ex. Benth	Mimosaceae	Mengris	Pb.	
112	*Licaniea splendens* (Korth.) Prance	Chrysobalanaceae	Malas	Ps.	
113	*Licuala spinosa* Thunb.	Arecaceae	Palas	Sm.	
114	*Litsea angulata* Blume	Lauraceae	Medang huru	Ps.	
115	*Litsea calophyllantha* K. Schumann	Lauraceae	Medang huru	Ps.	
116	*Litsea firma* (Blume) Hook. F.	Lauraceae	Medang kuning	Ps.	
117	*Litsea gracilipes* Hook. F.	Lauraceae		Pk.	
118	*Litsea nidularis*	Lauraceae		Pk.	
119	*Lophopetakum pachypyllum* King	Celastraceae	Prupuk	Ps.	
120	*Lophopetakum pachypyllum*	Celastraceae	Prupuk	Ps.	
121	*Macaranga caladiifolia* Becc.	Euphorbiaceae	Mahang putih	Pk.	
122	*Macaranga pruinose* (Miq.) Mull. Arg.	Euphorbiaceae	Mahang putih	Pk.	
123	*Macaranga semiglobosa* J. J. Smith.	Euphorbiaceae	Mahang putih	Pk.	

124	*Madhuca crassipes* (Piere ex Becc.) H. J. Lam	Sapotaceae	Nyatoh	Ps.	
125	*Madhuca motleyana* (de Vr.) F. Macbr.	Sapotaceae		Ps.	
126	*Mallotus paniculatus* (Lmk.) M. A.	Euphorbiaceae	Balik angin	Pk.	
127	*Mangifera parvifolia* Boerl. & Koord.	Anacardiaceae			
128	*Mezzetia parviflora* Becc.	Annonaceae	Pisang-pisang	Pk	
129	*Mezzettia havilandii* Ridl.	Annonaceae			
130	*Myristica lowiana* King	Myristicaceae	Mendarahan	Ps.	
131	*Myristica lowiana* King	Myristicaceae			
132	*Myrisica sp.*	Myristicaceae	Mendarahan	Ps.	
133	*Neonauclea sp.*	Rubiaceae		Pk.	
134	*Neoscortechinia kingii* (Hok. F.) Pax & K. Hoffm	Euphorbiaceae	Mersikulit	Pk.	
135	*Nephelium lappaceum* L.	Sapindaceae		Ps.	
136	*Nephentes melanophore* Blume	Nephentaceae	Kantong semar	Pj.	
137	*Nephrolepis radicans* (Burm. F.) Kuhn.	Polypodiaceae	Paku rawa	Tr.	
138	*Ormosia calavensis* Azaola	Fabaceae	Tenggayun	Pb.	
139	*Ostodes pendula* A. Maewose	Euphorbiaceae		Pk.	
140	*Palaquium burckii* H. J. Lam	Sapotaceae	Balam	Ps.	
141	*Palaquium dasyphyllum* (de Vriese) Piere ex Dubard	Sapotaceae	Balam	Pb.	
142	*Palaquium hexandrum* Engl.	Sapotaceae	Nyatoh	Ps.	
143	*Palaquium leiocarpum* Boerl.	Sapotaceae	Suntai	Ps.	
144	*Palaquium leiocarpum* Boerl.	Sapotaceae	Nyatoh	Pb.	
145	*Palaquium obovatum* (Griffith) Engl.	Sapotaceae	Nyatoh	Pb.	
146	*Palaquium obovatum* Engl.	Sapotaceae	Balam	Ps.	
147	*Palaquium ridley* King & Gamble	Sapotaceae	Balam	Pb.	
148	*Pandanus atrocarpus* Griff.	Pandanaceae	Pandan rawa	Pk.	
149	*Pandanus helicopus* S. Kurtz.	Pandanaceae	Bengkuang	Pk.	
150	*Pandanus immersus* Ridl.	Pandanaceae	Pandan rawa	Pk.	
151	*Pandanus sp.*	Pandanaceae	Pandan rawa	Pk.	
152	*Parastemon urophyllus* (Wallich ex A. DC.) A. DC.	Chrysobalanaceae	Milas	Ps.	
153	*Phaentus sp.*	Annonaceae		Pk.	
154	*Piper miniatum* Blume	Piperaceae	Sesuruhan	Pj.	
155	*Plachonella obovata* H. J. Lam	Sapotaceae		Ps.	
156	*Plectronia didyma* (Roxb.) Kurtz.	Rubiaceae		Pk.	
157	*Prunus arborea*	Rosaceae		Ps.	
158	*Pternandra carulescens*	Melastomataceae		Pk.	
159	*Pternandra tuberculata*	Melastomataceae		Pk.	
160	*Quassia borneensis* Nooteb.	Simarubaceae	Spais	Ps.	
161	*Salacca converta* Griffith	Arecaceae	Salak paya	Pr.	
162	*Santiria apiculata* A. W. Benn.	Burseraceae			
163	*Santiria laevigata* Blume	Berseraceae	Kenari rawa	Ps.	
164	*Santiria longifolia*	Burseraceae		Ps.	
165	*Santiria oblongifolia* Blume.	Burseraceae			
166	*Sarcotheca diversifolia* (Miq.) Hellier. F.	Oxalidaceae	Blimbing hutan	Pk.	
167	*Scaphium macropodum* Beumee ex Heyne	Sterculiaceae			

168	*Semecarpus heterophylla* Blume.	Anacardiaceae	Rengas	Pb.	
169	*Shorea parvifolia* Dyer	Dipterocarpaceae	Meranti	Pb.	EN
170	*Shorea teysmanniana* Dyer	Dipterocarpaceae			EN
171	*Shorea teysmanniana* Dyer ex Brandis	Dipterocarpaceae	Meranti bunga	Pb.	EN
172	*Shorea uliginosa* Foxw.	Dipterocarpaceae	Meranti batu	Pb.	EN
173	*Shorea uliginosa* Foxw.	Dipterocarpaceae			EN
174	*Sloanea sp.*	Bombacaceae			EN
175	*Stemonurus secundiflorus* Blume	Icacinaceae	Pasir-pasir	Ps.	
176	*Stemonurus scorpinoides* Blume	Icacinaceae	Pasri-pasir	Ps.	
177	*Stenochlaena polustris* (Burm. F.) Bedd.	Pteridaceae	Paku rawa	Pj.	
178	*Sterculia gylva* Miq.	Sterculiaceae	Selemah	Ps.	
179	*Symplocos cochinchinensis* (Lour.) Moore	Symplocaceae	Sisarah		
180	*Syzygum decipens*	Myrcaceae	Jambu-jambu	Ps.	
181	*Syzygum fastigiatum*	Myrtaceae	Jambu-jambu	Ps.	
182	*Syzygum racemosum*	Myrtaceae	Jambu-jambu	Ps.	
183	*Syzygum setosum*	Myrtaceae	Jambu-jambu	Ps.	
184	*Syzygum spicatum*	Myrtaceae	Jambu-jambu	Ps.	
185	*Syzygum varifolium*	Myrtaceae	Jambu-jambu	Ps.	
186	*Tetractomia tetandra*	Rutaceae		Pk.	
187	*Tetramerista glabra* Miq.	Theaceae	Punak	Pb.	
188	*Timonius flavescens*	Rubiaceae		Pk.	

b. Biodiversity of fauna

Monitoring of wildlife in the GSK-BB BR has been conducted using camera traps. The observed groups of fauna include mammals, reptiles, and birds, with cameras placed in conservation areas, protected forests, and acacia plantation forests. The results of this wildlife monitoring with camera traps are presented in Table 4.

The impact of vegetation variation on trapping rates was assessed through model selection. Species classifications such as EN (endangered) and VU (vulnerable) are based on the IUCN Red List (IUCN 2012). Primary food habitat categories were determined according to Matsubayashi et al. (2007), Smythies (1999), and Myers (2009), with classifications including ca (carnivore), hf (herbivore and frugivore), in (insectivore), and om (omnivore). Models with $\Delta AIC > 2$ were considered for evaluation.

The total number of camera-working days amounted to 3978 days across 20 camera setting points in the four plots situated within the natural forest inside the Wildlife Reserves. In addition, there were 3336 days recorded across 15 points in the three plots within the natural forest located within the protected areas of the HTIs. Similarly, 3675 days were logged across 15 points in the three plots situated within the planted acacia forest inside the this (Samejima *et al.*, 2022).

Over the course of 10,989 camera-working days across a total of 50 points, we documented 1856 sightings of 19 mammal species, 3 terrestrial bird species, and 1 monitor lizard (refer to Table 4.2). Among these were 11 species categorized as vulnerable or endangered according to the IUCN Red List (IUCN 2012), including the sun bear, Sunda clouded leopard (*Neofelis diardi*), marbled cat (*Paradofelis marmorata*), and Sunda pangolin (*Manis javanica*). Images of all recorded species were included in Fujita *et al.* (2012).

Table 4. Average trapping rates of mammal, bird, and reptile species in the GSK-BB Biosphere Reserve in Riau Province (Samejima *et al.* 2023)

			Natural forest										
			Wildlife Reserve			Protected area			Planted acacia forest				
No of plots			4			3			3			Difference of	
Total camera working days			3978			3336			3675				
Species name	Threatened status	Main food habit	No of records	Mean trapping rate		No of records	Mean trapping rate		No of records	Mean trapping rate		WR-PA	WR-AF
				Mean	Range		Mean	Range		Mean	Range		
Echinosorex gymnura		in	9	0.18	(0.00–0.32)	10	0.28	(0.00–0.54)					[a]
Manis javanica	EN	in	3	0.08	(0.00–0.18)	3	0.13	(0.00–0.39)					[a]
Nycticebus coucang	VU	he				1	0.03	(0.00–0.09)					
Presbytis femoralis percura		he & fr				3	0.11	(0.00–0.34)					
Macaca nemestrina	VU	om	196	4.81	(1.65–6.83)	109	3.22	(2.99–3.60)	36	0.96	(0.00–2.17)		[a]
Helarctos malayanus	VU	om	10	0.29	(0.00–0.50)	8	0.26	(0.20–0.34)	3	0.08	(0.00–0.23)		
Mustela flavigula		ca	1	0.02	(0.00–0.10)	1	0.02	(0.00–0.07)					
Viverra tangalunga		om	2	0.05	(0.00–0.13)	5	0.16	(0.13–0.20)	15	0.42	(0.09–0.89)		[a]
Arctictis binturong	VU	om				1	0.04	(0.00–0.11)					
Arctogalidia trivirgata		om	2	0.03	(0.00–0.12)								
Paradoxurus hermaphroditus		om							3	0.09	(0.00–0.28)		
Hemigalus derbyanus	VU	om	14	0.31	(0.00–0.82)	10	0.29	(0.16–0.36)					[a]
Prionodon linsang		ca	2	0.04	(0.00–0.10)	2	0.07	(0.00–0.20)					
Herpestes brachyurus		ca				7	0.24	(0.00–0.49)				[a]	
Neofelis diardi	VU	ca	1	0.03	(0.00–0.13)								
Pardofelis marmorata	VU	ca	2	0.06	(0.00–0.13)	1	0.04	(0.00–0.13)					
Prionailurus bengalensis		ca	1	0.02	(0.00–0.06)	1	0.02	(0.00–0.07)	7	0.20	(0.06–0.32)		[a]
Sus barbatus & *S. scrofa*		om	501	10.65	(3.73–20.37)	378	12.72	(4.05–26.15)	75	1.97	(0.66–3.33)		[a]
Tragulus kanchil		he & fr	391	8.29	(0.89–20.64)	3	0.09	(0.00–0.20)				[a]	[a]
Birds													
Lophura erythrophthalma	VU	om	23	0.46	(0.09–0.72)	3	0.09	(0.00–0.19)				[a]	[a]
Melanoperdix niger	VU	om	2	0.05	(0.00–0.10)								[a]
Gallus		om							9	0.26	(0.06–0.56)		[a]
Reptiles													
Varanus rudicollis		ca				2	0.07	(0.00–0.11)					
Total			1160	29.16	9.22–51.85	548	16.42	8.75–31.76	148	4.02	2.29–6.38		[a]
			Total	Mean	Range	Total	Mean	Range	Total	Mean	Range		
Number of species			16	9.75	9–11	18	11	11	7	5.3	4–6		

The total Mean Trapping Rates (MTRs) of all species varied between 9.22 and 51.85 (mean: 29.16), 8.75 and 31.76 (mean: 16.42), and 2.29 and 6.38 (mean: 4.02) in the natural forest within the Wildlife Reserves, the natural forest within the protected areas of HTIs, and the planted acacia forest within the HTIs, respectively. Camera-trap images were predominantly of three species (see Table 4) wild boar (Sus sp.), southern pig-tailed macaques, and lesser mouse-deer (*Tragulus kanchil*). Wild boar accounted for 43.2%, 69.0%, and 50.7% of all sightings in the Wildlife Reserves, the protected area of HTI, and the planted acacia forest, respectively. Southern pig-tailed macaques contributed 16.9%, 19.9%, and 24.5%, respectively. Lesser mouse-deer, primarily found in the Wildlife Reserve, constituted 33.7% of all images. Other species had lower MTRs compared to these dominant three. Among the three terrestrial bird species detected, the crestless fireback (*Lophura erythrophthalma*) was dominant in the natural peat swamp forest, representing 82.1% of all sightings, while the red jungle fowl (Gallus gallus) was only observed in the planted acacia forests (Samejima *et al.*, 2022).

Apart from the species captured by our camera traps, local residents informed us of the presence of sambar deer and Sumatran tigers (*Panthera tigris*) in the natural peat swamp forest of this region. They discovered the skull of a male sambar deer at an illegal bird-hunting camp located within the core areas. Additionally, there were reports of a resident being attacked and fatally injured by a tiger in the transition areas. Quantitative data regarding the existence and population of the Sumatran tiger are lacking due to disruptions caused by human activities converting forests in the GSK-BB biosphere reserve, which likely leads to fragmentation of their home range. Research on the population of the Sumatran tiger becomes a priority to ensure the survival of this key species in harmony within the biosphere, with efforts to stop or minimize disturbances to the biosphere reserve promptly.

The conversion of natural peat swamp forests into industrial tree plantations and oil palm plantations can result in significant biodiversity loss, although this phenomenon has not been thoroughly studied yet (Posa 2011; Posa *et al.* 2011). While some animal species in peat swamp forests may be able to adapt to the new vegetation (Meijaard *et al.* 2010), plantations can also lead to considerable biodiversity loss, particularly among species vulnerable to habitat development in surrounding lowland forests in the area (Fitzherbert *et al.* 2008; McShea *et al.* 2009). Understanding the impact of plantation development on the animal community in peat swamp forests is essential for effective management of the region's peat swamp landscape.

The natural peat swamp forests exhibited greater species richness compared to the planted acacia forests. The average number of species per plot ranged from 9 to 11 in the Wildlife Reserve, 11 in the protected areas of HTIs, and 4 to 6 in the planted acacia forests inside the HTIs (Table 4.). A total of 16 species were recorded in the Wildlife Reserve, 18 in the protected areas of HTIs, and seven in the planted acacia forests inside the HTIs. The higher species richness in the natural peat swamp forest was attributed to the presence of rare species. Among the 11 vulnerable or endangered species documented in this study, eight were observed in the natural forests, while the remaining three were found in both vegetation types. None of the 11 vulnerable or endangered species were exclusively recorded in the acacia forest.

Certain species, such as the Malay civet, leopard cat, and red jungle fowl, appear to have adapted to the new plantation environment. McShea *et al.* (2009) also found that wild boar (*Sus barbatus*), civets, and mongooses (*Herpestes brachyurus*, *H. semitorquatus*, *Paradoxurus hemaphroditus*, and *Hemigalus derbyanus*), along with felids (*Pardofelis marmorata* and *Prionailurus bengalensis*), were more frequently observed in acacia forests than in logged natural forests. The adaptability of these species suggests that while frugivorous species may have limited food resources in the planted acacia forests, carnivorous species are not significantly affected.

In the Bukit Batu region, planted acacia forests may also serve as buffer zones, protecting intact natural forests in the core areas from forest fires that frequently occur in the transition zone. The northern part of this transition areas has repeatedly burned, resulting in an open area with few scattered trees. Plantation companies have actively monitored and prevented the spread of forest fires from the transition areas into their planted acacia forests.

Currently, a limited area of natural forest remains in lowland Sumatra. These findings indicate that natural peat swamp forests in the core areas are essential for maintaining regional biodiversity. Implementing more appropriate landscape designs, such as acacia-natural forest mosaics, may enhance biodiversity within industrial tree plantations

- Mammals

Elephants and tigers are two key mammal species in the GSK-BB BR, playing a crucial role in the protection of wildlife. These animals interact directly with local communities in the GSK-BB area, often leading to conflicts due to disruptions in their home ranges. Therefore, it is essential to develop strategies for managing these wildlife species to ensure that the business processes within the GSK-BB Biosphere Reserve, which emphasize the preservation of biodiversity based on conservation activities and sustainable development, can be implemented smoothly and effectively.

Elephants are a key species in the GSK-BB BR, with their movements primarily observed in the buffer zone and transition areas (Figure 6). The GSK-BB BR faces various challenges that require an integrated approach for sustainable management. Effective wildlife management, forest resource utilization, and regional economic development are crucial for the sustainability of the biosphere reserve and biodiversity conservation. A comprehensive management strategy must balance ecological preservation with community needs, ensuring long-term benefits for both nature and people. Understanding existing issues and finding viable solutions can guide the systematic and effective management of the GSK-BB BR.

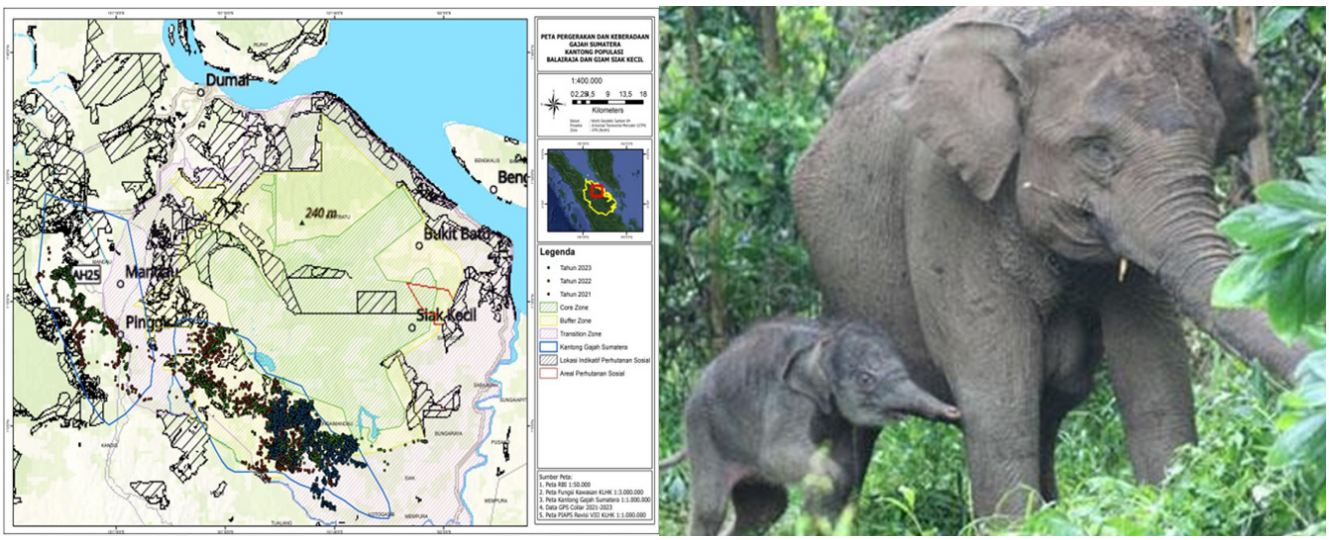

Figure 6. The observed movements of elephants, mapped within the GSK-BB area, primarily occur in the buffer zone and transition areas. This is likely due to forest fragmentation resulting from human activities. Sumatran elephants in the GSK-BB Biosphere Reserve adapt by adjusting their home range, seeking shelter, and finding food, leading these key species to move in an effort to sustain their increasingly pressured populations within the limited forest cover.

The size of a tiger's home range varies significantly depending on the region. In the savannahs of India, tigers occupy a range of 10-20 km², whereas in the boreal forests of Russia, their home range expands to 200-400 km². In the tropical forests of Sumatra, male Sumatran tigers have a home range of approximately 100 km², while females cover around 50 km². Resident Sumatran tigers typically move 10-15 km per day. Additionally, the density of Sumatran tigers is notably low, with only 0.3-5.5 adult animals per 100 km², highlighting their vulnerability and the need for effective conservation efforts.

The Sumatran tiger must be urgently protected, and its population in Giam Siak Kecil Bukit Batu (GSK-BB) must be accurately assessed. The logistical support of the biosphere reserve is crucial,

requiring intensive and collaborative research efforts from research institutions (BRIN) and university academics. Conservation area managers and NGOs with international funding connections must work together to protect this keystone species in the Giam Siak Kecil Bukit Batu Biosphere Reserve in Riau province. The potential tiger corridors in the GSK-BB Biosphere include two key areas, both also designated as industrial forest plantation concessions in Riau province: the Giam Siak Kecil Nature Reserve, which has good forest cover and spans 84,967 hectares with two identified possible corridors, and the Bukit Batu Wildlife Sanctuary, which offers a good habitat and covers 21,500 hectares with two possible corridor options. Additionally, the Centre for Elephant Training of Sebanga, spanning 5,873 hectares and located only 12.21 km from DSF, faces massive anthropogenic barriers, making corridor establishment impossible.

The shared responsibility of managing the GSK-BB BR to sustain the Sumatran tiger's population is imperative. This requires planned and measurable management and rescue strategies from all stakeholders. Industrial forest plantation managers, as concession holders, play a crucial role in ensuring that the designated corridors provide a safe and sustainable habitat for the Sumatran tiger. Conservation efforts must focus on maintaining a large area to support a viable tiger population, developing habitat networks that connect various tiger populations, and securing the commitment of landowners to establish permanent and high-quality corridors (Figure 7.)

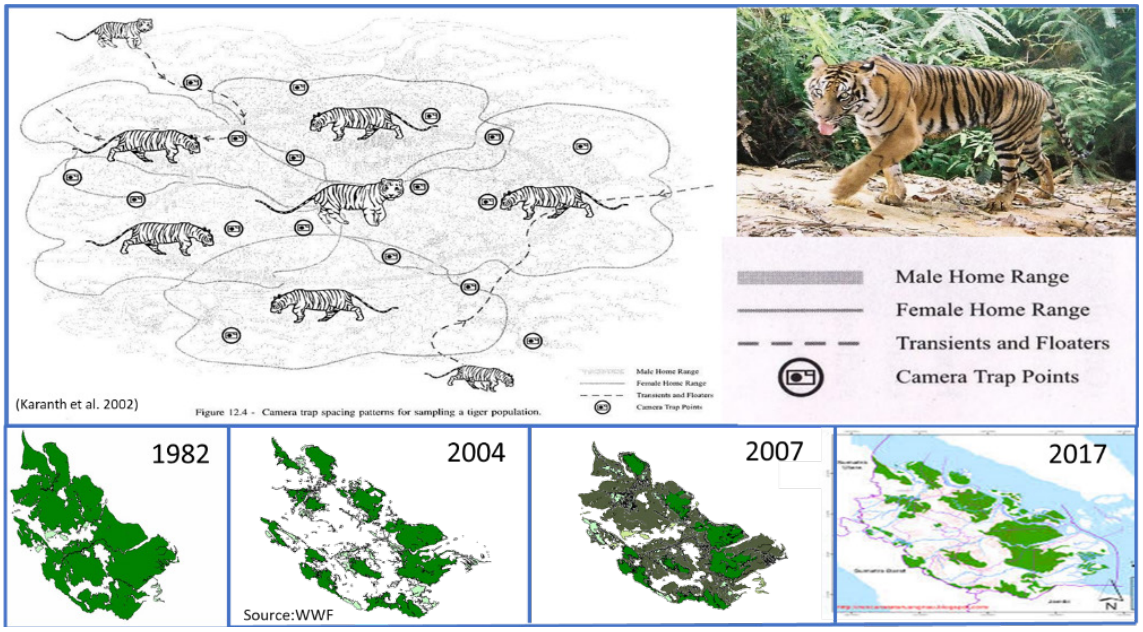

Figure 7. Deforestation Threatens the Future of the Sumatran Tiger in the GSK-BB BR. Between 1985 and 2009, Sumatra lost nearly 13 million hectares of its forest. In Riau Province alone, over 60% of forest cover was lost between 1982 and 2007. This extensive deforestation has led to the Sumatran tiger's habitat becoming smaller and increasingly fragmented. As a result, the remaining habitat can no longer sustain a viable tiger population. The small and isolated tiger populations now face a significantly higher risk of extinction due to their reduced numbers and limited genetic diversity.

- Birds

The study conducted by Fujita *et al.* (2011) in the Bukit Batu Wildlife Reserve reported a total of 172 bird species recorded over 204 mist-net days, 3,720 minutes of point count surveys, camera-trapping, and other observations. This accounts for 43.3% of the 397 resident bird species recorded in Sumatra (MacKinnon and Phillipps, 1993). Among these species, three have been categorized as "vulnerable species" according to the IUCN Red List (IUCN, 2011): the Black Partridge (*Melanoperdix*

niger), Crestless Fireback (*Lophura erythrophthalma*), and Hook-billed Bulbul (*Setornis criniger*). Additionally, 32 species were listed as "Near-threatened species," including the Long-tailed Parakeet, Blue-rumped Parrot, and Black-bellied Malkoha, among others.

There was a notable difference in bird species composition between the natural peat swamp forest (Wildlife Reserve and protected area) and the artificially-modified vegetations (planted acacia forest, rubber jungle, and residential area). The natural forest boasted distinctive species groups such as Trogons (*Harpactes* spp.), Leafbirds (*Chloropsis* spp.), Bulbuls (*Setornis criniger*, *Trcholestes criniger*, *Ixos malaccensis*), Babblers (*Pellorneum capistratum*, *Trichastoma* spp., *Malacocincla* spp., *Malacopteron* spp., *Stachyris* spp.), and Flycatchers (*Rhinomyias umbratilis*, *Philentoma pyrhoptera*) (Bettycopa *et al.* 2022).

Many fewer species were found in disturbed sites compared to the natural peatland forests in Bukit Batu. Out of the 44 species identified in the natural forests of Bukit Batu, only eight species were found in the planted acacia forest, 12 species in the planted rubber forest, and nine species in the residential village, indicating that over 70% of species were lost in the disturbed sites. In non-peat lowland areas, 88 species were found in the planted rubber forest out of 180 species in the natural forest , 66 species in the planted rubber forest out of 147 species in the natural forest, and 42 species in the planted acacia forest out of 82 species in the natural forest, accounting for approximately 50% of species loss in the disturbed sites. The oil palm plantation showed a drastic species loss of up to 94%, with only eight species found in oil palm plantation compared to 147 species in the natural forest (Fujita *et al.* 2023).

On the other hand, the bird fauna in planted acacia forest, rubber jungle, and village areas were characterized by different species such as open land Bulbuls (*Pycnonotus aurigaster* and *Pycnonotus goiavier*), Prinias (*Prinia* spp.), and Munias (*Lonchura* spp.). Some Kingfishers (*Alcedo meninting*, *Pelargopsis capensis*, and *Halcyon smyrnensis*) appeared to be more associated with acacia forests and village areas.

Compared to the species list in Giam Siak Kecil Wildlife Reserve by Giesen and van Balen (1991), 91 species out of the 172 species detected in this study were not recorded by them, mostly forest species such as Hornbills, Trogons, Babblers, and Bulbuls. Conversely, 42 species out of 121 species they detected were not observed in our study site, mostly raptors, water birds, and open-habitat species. Continuous surveying in the GSK-BB BR will further elucidate these findings.

Danielsen and Heegaard (1995) recorded 192 bird species in primary and disturbed forest on mineral soil in the Bukit Tiga Puluh area, in the southern part of Riau. Comparing their results, it appears that some common or not uncommon species out of the 192 species they detected were absent in our study area. Possible reasons for the lack of these species could include limited survey effort, differences in observers, habitat degradation, and ecological and environmental factors of peat swamp ecosystems. These factors underscore the importance of understanding biodiversity in peatland ecosystems and its response to human disturbance.

Several key species of hornbill birds recorded in the core areas of the GSK-BB Biosphere Reserve are protected and endangered under Appendix 1 of CITES, including the Great Hornbill (*Buceros bicornis*) and the Milky Stork (*Mycteria cinerea*). However, research and publications related to these species remain very limited. The bird species that inhabit and thrive in the GSK-BB Biosphere Reserve play a crucial role in the peatland ecosystem's food chain. Seed dispersal by these endemic birds contributes to sustainable conservation processes. Research is essential to understand the roles and current conditions of the bird species in the GSK-BB BR. Conservation efforts are also imperative, particularly for the two hornbill species (*B. bicornis* and *Mycteria cinerea*) listed in Appendix 1 of CITES. Why have hornbills become endemic? Is it due to hunting by humans, habitat destruction, or the loss of their food sources, making it difficult for them to reproduce? Or are there other factors, such as climate change, that have made hornbill populations extremely sensitive? These are the questions that hornbill researchers must answer, along with finding solutions for both in-situ and ex-situ conservation of hornbills (Figure 8).

Figure 8. Key hornbill species recorded in the core areas of the GSKB BR are protected and endangered under Appendix 1 of CITES, including the Great Hornbill (*Buceros bicornis*).

- Termites

Insects are the most diverse group of organisms on Earth. While some view insects as pests and destroyers of human-built structures and facilities, they actually play a crucial role in ecosystems, including peatland ecosystems. Insects are important vectors for pollination, enabling agricultural crops, forestry, and wild vegetation to reproduce naturally. Additionally, insects that inhabit waterlogged peatlands, where oxygen is scarce, are integral to decomposition processes. For example, termites in peatland ecosystems are not well-studied, but they may play a significant role in decomposing litter and peat through specific enzymes and microorganisms found in their guts. This basic bioprospecting research is a critical responsibility for biosphere reserve logistics. However, substantial research in the GSK-BB BR has been lacking, partly due to insufficient commitment from the reserve's management. Often, enthusiasm for nominating a biosphere reserve to UNESCO does not translate into effective coordination and active management, resulting in inactivity and missed opportunities for scientific research and conservation efforts (Table 5).

Termites are important members of the food chain in a tropical forest ecosystem (Holt and Lepage, 2000). They play a crucial role as ecosystem service providers, significantly contributing to soil processes and nutrient cycling in tropical ecosystems. Despite this, their ecological services are often overlooked due to their reputation as pests in human-dominated landscapes. Their presence contributes to supplying nutrients to the root systems of forest plants and the microbial communities operating in the below-ground ecosystem of peat swamp forests in the GSK-BB BR. However, this vital ecological role is often overlooked, despite the fact that 5% of the world's 2300 termite species are considered pests, causing negative economic impacts on human settlements or agriculture (Su and Scheffrahn, 2000). The recent intensification of land use has further elevated the pest status of termites. To comprehend the potential roles of termites in peatland ecosystems, termite samplings were conducted in abandoned degraded peatlands and peatlands cultivated with oil palm in Riau, Sumatra.

Climate change and alterations in the structure of tropical forests within peatland ecosystems will inevitably transform the composition of both aboveground and belowground communities. Research activities, including monitoring and evaluating the existence of biodiversity, such as termite species in peatlands, require human resources with expertise in termites. Changes in air temperature and peatland conditions should not only be seen as causing a reduction in peatland height, but we must also focus on the role of termites as decomposers. It is crucial to understand the extent to which termite species and their colonies contribute to the decomposition process in peatland ecosystems.

When there are changes in peatland forest cover due to illegal logging, encroachment, and peatland conversion, termites play a significant role in the decomposition process in forests where the vegetation has been cleared. Similarly, when peatland is converted into oil palm plantations, the population of

termites, such as *Coptotermes curvignatus*, increases due to the creation of a massive monoculture area. Consequently, the population of this termite species rises significantly (Figure 9.).

Table 5. Average trapping rates of mammal, bird, and reptile species in the GSK-BB Biosphere Reserve in Riau Province (Samejima *et al.* 2023)

Taxonomic group	Feeding group[a]	Riau Province[b]		Sarawak(Borneo- Malaysia)[c]				Perak (Malaysia Peninsular[d]					Pahang (Malaysia)[e]
		ADL	5 years	CL	2 years	5–7 years	13–15 years	4 years	8 years	15 years	20 years	21 years	6–16 years
RHINOTERMITIDAE													
COPTOTERMITINAE													
Coptotermes													
C. kalshoveni	W	✓	✓										✓
C. gestroi	W	✓								✓		✓	✓
C. curvignathus	W					✓		✓	✓	✓	✓	✓	✓
C. sepangensis	W					✓	✓	✓	✓	✓	✓	✓	✓
C. borneensis	W					✓	✓						
C. travians	W												✓
RHINOTERMITINAE													
Schedorhinotermes													
S. brevialatus	W			✓	✓								✓
S. malaccensis	W		✓		✓	✓	✓						✓
S. medioobscurus	W	✓	✓		✓	✓	✓						✓
Schedorhinotermes spp.	W							✓		✓		✓	
Parrhinotermes													
P. aequalis	W	✓	✓			✓	✓						✓
P. pygmoeus	W		✓										✓
P. inaequalis	W												✓
KALOTERMITIDAE													
Kalotermitinae													
Glyptotermes brevicaudatus	W												✓
TERMITIDAE													
AMITERMITINAE													
Globitermes													
G. sulphureus	W								✓	✓		✓	
G. globosus	W						✓						✓
Amitermes													
A. dentatus	W						✓		✓				✓
A. minor	W												✓
Microcerotermes havilandi	W												✓

Taxonomic group	Feeding group[a]	Riau[b]		Sarawak[c]				Perak[d]					Pahang[e]
		ADL	5 years	CL	2 years	5–7 years	13–15 years	4 years	8 years	15 years	20 years	21 years	6–17 years
NASUTITERMITINAE													
Bulbitermes													
B. borneesis	W				✓								
B. constrictus	W				✓								
B. germanus	W												✓
B. singaporiensis	W												✓
B. contrictiformis	W												
B. neopusillus	W												
Nasutitermes													
N. matangensiformis	W					✓	✓						
N. proatripennis	W					✓							✓
N. havilandi	W					✓	✓	✓				✓	✓
N. rectangularis	W					✓	✓						
N. johorieus	W												✓
N. longinus	W												✓

Taxonomic group	Feeding group[a]	Riau[b]		Sarawak[c]				Perak[d]					Pahang[e]
		ADL	5 years	CL	2 years	5–7 years	13–15 years	4 years	8 years	15 years	20 years	21 years	6–17 years
N. matangensis	W												✓
N. longinasoides													✓
N. neopusillus													✓
N. roboratus													✓
Hospitalitermes													
H. hospitalis	E												✓
H. umbrinus	E												✓
Orientubulitermes													
Orientubulitermes sp.	S			✓									
TERMITINAE													
Pericapritermes						✓	✓						
P. nitobei	S					✓							✓
P. paraspeciosus	S												✓
P. dolichocephalus	S												✓
P. latignathus	S												✓
P. mohri	S												✓
P. semarangi	S												✓
P. buitenzorgi													✓
Termes													
T. rostratus	W/S						✓				✓		✓
Prohamitermes													
P. mirabilis	W/S				✓		✓						
MACROTERMITINAE													
Macrotermes													
M. gilvus	W/L						✓						

ADL abandoned degraded peatland, *CL* recently cleared peatland, *W* wood feeder, *S* soil feeder, *W/S* wood/soil feeder, *W/L* wood/litter feeder,

E microepiphyte-feeder

[a]Classification of feeding group based on Donovan *et al.* (2001)

[b]Present study in Bukit Batu transitional areas

[c]Data sources from Vaessen *et al.* (2011) and Kon *et al.* (2012)

[d]Data source from Cheng *et al.* (2008)

[e]Data source from Faszly *et al.* (2011) and Jalaludin *et al.* (2018)

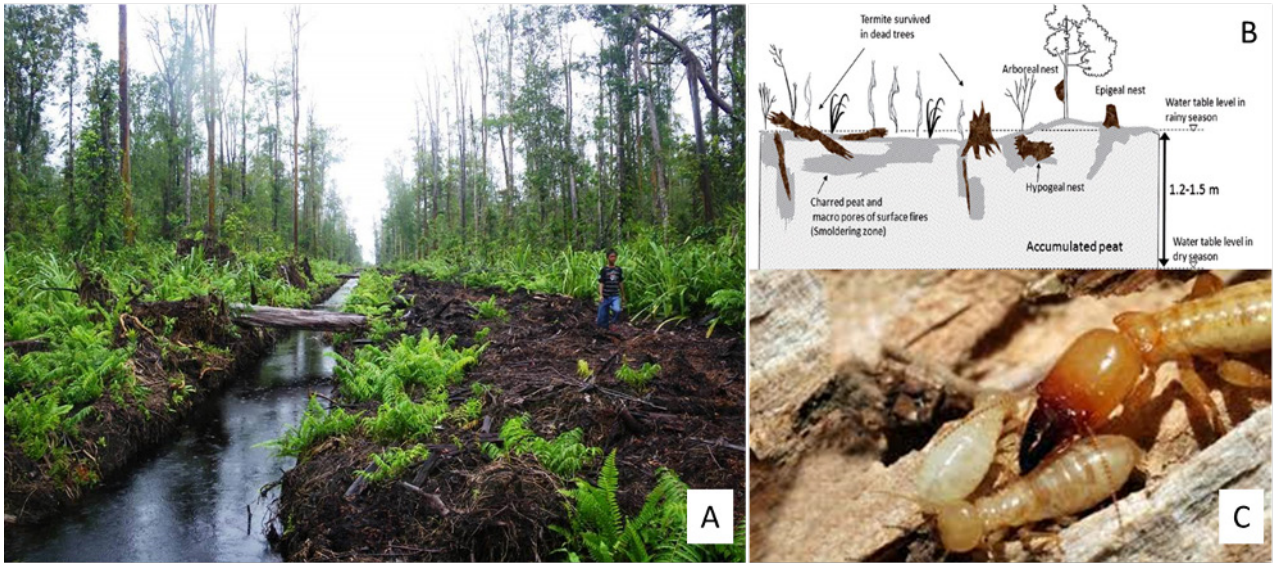

Figure 9. The behavior of termites in the forest and oil palm plantations of degraded peatland ecosystems during fire events in Sumatra is notable (A and C). The diagram shows that the water table level can drop by 1.2 to 1.5 meters below ground level during the dry season. In these periods, the surface layer of peat may burn at temperatures reaching 400 °C, potentially penetrating the ground surface to depths of 20 to 50 centimeter (B). (Neoh *et al.* 2016).

In the Table 6, the list of flora and fauna included in the CITES Appendix 1 is a crucial task for the GSK-BB BR to plan logistical functions, providing fundamental data on each individual species listed in Appendix 1. The initial step involves inviting national research institutions (BRIN) and national universities comprising expert researchers in their respective fields. Planning and research roadmaps should already be initiated; delaying research efforts could lead to regrettable extinctions of numerous rare species, both flora and fauna. Concurrently, the biosphere reserve coordinating Board must promptly mitigate damage to protected forest areas in the core areas and buffer zones, crucial habitats for rare flora and fauna within the GSK-BB biosphere reserve.

3.1.3. Endangered Species

Tables 6 and 7 present the list of rare flora and fauna species within the GSK-BB BR that are included in the CITES Appendix (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). This highlights international concern over the critical endangerment of several species in the area. Table 7 lists flora and fauna commodities with high economic value, such as various fish species living in the rivers of the peatland ecosystem, which are a vital protein source for the local community. However, these fish are rare, as are certain native tree species that should be propagated through research and innovation

Table 6. Listed as endangered or protected under Appendix 1, CITES

No	Species	CITES
A	**Large mammals**	
1	Gajah Sumatran (*Elephas maximus*)	Appendix 1 CITES
2	Beruang madu (*Helarctos malayanus*)	Appendix 1 CITES
3	Harimau Sumatran (*Panthera tigris sumatrae*)	Appendix 1 CITES
4	*Tapir* (*Tapirus indicus*)	Appendix 1 CITES
B	**Birds**	
1	*Hornbill (Buceros bicornis)*	Appendix 1 CITES
2	*Mycteria cynerea*	Appendix 1 CITES
C	**Reptile**	
1	*Senyulong (Tomistoma schlegelii)*	Appendix 1 CITES
2	*Crodylus porosus*	Appendix 1 CITES
D	**Fishes**	
1	*Arwana (Scleropages formosus)*	Appendix 1 CITES
E	**Plants**	
1	Orchid (*Acryopsis javanica*)	Appendix 1 CITES
2	*Pasak linggau* (*Aglaia* sp.)	Endangered
3	*Medang lendir* (*Alseodaphne umbellifora*)	Endangered
4	*Mersawa (Anisoptera costata)*	Endangered
5	*Ramin (Gonystylus bancanus)*	Endangered
6	*Meranti (Shorea parvifolia)*	Endangered
7	*Meranti (Shorea teysmanniana* Dyer*)*	Endangered
8	*Meranti (Shorea teysmanniana* Dyer*)*	Endangered
9	*Meranti bunga (Shorea teysmanniana* Dyer ex Brand*is)*	Endangered
10	*Meranti batu (Shorea uliginosa* Foxw*)*	Endangered
11	*Vatica rassak* Blume.	Endangered
12	*Jelutung paya* (*Dyera polyphylla)*	Endangered
13	*Ganitri (Elaelocarpus stipularis)*	Endangered
14	*Manggis hutan (Garcinia bancana)*	Endangered

The peatland ecosystem in GSK-BB BR is an essential ecosystem that supports the livelihood of local communities who have traditionally relied on its bioresources for daily income, firewood, protein from local fish, vegetables, and other food sources that grow in the peatland. The question arises: are the key fish species living in peatland rivers, native commercial tree species that function well ecologically, and the biodiversity documented in the nomination book and the five-year management plan for GSK-BB BR still present in the wild? Concerns persist, given the drastic changes in human behavior and population explosions on Earth, which could lead to the extinction of key species recorded in GSK-BB BR's documents. The role of GSK-BB BR management is crucial in monitoring these key species, which have long been considered unique icons and the reason why GSK-BB BR was designated as a biosphere reserve by UNESCO (Table 7).

Table 7. Key species that have local economic value and their uses

No	Local Name	Scientific Name	Uses
1	*Labi-labi*	*Amyda cartilagina*	Food
2	*Ikan tapa*	*Wallago attu*	Food
3	*Ikan toman*	*Channa* spp.	Food
4	*Ikan selais*	*Kryptopterus macrocephalus*	Food
5	*Ikan kepar*	*Ballontia hasseltii*	Food
6	*Ikan arwana*	*Scleropages formosus*	Ornamental Fish
7	*Mersawa*	*Anisoptera costata*	Timber
8	*Ramin*	*Gonystylus bancanus*	Timber
9	*Meranti*	*Shorea parvifolia*	Timber
10	*Meranti*	*Shorea tesymanniana*	Timber
11	*Meranti*	*Shorea tesymanniana*	Timber
12	*Meranti bunga*	*Shorea tesymanniana*	Timber
13	*Meranti batu*	*Shorea uliginosa*	Timber
14	*Vatica*	*Vatica rassak*	Timber
15	*Jelutung paya*	*Dyera lowii)*	Latex
16	*Gaharu*	*Aquilaria beccariana*	Bark for incense
17	*Pasak bumi*	*Eurycoma longifolia*	Medicinal plant

Native tree species from the Dipterocarpaceae family dominate the upper canopy in tropical rainforests. Notably, species such as *Shorea balangeran*, *Shorea tesymanniana*, *Shorea uliginosa*, *Anisoptera costata*, *Vatica rassak*, and *Hopea* spp. grow adaptively in peatland ecosystems. It remains to be seen if these parent trees and their natural regeneration still exist in the wild. Regular evaluation and monitoring through vegetation inventories of these tree species are crucial conventional methods. Conservation efforts, such as establishing collections of these species in botanical gardens or arboretums, are effective ways to preserve the genetic diversity of endemic species. These arboretums can serve as sites for ecotourism and education, from primary to higher education levels. Early-stage research activities within the biosphere reserve should be coordinated by GSK-BB BR management in collaboration with local and national universities that have forest resource conservation programs.

3.2. Environmental Changes

Environmental changes in biosphere reserves can be monitored through research activities using appropriate tools and methods. Amidst climate change and progressive population growth in Riau, the demand for land for food production or industrial raw materials is increasing. Illegal activities such as encroachment on production forest land and land clearing through burning are unwise and do not adhere to existing regulations. The establishment of the GSK-BB biosphere reserve in Riau province is a way to harmonize and sustainably utilize forests and the environment, where natural resources and human needs are managed in accordance with sustainable practices and regulations set by the MAB-UNESCO protocol, thereby minimizing environmental change mitigation. Deviant activities at the ground level that lead to the further extinction of key flora, fauna, and microbial species can be easily detected and recognized by the global community concerned about the existence of biosphere reserves that have gained worldwide recognition.

The GSK-BB Biosphere Reserve holds great potential as a model landscape for sustainable development, primarily serving as a life support system by maintaining eco-hydrological balance. It also functions as a leading research station for studying and harnessing the biodiversity potential of peat swamp forests, while simultaneously promoting ecotourism based on the area's natural and cultural

beauty to uplift the welfare of local communities. To mitigate climate change and effectively develop the landscape of the GSK-BB Biosphere Reserve, the management of the GSK-BB biosphere reserve, together with industrial partners, has undertaken steps over the past five years. Supporting activities and logistical efforts have also been focused on several initiatives outlined below:

3.2.1. Carbon Emissions reduction

This initiative is supported by the private sector APP Sinarmas. APP is fully committed to supporting Indonesia's Low Emissions Development Goal in line with The Paris Agreement, which aims to reduce emissions by 29% by 2030. Our Forest Conservation Policy (FCP) contributes to avoiding carbon emissions compared to business as usual practices through sustainable forest management, fire prevention, and peatland protection. In 2018, we commissioned an independent consultant, Ata Marie, to analyze the carbon emissions avoided through the implementation of our FCP since 2013, and to project long-term emission avoidance. The study modeled two scenarios of land use change: Business as Usual (BAU) and FCP. It revealed that the emission avoidance from 2013 to 2016 was primarily due to the implementation of our FCP. Furthermore, the assessment highlighted our integrated fire management program since 2017 and peatland management since 2019 as the most significant activities contributing to specific carbon avoidance. We anticipate that major potential for long-term emissions avoidance will come from peatland rewetting and reducing fires in peatland areas. While significant emissions avoidance initially stems from no deforestation, potential savings from this will diminish over time.

Based on the observations by APP Sinarmas and consultations in 2019, the implementation of FCP has yielded the following results: (a) Achieved a 64% reduction in annual carbon emissions compared to business as usual (BAU). (b) Resulted in the avoidance of 44 million metric tons of CO2 equivalent per year compared to BAU (Figure 10).

RADARSAT-2 Case Study:

The Radarsat-2 program, undertaken by APP Sinarmas, involves monitoring the following areas: (a) Monitoring nearly 3.6 million hectares, including 38 concessions belonging to APP suppliers, the Giam Siak Kecil-Bukit Batu biosphere reserve, and the PT. Karawang Ekawana Nugraha ecosystem restoration concession near APP's OKI pulp and paper mill. (b) Utilizing the Radarsat-2 sensor, which covers a large swath (125 km) with high resolution (0.5 m), enabling large-scale monitoring in near real-time. This marks a significant advancement in radar remote sensing technology. (c) Employing an automated process for data acquisition, processing, and forest change alerts, with georeferenced polygons delivered directly to APP's enterprise servers. (d) Enabling the detection of encroachment, illegal logging, forest damage from natural causes, and infrastructure changes. (e) Capable of identifying individual trees that have been removed from the forest canopy.

In 2019, we continued to leverage the latest satellite technology to monitor and respond to forest cover changes. Our monitoring scope includes 3.6 million hectares of production forest and conservation areas, including the Giam Siak Kecil – Bukit Batu biosphere reserve (GSK-BB BR). The fine resolution allows us to detect even subtle changes in forest cover, aiding in mapping forest cover changes caused by various factors such as encroachment, illegal logging, or natural phenomena. Additionally, this technology helps us assess the long-term impact of our FCP and understand how our efforts mitigate the risk of land use change. Furthermore, the data obtained is crucial for monitoring remote forest areas that are challenging to monitor manually, supporting our Collaborative Conservation Management and SMART Patrol initiatives. In 2020, we plan to shift our focus towards protected areas identified through our HCV and HCS assessments, allowing us to prioritize areas most vulnerable to forest disturbance.

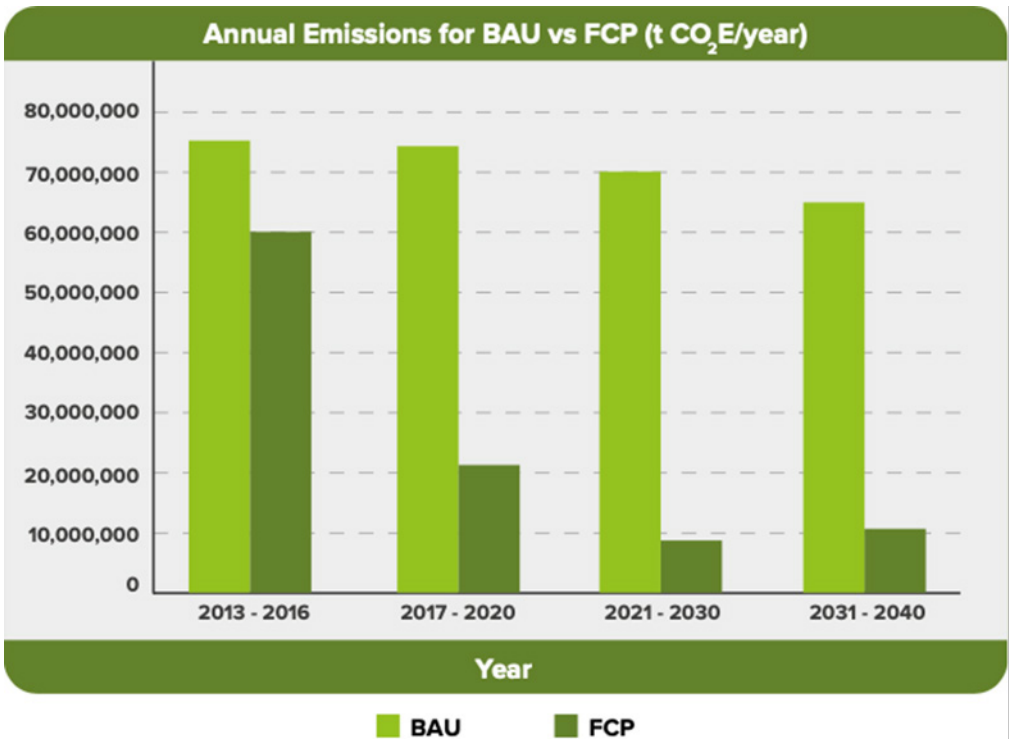

Figure 10. Annual emissions for Business as Usual (BAU) compared to Forest Conservation Policy (FCP) (Tons of CO2 Equivalent per year).

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3.2.2. Ecohydrology for Life Support Systems Protection:

Encompassing an area of approximately 705,271 hectares with a relatively flat topography and an altitude ranging between 0 to 50 meters above sea level, the landscape serves as a vital water catchment area for downstream regions. The peat swamp forest's water catchment function supplies water to small lakes ("tasik") and the rivers flowing beneath them. Surface water is crucial for sustaining industrial forest plantations, agriculture, aquaculture, animal husbandry, and maintaining river water levels for transportation. Hence, the GSK-BB Biosphere Reserve holds immense potential as a conservation area dedicated to safeguarding life support systems through its hydrological balance maintenance, marking the primary focus of its development.

3.2.3. Research and Education on Peatland Resources:

Given the biodiversity conservation imperative of the GSK-BB Biosphere Reserve, continuous, long-term observations of peat swamp forest dynamics are essential. Periodic species inventories are necessary to explore and monitor potential changes. Continuous monitoring and study of forest functions are crucial to understanding their response to natural phenomena, including climate change. Research encompassing forest structure, composition, functions, status, species diversity, and biodiversity utilization knowledge optimization is imperative for sustainable use. Establishing a research station in Tasik Betung Village (as recommended by the 2007 BRIN study) and developing biological resource gardens (Bundayati) in Siak Sri Indrapura and Bengkalis City for ex-situ conservation are fitting measures to study the biodiversity potential within the core areas of the GSK-BB Biosphere Reserve. Furthermore, the GSK-BB Biosphere Reserve plays a vital role in natural resource education. As a unique area featuring the peat swamp forest ecosystem with its characteristic "tasik" and a local community closely connected to nature, it offers an ideal setting for natural resource education. With its diverse flora and fauna, the area provides valuable educational material for youth, students, and the community, enhancing understanding of biodiversity and ecological dynamics. Education and research on peat swamp forest resources, facilitated by field research stations, constitute the reserve's secondary hallmark, furthering the preservation of plant and animal species diversity and their ecosystems.

3.3. Socio-Economic Assessment

3.3.1. Population Dynamics

The Giam Siak Kecil - Bukit Batu Biosphere Reserve spans two Regencies, Bengkalis and Siak, within the Province of Riau, Sumatra, Indonesia. Situated at altitudes ranging from 0 to 50 meters above sea level, the area primarily comprises peat swamp forests. As reported in Periodic Review in 2022 (Purnomo *et al.*, 2022), A total of 80 villages surround the biosphere reserve, with a combined population of 237,763 people. Among these villages, twelve villages lie within the buffer zone, while the remainder are situated in the transition area. The buffer zone, comprising 88% industrial plantation forests, is managed sustainably to safeguard the core areas. Serving as a protective barrier, it aims to shield the core areas from external threats. The Transition areas serves as a space for human habitation, business, and industry, interspersed with patches of vegetation and habitat corridors. These corridors play a vital role in connecting the buffer and core areas. The planning scheme for the GSK-BB biosphere reserve includes 'development limits' to curb future expansion and robust vegetation protection mechanisms such as the Biodiversity Overlay, aimed at maintaining sustainable vegetation and landscapes.

The biosphere reserve's socio-economic landscape is characterized by rapid population growth, driven by industrial plantation forestry and palm oil industry activities in the buffer and transition area (Table 8). This growth has attracted migrants seeking employment opportunities in various sectors, including oil palm conversion and agricultural development. Despite challenges, such as environmental degradation and socio-economic disparities, efforts are underway to promote inclusive and sustainable development within the biosphere reserve**.**

Table 8. Human Population of the Biosphere reserves

Zones	Previous period (2016)	At present (2020)
Core Area(s) (permanent and seasonally)	235 person/24 persons	250 persons
Buffer Zone(s) (permanent and seasonally)	7,124 persons/10.000 persons	7,870 persons
Transition Area(s) (permanent and seasonally)	28,232 persons	Siak Regency 9,128 persons (S. Mandau) Bunga Raya 26,462 persons

Noted: Bunga Raya and Mandau sub-districts have migrated a lot from Nias and North Sumatra to work as employees in HTI companies and oil palm plantations.

The population expansion within the GSK-BB Biosphere Reserve region is burgeoning, currently hosting 120,904 inhabitants distributed across various sub-districts. In Siak Regency, Sungai Mandau and Bunga Raya Sub-districts accommodate 35,905 individuals, while in Bengkalis Regency, the population is spread across four sub-districts: Bukit Batu (21,771), Bandar Laksamana (15,042), Talang Mandau (24,000), and Siak Kecil (24,186), totaling 84,999 residents according to the 2020 Population Census. This rapid demographic growth can be attributed to the prevalence of industrial plantation forestry and palm oil industry activities dominating the buffer zones and transition areas. Consequently, numerous migrants from other provinces or regencies are drawn to this locale seeking employment opportunities, predominantly within the oil palm conversion, industrial forest plantation development, peatland agricultural expansion, and other cultivated plant development sectors. This growth is mainly due to the population structure which currently has many new arrivals from other regions, regional openness and ease of communication that facilitates population data collection. Although population growth is increasing, there are signs that economic growth is also picking up. The dynamic of population in Buffer Zone and Transition Areas of the GSK-BB Biosphere Reserve can be depicted as the Table 9.

Table 9. Population Dynamics in Bengkalis and Siak Regency (Buffer and Transition Areas)

	Bengkalis Regency	Siak Regency
Population growth	3,72 % per year Increased from 551,683 in 2016 to 573,003 in 2019)	2,51 % per year Increased from 453,052 in 2016 to 489,996 in 2019)
The average monthly and annual income of households	IDR 455.021 per month in 2016 to IDR 581.416 per month in 2020	No information
Number of Poor Population	Decreased from 3,749,000 in 2019 to 3,696,000 in 2020	Increased from 2,486,000 in 2016 to 2,538,000 in 2020
Percentage of Poor population	6,82% in 2016 to 6.40% in 2020	
Human Development Index (HDI)	Increased from 71.98 in 2016 to 73.46 in 2020.	Increased from 72,70 in 2016 to 73,69 in 2020
Component of HDI	life expectancy up to 71.20 years; long school expectations 12.87 years; average length of schooling 9.69 years; and per capita expenditure of 11.33 million per year.	Life expectancy of 71.20 years; Old School Expectation 12.87 years; Average School Age 9.69 years; and Per capita Outcome IDR 11.33 million/years.
Economic Growth		1-5%

Source: Periodic Review of GSK-BB BR in 2022 (Purnomo, et al, 2022)

The table illustrates the socio-economic dynamics and progress in both regencies over the specified period, highlighting improvements in income, poverty reduction, and human development. This comparison between Bengkalis Regency and Siak Regency reveals significant differences and similarities in various socio-economic indicators. Bengkalis Regency witnessed a higher population growth rate of 3.72% annually compared to Siak Regency's 2.51%, reflecting varying demographic trends. Remarkably, Bengkalis Regency experienced notable income growth, with household incomes rising from IDR 455,021 per month in 2016 to IDR 581,416 per month in 2020. Conversely, data on household income for Siak Regency are unavailable. Poverty alleviation efforts in Bengkalis Regency resulted in a decrease in the number of impoverished individuals from 3,749,000 in 2019 to 3,696,000 in 2020, while Siak Regency observed a rise from 2,486,000 in 2016 to 2,538,000 in 2020. Furthermore, the percentage of poor population in Bengkalis Regency declined from 6.82% in 2016 to 6.40% in 2020. Both regencies displayed improvements in Human Development Index (HDI), with Bengkalis Regency's HDI increasing from 71.98 in 2016 to 73.46 in 2020 and Siak Regency's from 72.70 in 2016 to 73.69 in 2020, underscoring advancements in life expectancy, education, and per capita expenditure. Economic growth in Siak Regency ranged from 1% to 5%, driven by various factors including income growth and economic diversification. Overall, these findings shed light on the socio-economic progress and challenges faced by both regencies, emphasizing strides in income, poverty reduction, and human development in GSK-BB BR.

3.3.2. Livelihoods and Economic Activities

In pursuit of one of the development objectives of the Biosphere Reserve, which prioritizes sustainable socioeconomic growth rooted in natural resources and the environment, various initiatives have been enacted for the local community inhabiting the buffer zone and transition areas. This reserve is dedicated to transitioning local communities from reliance on natural resources for mere subsistence to fostering sustainable self-reliance, while actively engaging them in sustainable development efforts.

The primary aim of the community development program within the GSK-BB Biosphere Reserve is twofold: to offer alternative sources of income and livelihood for local residents and to mitigate illegal and unsustainable practices that pose threats of environmental harm and degradation. The GSK-BB region holds promise for fostering economically viable activities that align with environmental preservation. There's a growing demand for products cultivated through ecologically sustainable methods, paving the way for the potential expansion of certified natural resource-based and environmentally friendly goods. Economic endeavors rooted in the preservation of natural resources and ecosystems within the GSK-BB BR area aim to uplift the quality of life for communities residing in the vicinity of the conservation zone.

The Agricultural and Food Sector is witnessing continuous expansion within the GSK-BB Biosphere Reserve territory, poised to play a more significant role in the future lives of local residents. Innovations in agricultural technology, alongside favorable bio-physical conditions in buffer zones and transition areas, enable various organic farming initiatives, encompassing fruits, vegetables, and essential crops, catering to both local and national markets. There is a discernible trend towards embracing more sustainable agricultural practices among rural landowners, prioritizing the production of high-quality food while safeguarding soil health in buffer zones and transition areas for future generations. Traditional activities such as agriculture, animal husbandry, and fisheries persist, employing diverse traditional methods that yield high-quality outputs, inherently aligning with the goals of the GSK-BB Biosphere Reserve. Particularly in plantation sectors like oil palm, rubber, coffee, and cocoa cultivation within the GSK-BB biosphere reserve, the agricultural industry contributes to the economic progress of local communities. These production endeavors are seen as opportunities to integrate traditional practices with landscape conservation, cultural preservation, and the sustainable management of natural resources.

Table 10. Economic Activities by Community at Each Zone of the GSK-BB BR

Zones	Economic Activities by Community
At the core areas	Communities in the border areas of the core area and buffer zones have subsistence activities to meet their needs by: • Subsistence farming • Fisheries • Non-timber forest products collection
At the buffer zone	• Fisheries • Plantation forestry • Palm oil and commodities cultivation • Subsistence farming • Timber and non-timber forest products gathering
At the transition areas	• Livelihood and subsistence farming • Oil palm and rubber farmers • Employees/laborer's in large plantations • Agri-based industries • Forest-based industries • Mining • Gas and oil exploitation • Various trades

Source: Purnomo, et al 2022

Predominantly, the buffer zone area is dedicated to industrial plantation forests (comprising 88%), primarily producing pulp and paper through companies affiliated with APP/Sinarmas Group. The remaining portion consists of production forests and oil palm plantations, owned by local residents and companies alike. Agricultural development in these areas focuses on both food and plantation crops, encompassing oil palm, rubber, coffee, and cocoa. Food crop varieties cultivated include lowland rice, dry-field rice, horticultural produce (vegetables and fruits), as well as secondary crops such as corn, cassava, and peanuts. The buffer and transition areas, overseen by provincial and district governments for regional development, are earmarked for innovative economic growth as "Smart Regions". New infrastructural developments and capacity-building initiatives, supported by various stakeholders, aim to expedite progress in the GSK-BB biosphere reserve area. This endeavor not only benefits the core conservation areas but also ensures the integration of buffer and transition areas into sustainable development efforts, safeguarding vulnerable core areas. Additionally, local governments are integrating digital technology education into school and university curricula, paving the way for future job opportunities and benefiting all age groups.

Efforts to promote the development of food crops are facilitated through farmer groups established by the Department of Agriculture (under local government jurisdiction). These groups aim to synchronize production activities, such as planting schedules, while disseminating knowledge regarding productive and high-quality food production within the region. Presently, each village hosts several agricultural groups comprising approximately 20-30 members, organized based on their respective activities, such as farmer groups, food crop groups, inland fisheries groups, rubber farmers groups, oil palm farmers groups, among others.

There are some efforts by the management in reorganization and broadening of activities aimed at enhancing the economic role of the GSK-BB biosphere reserve involve several strategies. These

include fostering local economic ventures, revitalizing marketing facilities and infrastructure for local products, establishing branding initiatives, and enhancing the capacity of agricultural communities. These efforts represent significant milestones for local economic growth, benefiting local communities and governments. They are supported by the development and implementation of various measures, including those pertaining to land management and utilization.

The development initiatives within the GSK-BB Biosphere Reserve adhere to a collaborative and coordinated management strategy, representing a crucial endeavor towards achieving sustainable development in the area. Additionally, within the government programs of Bengkalis Regency and Siak Regency spanning different periods (2010-2014; 2015-2019; and 2020-2024), there's a pivotal emphasis on enhancing the management of the GSK-BB Biosphere Reserve to ensure its sustainability and longevity.

Table 11. The Community Development Plan Programs in the GSK-BB Biosphere reserve

Programs	Commodities	Activity Documentation
Development of potential non-timber forest products	Communities around forest areas, especially those in buffer zones, are trained to plant species of plants that have important values, such as jelutung (*Dyera costulata*), gaharu (*Aquilaria malaccensis*), rattan (*Calamus spp*.), honey bee, and others	 
Development of freshwater fisheries	Local communities are trained to raise fish by making cages and captive breeding of labi-labi/soft shell turtle (*Amyda spp.*) to produce medicinal products and food and fish rearing activities through fish cage cultivation in Tasik (Small Lake) and Rivers (in collaboration between the Islamic University of Riau and the community in Tanjung Leban). The keramba were built in Tasik (Natural Small Lakes) located around residential areas in the buffer zone area.	 

Agriculture development	Agricultural development activities include food crops, horticultural crops such as pineapple cultivation, melon plants, dragon fruit and others. The development of plantation crops includes the development of rubber, oil palm, coffee and coconut cultivation. For the development of livestock for communities in buffer zones and transition areas by cultivating chickens with the aim of meeting the needs of meat and eggs independently	   
Development of community-based tourism	Development of community-based tourism showcasing local or indigenous knowledge and traditions, which will in turn enhance the cultural value of the local communities	
Education and Health	Through the implementation of Corporate Social Responsibility (CRS) programs of the respective corporate member-participants in this biosphere reserve, the community development and empowerment activities will also be directed to improve education, health, and other community needs and welfare	
Alternative energy (bioenergy) development	The development of alternative bio-energy is carried out by building a bio-gas reactor and research to find sources of bio-ethanol. Bio-gas development activities are carried out to utilize palm oil processing waste and to fulfill household energy for rural communities	
Clean water development	The program to purify peat water into fresh water whose pH has reached around 7 and is suitable for consumption on condition that it must be cooked first	 

Conservation and Protection	Protection and conservation activities are carried out starting from nursery activities to planting several types of native plants such as meranti bakau (Shorea uliginosa). This species of meranti bakau, based on research from the collaboration of LIPI and Kyoto University, shows that it has prospects to be developed as a source of bio-ethanol. The protection and conservation activities carried out are conducting area patrols to prevent and protect the area from illegal activities such as illegal logging, encroachment, and other illegal activities	   
Capacity building for Local Community	Human resource capacity building activities at the site level are carried out to increase local community knowledge in the fields of agriculture, forestry, and the environment	 

3.3.3. Cultural Practices

The GSK-BB Biosphere Reserve encompasses approximately 80 villages, each boasting a unique cultural heritage and indigenous knowledge. The local inhabitants living within or near the GSK-BB BR include Melayu, Batak, Java, and Minang. These communities rely on the functioning of local ecosystems for their livelihoods and cultural practices, emphasizing the need for collaborative management among stakeholders. These communities rely on the reserve's ecological systems for sustenance, livelihoods, and cultural practices. Collaborative management among stakeholders is advocated to ensure the preservation of these resources. The local communities demonstrate a strong interest in safeguarding their cultural heritage while managing natural resources. Efforts are made by various organizations to maintain traditional values, including rituals and celebrations associated with resource management, lifecycle events, and religious practices. These cultural traditions, dating back to the 18th century, continue to be preserved and could serve as tourist attractions.

In addition to conservation, the GSK-BB Biosphere Reserve aims to promote Malay identity, culture, and heritage. Infrastructure development and cultural festivals are supported by local governments to preserve and promote Malay traditions. Incorporating traditional practices into educational activities is a key aspect of the reserve's intervention. Utilizing traditional wisdom, the reserve identifies and inventories cultural traditions to support sustainable resource management. In the development of the GSK-BB biosphere reserve, there are many activities that promote local traditions. Cultural promotion is carried out in various activities, including: a Malay cultural festival which is held every year, an approach to area protection by involving traditional stakeholders, adopting a traditional utilization system in the utilization of sacred areas as local conservation areas. These values, aligned with conservation principles, include the preservation of sacred sites and customary boundaries. Cultural festivals and traditional utilization systems further promote local traditions within the reserve. Moreover, dance, music, and cultural festivals serve to foster community cohesion and promote sustainable resource use.

Ethnic diversity within the region is highlighted, with communication occurring in both Indonesian and local languages. Efforts to preserve local culture are reiterated, particularly among youth and cultural organizations. These celebrations and rituals play an important role in preserving the culture of managing natural resources and their ecosystems. Religious festivals are estimated to have developed during the royal period in the 18th century. These cultural rituals are still preserved today and play an important role, both as a manifestation of religion and Malay culture, and this attraction can become a cultural tourist attraction today. We can use these socio-cultural activities to promote biosphere reserve products as well as to disseminate information about local community activities in developing their area in a sustainable manner within the framework of implementing the biosphere reserve concept in GSK-BB.

Finally, research endeavors focus on local knowledge and wisdom to inform biodiversity management strategies. Researchers from the Ethnobiology Laboratory at the LIPI Biology Research Center conducted ethnobiological research in 2011 and 2018 within the GSK-BB biosphere reserve. This research aimed to investigate the indigenous knowledge and wisdom of local communities regarding biological natural resources and ecosystems. The findings revealed the presence of local wisdom in managing areas not aligned with ecological principles, such as the conversion of deep peatlands into agricultural land, plantations, and industrial forest plantations. These practices pose significant environmental risks, including habitat destruction for flora and fauna in tropical peat swamp forest areas. To address these challenges, efforts were made through socialization, education, and various mitigation strategies, including legislative regulations governing peatland use and the formulation of sustainable utilization strategies. Additionally, the traditional wisdom of local communities, particularly regarding "sacred areas and sacred forests," plays a crucial role in preserving habitat and biodiversity. Leveraging this local knowledge and wisdom can serve as valuable content for environmental education among students and young generations, fostering public awareness and appreciation for the environment and its resources, ultimately benefiting future generations.

3.3.4. Human Impact on the Environment

The primary aim of creating the GSK-BB Biosphere Reserve is to establish a balanced relationship among people, nature, and the environment. This involves ensuring a sustainable supply of natural resources, promoting sustainable socio-economic development, and preserving cultural and biological diversity. The establishment and growth of the GSK-BB biosphere reserve have undeniably benefited the welfare of the community within and around the reserve, boosting regional/state income and enhancing the sustainability of natural resources and ecosystems. However, various socio-economic activities also pose risks of negative environmental impacts. The establishment of the GSK-BB Biosphere Reserve coincides with a critical period marked by significant pressures and threats such as illegal logging, poaching, overfishing, forest encroachment, and forest and peat fires resulting from slash-and-burn methods. Additionally, unsustainable agricultural expansion, land conversion for agriculture, and uncontrolled drainage further threaten the ecological integrity of the biosphere reserve. These activities, occurring in various types of forests and water bodies within the reserve, including peat swamp forests, permanent and seasonal lakes, alluvial bench forests, and riparian areas, jeopardize the reserve's ability to provide crucial environmental, social, and economic services, leading to rapid environmental degradation and loss.

Table 12. The human impact on environment in GSK-BB BR, Riau Province

No	Location	Function	Human impacts on environment
1	Bukit Batu Wildlife Reserve	Conservation of biological natural resources, especially flagship species: elephant Sumatra, tiger Sumatra, and flora, and peatland forest conservation	Illegal logging, encroachment, illegal hunting, and forest fire
2	APP Sinarmas and Partners Concession Area (Forest Production)	This area must be ecologically conserved because it is a deep peat area, peat dome and many small lakes (tasks) are found. This area is more suitable as a conservation area than its status as a production forest	Illegal logging, encroachment, illegal hunting, and forest fire
3	Rivers and small lakes (Tasik)	Tourism and fishery	Overfishing, weed or Water hyacinth invasion
4	Industrial Forest Plantation	Pulp and Paper	Private property access, environmental impacts including potential contamination of water
5	Oil palm plantation	Oil palm	Private sector domination
6	Timber	Building Material	Illegal logging
7	Decrease soil quality	Plantation	Loss of soil sediment into waterways and land subsidence
8	Fresh water supply	Clean water supply for household	Water pollution and peat water quality that is not suitable for drinking water

Source: Periodic Review GSK-BB BR 2022 (Purwanto, *et al.*, 2022)

The issue at hand pertains to the management of natural resources and their ecosystems within the GSK-BB BR region. Implementing the biosphere reserve concept in GSK-BB is seen as a potential solution to the challenges encountered in managing conservation areas. A significant obstacle arises from the shortage of human resources allocated to oversee these areas, resulting in suboptimal control over the wildlife reserves. Consequently, instances of illegal activities and encroachment for activities like oil palm and rubber plantations, as well as agriculture, have occurred. However, the introduction of the biosphere reserve concept and the zoning system of the GSK-BB BR have brought about a shift in perspectives and attitudes among stakeholders concerning the significance of conservation areas. Socialization efforts and community engagement have led to a change in mindset and a collective agreement to refrain from unlawful activities and encroachment within the wildlife reserve and protected areas, recognized as the core areas of the GSK-BB BR. The management of conservation areas, such as the two wildlife sanctuaries, falls under the jurisdiction of Riau BBKSDA. Meanwhile, the responsibility for the concession area, designated as a production forest but conserved, lies with the concession holder. Through mutual agreements between private sector entities and stakeholders, these areas are permanently conserved and integrated into the core areas of the GSK-BB BR. The adoption of the zoning system facilitated by the GSK-BB BR has enabled parties to address the issue and delineate authority for managing the region effectively. Furthermore, the demarcation of the biosphere reserve area serves as a platform for coordinating and deliberating on issues among key stakeholders, fostering collaboration in finding viable solutions.

Establishing the GSK-BB BR Management Coordinating Board serves as a platform for stakeholders to collaborate and address challenges encountered within the region. Additionally,

developing the "Integrated Management Plan and Action Plan" of the GSK-BB BR, tailored to the interests of all parties involved, provides a framework for coordinating regional development initiatives to be executed. Acquiring biosphere status enhances the significance of natural resources within GSK-BB in addressing these issues. For instance, the involvement of communities and administrators with local governments in managing core, buffer, and transition areas, predominantly comprised of Wildlife Sanctuaries, Plantations, and Forestry Plant Industries, offers additional benefits through biosphere status. The planning scheme for the development of the GSK-BB biosphere reserve governs development activities within the reserve area. By incorporating biosphere reserve principles and concepts into planning schemes, it aids in reducing and regulating resource utilization within this zone.

3.4. Stakeholders Analysis

The GSK-BB Biosphere Reserve initiative is conceptualized as a pioneering model for a novel collaboration involving the public, business sector, and multiple stakeholders in conservation, protection, community development, and sustainable forest management. This partnership encompasses various entities including local and national governments, such as the Ministry of Environment and Forestry and the Indonesia MAB Program National Committee, research institutions like the Indonesian Institute of Sciences (LIPI), the provincial government of Riau along with the Bengkalis and Siak regencies, the 80 villages located within the biosphere reserve spanning these two regencies, as well as other stakeholders. Additionally, the private sector, represented by Sinarmas Forestry, plays a pivotal role in this distinctive alliance, marking the first-ever public-private MAB-UNESCO Program partnership to be implemented on a global scale.

The amendment and enhancement of the management framework for the GSK-BB BR involved revising Governor's Decree No. Kpts 920/V/2010, which was subsequently rectified by Governor's Decree No. Kpts.7/1//2017. This rectification addressed changes in the nomenclature of governmental bodies and improved the organizational structure to foster greater effectiveness and cooperation among stakeholders. The institutional management of the GSK-BB biosphere reserve is structured around the Coordinating Board for the Management of the GSK-BB BR, administratively under the Regional Development Planning Agency (BAPPEDA) of Riau Province. This coordinating entity, directly overseen by the Riau Governor, is responsible for facilitating collaboration among stakeholders to formulate policies and plans for managing and developing the biosphere reserve. It coordinates policy planning for biodiversity conservation, sustainable economic development, and logistics support within the GSK-BB Biosphere Reserve area. Additionally, it oversees the development and implementation of the management plan, supervises reserve management activities, promotes the use of the reserve's logo on products and services, and recommends initiatives to advance the reserve's objectives.

To achieve synergies and sustainable regional development objectives, the coordinating Board responsible for overseeing the biosphere reserve aims to enhance the involvement of stakeholders and promote active collaboration among them (involving various actors and local entities, both public and private) who are members of the GSK-BB Biosphere Reserve Management Coordinating Board. The coordination institutions for managing the GSK-BB biosphere reserve are outlined in Governor of Riau Decree No. Kpts 7/1/2017.

The importance of collaboration across sectors underscores the significance of collaboration towards a common goal. Previously, the concept of "pentahelix" was employed, embracing elements of government (both central and regional), businesses, academia, non-governmental organizations (NGOs), and the community or society. Now, there is an additional stakeholder, which is the media, making a total of six collaborating elements referred to as "hexahelix". Media involvement is crucial as a platform for disseminating the performance and best practices of biosphere reserves and to enhance public awareness regarding the importance of socio-economic and environmental balance in resource management. Furthermore, the media can play a role in promoting biosphere reserves as ecotourism destinations that support ecotourism development within these reserves. Nonetheless, the community or society remains

the fundamental basis for implementing sustainable biosphere reserve management. They are at the forefront when it comes to implementing management programs within biosphere reserves, including the utilization of non-timber forest products (NTFPs), environmental services, area patrols, fire control, wildlife conflict mitigation, and the prevention of hunting and wildlife trade.

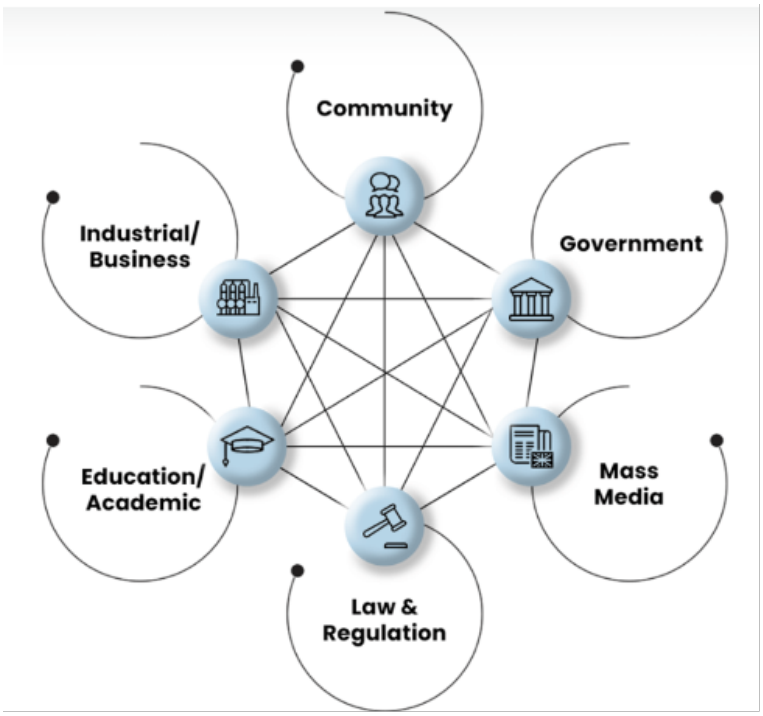

Figure 11. The Hexahelix collaboration scheme (Zakaria *et al.*, 2019).

The main key to the success of this model is synergy and strong commitment between stakeholders (Figure 11). Apart from making it easier to achieve the development goals of Biosphere Reserve, the Hexahelix Collaboration also helps prevent overlapping policies and programs between interested parties. In the development of Biosphere Reserve, the business world or companies become the locomotive that drives synergy between stakeholders and the development of Biosphere Reserve. The role of the media will strengthen the branding of biosphere reserves so that they can escalate the success of biosphere reserve management because the management of biosphere reserves is supervised and viewed by the public.

3.5. Integrated Strategic Management Plan (ISMP)

3.5.1. Zoning and Land Use

As outlined in the "Legal Framework for the Network of World Biosphere Reserves," the management of Biosphere Reserves is governed and executed through a zoning system or area division, which includes: (a) core areas, (b) buffer zones, and (c) transition areas. The GSK-BB BR is divided into Core Areas, Buffer Zones, and Transition Areas. These three zones form an integrated management unit for sustainable development as mandated by the MAB-UNESCO protocol. Transition Areas are typically managed by local governments because they involve community land use aimed at improving welfare. The Core Areas and Buffer Zones, on the other hand, are ideally regions of unique biodiversity, conservation activity where wildlife movement and forest vegetation growth can be utilized for future research and bioprospecting activities (Figure 12).

Figure 12. The illustration of the GSK-BB BR shows the division into Core Areas, Buffer Zones, and Transition Areas. These three areas form an integrated management unit for sustainable development as established by the MAB-UNESCO protocol. Transition Areas are usually managed by local governments as they involve community use of land for improving welfare. Ideally, the Core Areas and Buffer Zones are regions of unique biodiversity, where the movement of wildlife and the growth of forest vegetation can be utilized for future research and bioprospecting activities.

a. Core Areas

The core areas of the Biosphere Reserve require enduring legal protection to ensure the sustainability of its biodiversity. This protection extends beyond formal legal statuses, such as government-established wildlife sanctuaries, to include customary safeguards and community agreements, provided they endure over time. Natural forest areas retain their status as production forests unless converted into non-natural forest, allowing them to serve as the core areas of the Biosphere Reserve. Designating an area as the core of the Biosphere Reserve does not alter its existing legal status. Permissible activities within the core area include research, education, ecosystem monitoring, and other endeavors that preserve natural ecosystems, such as utilizing environmental services for carbon sequestration and promoting nature tourism (doc. Management plans).

The core areas of the GSK-BB BR spans approximately 178,722 hectares, comprising a blend of conservation forest and non-converted natural production forest. This combination marks a novel approach in Indonesia, diverging from the core area designation of national parks in the country's six existing Biosphere Reserves. Within the core area, the GSK-BB Biosphere Reserve encompasses the Giam Siak Kecil Wildlife Reserve (approximately 84,967 ha), the Bukit Batu Wildlife Reserve (approximately 21,500 ha), and the production forest area of the Sinar Mas Forestry business group (approximately 72,255 ha, including PT. Dexter Timber, Perkasa Indonesia 31,475 ha, PT Satria Perkasa Agung 23,383 ha, PT Sekato Pratama Makmur 12,302 ha, and PT Bukit Batu Hutani Alam 5,095 ha).

The biodiversity within the core areas of the GSK-BB BR is exceptionally rich, thriving within largely intact ecosystems. A BRIN study in 2007 reported the presence of at least 126 tree species from 67 genera and 34 families. This number is expected to rise when accounting for shrub and herb species. Notably, dominant tree genera include *Calophyllum*, *Camnosperma*, *Dyera*, *Alstonia*, *Shorea*, *Gonystylus*, and *Palaquium*. Of particular interest are the numerous species of ramin (*Gonystylus bancanus*), gaharu (*Aquilaria beccariana*), meranti flowers (*Shorea teysmanniana*), and punak (*Tetramerista glabra*),

which serve as indicators of healthy swamp forests. Ramin and gaharu are identified as superior species suitable for development in buffer zones and transition areas due to their compliance with the Ministry of Environment and Forestry criteria for cultivation in degraded forest areas. However, A. beccariana is not native trees from peatland ecosystems.

The fauna diversity within the core area remains robust, encompassing fish inhabiting river ecosystems and small lakes. The BRIN study (2007) recorded approximately 30 fish species with broad distributions, including economically valuable species such as tapah fish (*Wallago attu*), toman fish (*Channa* spp.), twill fish (*Ballontia hasseltii*), and lays fish (*Kryptopterus macrocephalus*). Lays fish, in particular, is popular in the Pekanbaru market, presenting an opportunity for development as a souvenir from the GSK-BB BR.

The swamp and lake forest ecosystem within GSK-BB BR serves as an ideal habitat for various bird species, including hornbills (*Anthracoceros malayanus*, *Aceros corrugatus*), long-tailed parrots (*Psittacula longicauda*), and numerous water bird species (*Mycteria cinerea*, *Ciconia stormi*, etc.). Wetland International and Birdlife foundations have identified the GSK-BB BR as a critical transit area for migratory birds, emphasizing the conservation importance of the region for avian species.

Despite the richness of biodiversity, the diversity of amphibians and reptiles in the core area remains comparatively low. The BRIN study (2007) recorded 11 amphibian species out of 93 in Sumatra, and 9 snake species out of 133 and 3 lizard species out of 72. This lower diversity may be attributed to the limited intensity of research on amphibians and reptiles in GSK-BB BR. Noteworthy species include labi-labi (*Amyda cartilaginea*) and sinyulong (*Tomistoma schlegelii*). Labi-labi, in particular, presents an opportunity for captive cultivation due to its economic value and demand in markets such as Singapore and Hong Kong.

The Giam Siak Kecil Wildlife Reserve and Bukit Batu Wildlife Reserve, serving as the core areas of the Giam Siak Kecil - Bukit Batu Biosphere Reserve, host a fascinating array of mammal species. According to a report by the Conservation of Natural Resources Agency (BBKSDA) Riau, these include langurs (*Trachypithecus cristatus*), sun bears (*Helarctos malayanus*), tapirs (*Tapirus indicus*), elephants (*Elephas maximus sumatranus*), and Sumatran tigers (*Panthera tigris sumatrae*). While these species may have inhabited the area decades ago when Sumatra was predominantly forested, their populations are now threatened due to forest fragmentation. Urgent research is needed to assess the population and distribution of Sumatran tapirs, elephants, and tigers within the GSK-BB BR.

In 2007, BRIN initiated detailed insect research in the core area, recognizing the pivotal role of insects in plant regeneration cycles and the importance of understanding their potential as pests. Various types of honey bees have been identified, with honey harvesting practiced by local communities. Honey bee cultivation holds promise for development in buffer zones and transition areas, supported by existing technology. Investigating insect pests and their predators within the core area is crucial for minimizing reliance on insecticides, and ensuring positive interactions between the core area and buffer zones (Figure 13)

b. Buffer Zone

The buffer zone of the Biosphere Reserve typically surrounds or adjoins the core area, serving to shield the core from detrimental human activities. Within this zone, various ecologically responsible activities can occur, including research, training, education, and forms of ecotourism. Additionally, sustainable utilization of renewable natural resources such as forest management, agroforestry, and other sustainable cultivation practices can be undertaken.

In the case of the GSK-BB Biosphere Reserve, the buffer zone predominantly comprises industrial plantation forests, accounting for 88% of its area, with a small portion allocated to other land uses. Encompassing approximately 195,259 hectares, this zone includes industrial forest plantation areas

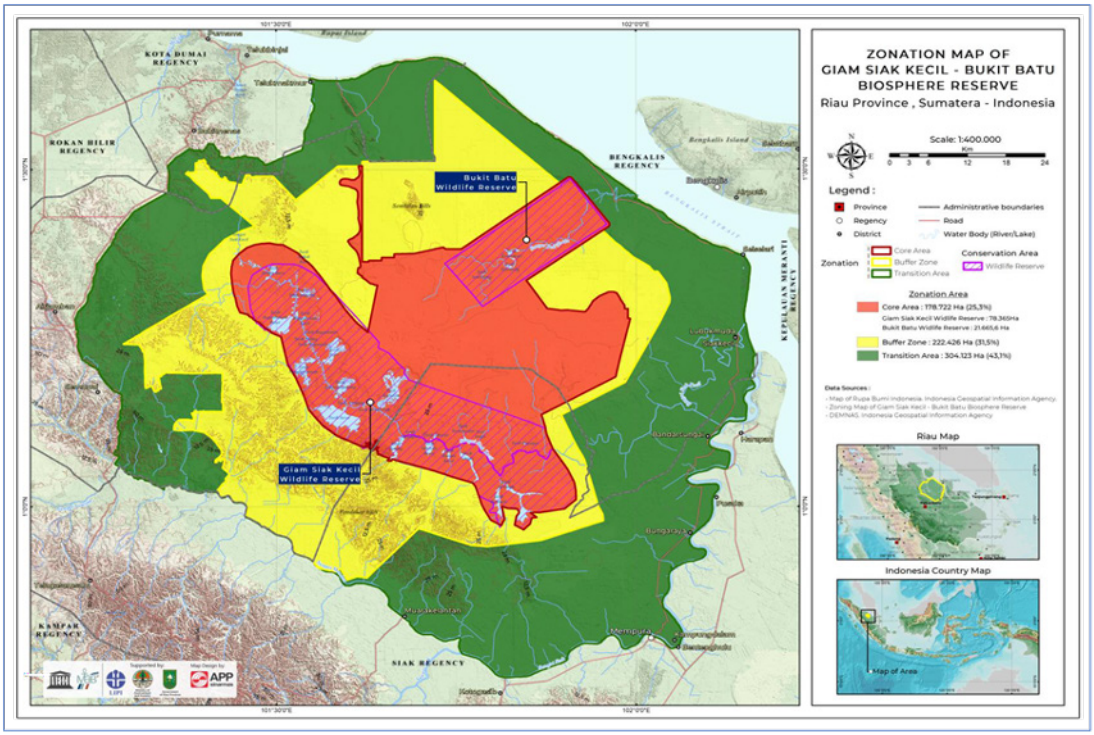

Figure 13. Map illustrating the zoning of the Giam Siak Kecil-Bukit Batu Biosphere Reserve (GSK-BB BR) in Riau Province, Indonesia.

(HTI) managed by the Sinar Mas Forestry business group, namely: PT. Arara Abadi, PT. Balai Kayang Mandiri, PT. Bukit Batu Natural Forest, PT. Riau Abadi Lestari, PT. Sakato Pratama Makmur, PT. Satria Perkasa Agung, alongside a minor section of non-Sinar Mas Forestry territory.

Ensuring the stability of boundaries and the authority of the buffer zone is paramount for maintaining the integrity of the core area, as it delineates clear responsibilities. APP Sinar Mas Forestry is expected to play a crucial role in safeguarding and preserving the core area by implementing forest plantation management practices aimed at minimizing disturbances and external threats to its integrity and sustainability. This management approach, sometimes referred to as the "ring concept," has been previously employed, notably in the establishment of Tesso Nilo National Park in Riau Province.

Conversely, water supply needs for *Acacia* and *Eucalyptus* plants and their pulp industry are sourced from the core areas where the ecosystem is carefully maintained. Canal construction in plantation forest management endeavors to regulate and maintain an optimal water level, thereby mitigating the risk of drying out the peat layer, which is highly susceptible to fire hazards.

c. Transition Area(s)

The outermost and most extensive region of the GSK-BB BR serves as the transition areas, often referred to as a "collaboration areas." Here, various cultivation activities involving stakeholders and the local community take place, emphasizing sustainable development models. The transition areas functions as a platform for implementing diverse sustainable development approaches, where local communities, conservation organizations, cultural groups, private entrepreneurs, and other stakeholders collaborate to manage and develop the area's resources.

It serves as a platform for introducing Biosphere Reserve development through collaborative efforts involving reserve managers, government entities, local administrations, businesses, non-governmental organizations, landowners, researchers, extension workers, community leaders, and other stakeholders. This area typically extends beyond the core and buffer zones and requires a clear but flexible outer

boundary that can adapt to evolving challenges. Ecologically, buffer zones and transition areas represent landscapes comprising multiple ecosystems, crucial for ensuring the functionality of core ecosystems. Additionally, Biosphere Reserve management must focus on biodiversity conservation not only within core areas but also in buffer zones and transition areas, whether naturally occurring in protected areas or deliberately cultivated for ex-situ conservation efforts.

The transition areas of the GSK-BB BR spans approximately 304,123 hectares, primarily encompassing non-forest concessions, with a small segment dedicated to Sinar Mas Forestry plantation forests covering around 5,665 hectares. Bounded by natural features such as the Mandau River - Siak River to its mouth in the Long Strait to the south and east, the Bengkalis Strait coast to the north, and the road from Guntung to Duri to the Mandau River bridge at Balai Pungut to the west, clarity regarding the outer boundary of this transition areas is crucial for identifying stakeholders within the GSK-BB BR.

The GSK-BB BR aims to conserve examples of the Sumatran peat forest ecoregion, featuring numerous "tasik" (small lakes). Situated in the Siak Kecil watershed, it plays a pivotal role in maintaining the eco-hydrological balance of the surrounding area, including Siak Sri Indrapura city. Hence, effective management planning is imperative, given the area's suitability for sustainable development implementation, especially in fulfilling the mandates outlined in Law no. 5 of 1990, focusing on the protection of life support systems, preservation of biodiversity, and sustainable use of natural resources and ecosystems.

Specifically, the management objectives of the GSK-BB BR include the preservation of biological resources and ecosystem balance to support community welfare, sustainable economic development, logistical support for conservation and sustainable development initiatives, zoning arrangements to secure conservation interests, management of natural resources and ecosystem diversity, sustainable utilization of resources for research and education, and enhancement of management capacity. The vision is to foster a harmonious and prosperous society through research, education, conservation, and sustainable resource utilization, alongside the empowerment of social, cultural, and economic wisdom within the local community. Based on collected data and considering the region's geographical attributes and interests, the GSK-BB Biosphere Reserve is envisioned as a distinctive landscape that contributes significantly to the prosperity and pride of Riau Province and Indonesia as a whole.

3.6. Organization and Execution of the Biosphere Reserve Concept

The management structure and format of a Biosphere Reserve vary in terms of legal authority, financial implications, and staffing levels. While generally identifiable, variations in field conditions significantly influence the management framework of each Biosphere Reserve. UNESCO's MAB program also refrains from dictating specific management structures or formats.

For instance, in Indonesia, there are currently 11 Biosphere Reserves with distinct characteristics and complexities. Although all have management structures akin to National Parks, they operate under different governance models. Some, like the Siberut Island and Komodo Biosphere Reserves, are situated within a single district, exhibiting simpler structures. Others, such as the Lore Lindu BR and Tanjung Puting BR, span two districts. The Cibodas BR covers three districts, while the Leuser BR extends across seven districts and two provinces. Consequently, implementing the Biosphere Reserve concept becomes a highly intricate process.

In general, the management structure of a Biosphere Reserve involves a collaboration of stakeholders, including the Directorate General of Conservation of Natural Resources and Ecosystems (KSDAE) under the Ministry of Environment and Forestry (KLHK), BRIN (National Research and Innovation Agency), universities, the Directorate General of Regional Development under the Ministry of Home Affairs, Regional Development Planning Agency (BAPPEDA), Regional Research and Development Agency (BALITBANGDA), local government, the private sector, non-governmental organizations (NGOs), traditional institutions, and the local community. Each of these entities plays a

role in implementing the Biosphere Reserve concept.

3.7. Integrated Management Plans of GSK-BB Biosphere Reserve

A Biosphere Reserve needs to have the necessary resources to attain its objectives. These resources may come in the form of a comprehensive strategy outlined in a Proposed Management Plan specifically tailored for the GSK-BB Biosphere Reserve. This plan should align with the principle that all conservation and non-conservation areas designated for forestry and non-forestry development must be managed in a manner that integrates them into local land use planning policies (SNBR, 1995; IUCN, 1994). The overarching aim is to achieve sustainable development across the landscape encompassing peat swamp forests, lakes, water systems, converted peatlands, plantation forests, agricultural areas, and settlements. Top of Form

The proposed Management Plan for the GSK-BB Biosphere Reserve is crafted with responsibility to ensure that management feels like a shared endeavor among various relevant institutions, especially stakeholders. Its primary objective is to provide clear policy direction for the area. Serving as a reference for all stakeholders, the Management Plan outlines detailed implementation of various specific activities to be undertaken within defined timeframes and spatial parameters. Therefore, the proposed GSK-BB Biosphere Reserve Management Plan is a dynamic document that can evolve continuously in response to changing circumstances.

A Biosphere Reserve should act as a facilitator to integrate and coordinate the efforts of all stakeholders while acknowledging historical ownership rights of land or resources. The development of the GSK-BB BR Management Plan must involve key parties such as the Conservation of Natural Resources Agency (BKSDA) Riau, Regional Governments (Provincial and Regency), scientists, researchers, universities, and resource users including forest entrepreneurs, farmers, planters, and fishermen. This inclusive approach distinguishes Biosphere Reserves from other conservation area networks (Council of Europe, 1995) and differs from the management planning process of other conservation areas in Indonesia, such as National Parks. Biosphere Reserves do not adhere to specific legal standards, as their principles are rooted in the interface between scientific knowledge and local socio-economic and cultural conditions.

The Biosphere Reserve approach primarily aims to effectively involve local communities in decision-making and action implementation, with an international dimension and reference system. The zoning system and human activities within the Biosphere Reserve also engage a variety of partners. It is important to note that the largest part of the Biosphere Reserve will not be strictly “protected” without the consent of stakeholders. Notably, recent initiatives to define policies for ecosystem management beyond protected areas are based on stakeholder dialogue and conventions, aligning with the approach to managing Biosphere Reserves.

The scope of development activities illustrated in the pie chart (Figure 14) is extensive and comprehensive. These activities must be discussed with the established GSK-BB BR coordination Board, ensuring there is a clear division of tasks, prioritized targets, shared funding strategies, and proper evaluation and monitoring processes. The scope of activities is highly complex, and although theoretically sound, it is challenging to coordinate and implement effectively. Therefore, it is essential to break down these activities and have discussions at the ground level to identify the urgent needs of the community in the transition area and determine what support is required. Without thorough discussion and information sharing, it will be difficult to execute the proposed program effectively.

Figure 14. Scope and Activity Program Development, including collaborative research logistics and accompanying innovations, to be achieved in GSK-BB BR in Riau Province for the period 2022-2026.

3.8. Community Engagement

Community engagement in Biosphere Reserve initiatives involves empowering the community through participation in planning, implementation, and monitoring and evaluation. For instance, local community representatives participate in regional development planning discussions organized annually by the Bengkalis Regency and Siak Regency governments, involving villages, sub-districts, and districts. Additionally, locals contribute to long-term conservation area management plans and technical plans for the GSK-BB BR's core area, such as community empowerment initiatives.

Furthermore, community involvement extends to activities like forest patrols, ecosystem restoration efforts, combating illegal activities, forest fire prevention, utilization of non-timber forest products (NTFPs), and engagement in tourism-related tasks like guiding tours and providing lodging services. The community plays an active role in Biosphere Reserve development programs, participating in income-generating activities and alternative livelihood programs while actively combating illegal and unsustainable practices that threaten environmental integrity.

Several community engagement efforts have been conducted by the managers of GSK-BB BR in line with the vision and mission of biosphere reserve development, making them worthy to be continued and expanded into a model for a wider area. Some of the community engagement activities that are worth continuing include:

a. Implementation of a forest fire prevention program, which involves the establishment of community groups focused on fire prevention and "manggala agni" or fire brigade community groups.

b. Collaboration to combat illegal activities through joint patrols involving law enforcement agencies, conservation area managers, the private sector, and community participation.

c. Raising public awareness about forest fire management by forming fire-aware communities and "manggala agni" or fire brigade community groups.

d. Enhancing the community's role in managing natural resources and their environment through participatory programs aimed at promoting sustainable resource use.

e. Establishment of a Community Development Training Center.

f. Implementation of a Conservation Village Program by the Natural Resources Conservation Agency, Riau (BBKSDA Riau).

g. Implementation of the Desa Makmur Peduli Api (DMPA) Program.

h. Natural Research laboratory for research and development of Socio-ecological topics

The establishment of the Community Development Training Center within the transition areas of the GSK-BB BR was initiated by the private sector, specifically Indah Kiat Pulp and Paper. Its primary objective is to support local communities in enhancing their agricultural activities, including plantation management, social forestry, food agriculture, horticulture, post-harvest handling, and forest fire prevention. Moreover, the center serves as a venue for students to conduct thesis research and for agricultural personnel and environmentalists to expand their knowledge base. Over the past decade, more than 350 farmers and 50 students have benefitted from the center's training programs. Additionally, the GSK-BB BR has served as a valuable natural laboratory for research in various scientific disciplines over the last decade, attracting researchers from local, national, and international levels. Research topics encompass a wide range of areas, including biological diversity, socio-cultural aspects, peatland studies, landscape ecosystem management, water management, carbon stock analysis, climate change, biosphere reserve product development, and community development, among others.

Figure 15. Community Training and Development Center in GSK-BB BR.

The BBKSDA Riau's rural community development initiative surrounding conservation areas encompasses various facets such as natural resource preservation, protection of conservation zones, fire prevention and management, and agricultural endeavors like horticultural and plantation cultivation, fisheries, livestock farming, beekeeping, and other production ventures. Forestry-related activities involve ecosystem restoration, tree planting initiatives, land rehabilitation efforts, and the establishment of a "Fire Care Society" aimed at preventing and addressing forest and land fires in the GSK-BB BR area through collaboration with local authorities (Figure 15).

Young individuals are also actively engaged in initiatives within the GSK-BB BR, participating in community gatherings and nature enthusiast groups throughout Bengkalis Regency and Siak Regency. They are actively involved in promoting environmental conservation efforts, including tree planting, land restoration, forest fire prevention, campaigns against illegal activities, river cleanup, and other

environmental preservation activities. Additionally, young people are acquiring various skills pertinent to peat forest restoration endeavors, learning about key plant species that thrive in peat forests, the unique characteristics of such ecosystems, and more.

Another best practive model of community engagement is the Desa Makmur Peduli Api (DMPA) Program in the GSK-BB BR, which is grounded in the Integrated Forestry and Farming System (IFFS). This participatory community engagement program aims to foster greater livelihood diversification for forest communities, empower them, reduce fire incidents, and enhance relationships between forest communities and other stakeholders, especially conservation area management and forestry companies. The prioritized criteria used in selecting beneficiary villages include: villages situated within or near conservation forest areas (core areas of a biosphere reserve) or within buffer zones; villagers closely interact with forest resources in the biosphere reserve's buffer zone; and villages with a recent history of forest fires, illegal logging, or deforestation within the last three years.

Figure 16. Desa Makmur Peduli Api (DMPA, Prosperous Village Cares for Fire) Programme.

The DMPA Program comprises two vital components: community livelihood enhancement and environmental sustainability (Figure 16). Firstly, concerning livelihood, the program aims to elevate household incomes, diversify livelihood options, sustain education and health standards, and maintain equity in livelihood opportunities. Secondly, in terms of environmental sustainability, the program endeavors to preserve trees and vegetation in the landscape and reduce the incidence of fire. By the end of 2019, the DMPA had been implemented in 85 villages within the GSK-BB BR and 236 villages in Riau Province. A primary focus of the program is to integrate community development initiatives with market access to optimize commercial prospects, boost income, and ensure community benefits. Specifically in 2019, efforts were concentrated on establishing connections between markets and agricultural communities, with instances of facilitating direct purchases of community products, such as compost, by industrial forest plantation companies. Working in tandem with the Integrated Fire Management Strategy, the program aims to intensify efforts in fire prevention by closely monitoring fire occurrences near DMPA project villages.

Challenges encountered and lessons learned include the need to sustain program momentum, despite resource limitations and barriers to accessing external markets. Strategies to address these challenges involve linking markets with community farmers and purchasing community products, like compost, and addressing logistical hurdles. Emphasis is placed on enhancing the quality of community products to foster growth and improvement in program-impacted villages. Collaboration with villages surrounding conservation areas is crucial to expanding program coverage, with approximately 30% of

village communities estimated to be reached thus far. Increasing profits from the program hinges on two key mechanisms: maximizing the capacity of village institutions such as cooperatives and Village-Owned Enterprises (BUMDES), and overcoming market access barriers at local, national, and international levels to ensure program sustainability.

The community engagement that has been implemented at CV GSK-BB BR is currently in line with recommendations from Gevisioner, et al (2019) regarding A Sustainable Community Empowerment Model, in which integrating local communities in environmental conservation efforts and developing sustainable economic practices to ensure the long-term health and stability of the GSK-BB biosphere reserve. This model recommended to strengthening the capacity and motivation of local institutions through training and support, encouraging community participation and private sector involvement in institutional activities, and developing strategies that promote creativity and innovation in community empowerment initiatives.

3.9. Sustainable Tourism

The GSK-BB BR holds immense potential for the advancement of tropical nature tourism. Its tourism appeal is diverse, unique, and strategically positioned for the Malaysian and Singaporean tourist markets. It is anticipated to emerge as a premier ecotourism destination on the travel landscape in the years to come. The Giam Siak Kecil Wildlife Reserve offers a distinctive ecosystem of peat swamp forests, with its intricate network of rivers and lakes, diverse flora, and fauna, making it an ideal candidate for various environmental services. This includes research, educational endeavors, and training programs tailored to a wide audience, alongside limited eco-tourism development. Prominent natural attractions such as Tasik Serai, Tasik Betung, and the Little Siak River further enhance its appeal. Similarly, the Bukit Batu Wildlife Reserve presents significant potential for natural tourism, notably with the presence of the Tapung River winding through the sanctuary. This offers opportunities for leisurely boat rides, providing visitors with picturesque views of the surrounding forest. Additionally, activities like bird watching and gentle treks within the forested areas contribute to the reserve's allure for eco-tourism.

The GSK-BB BR area can be segmented into three distinct tourism development zones: the core area representing natural assets, the residential area highlighting cultural elements, and the rivers and lakes area focusing on adventure-oriented activities. Development initiatives are tailored to the characteristics of each region. The core area is primarily geared towards educational and research tours, encompassing biodiversity, peat swamp forest ecology, lake ecosystems, and geological history. The buffer zone, centered on industrial plantation forests, aims at promoting educational and research tourism, while agro-ecosystems and settlements prioritize community-based eco-tourism. Adventure tourism is emphasized in the river and lake areas, along with forest trekking, tracing historical trade routes of the Siak Sri Indrapura Kingdom across the Siak River, the Siak Kecil river, and exploring ancient rubber plantations.

Tourism development within the GSK-BB BR is focused on nature and eco-tourism, emphasizing special interest tourism, with physical development tailored to a small scale and preserving the original cultural architecture of the local community. Management responsibilities are entrusted to cooperatives and the local populace. However, the ecotourism program scheme within the GSK-BB Biosphere Reserve extends beyond the natural beauty or the allure of wildlife in protected forests. The local community can also showcase a variety of culinary delights unique to the Riau province. For instance, in Bengkalis Regency, the cultivation of sago plants is prevalent, serving as a source of flour for various rice substitute delicacies such as noodles, cakes, and over 300 other sago-based dishes that are consumed and traded on a daily basis.

The growing recognition of the GSK-BB BR as a conservation hub for tropical peat swamp forests, coupled with its potential for specialized and cultural tourism, has spurred governmental and community efforts to enhance infrastructure and tourism facilities. These initiatives encompass improvements in

transportation, accommodation, attraction development, public awareness campaigns, and workforce training. Like other biosphere reserves in Indonesia, the GSK-BB BR is evolving into an ecosystem services provider, catering to both local communities and visitors from across Indonesia. However, inadequate infrastructure currently impedes the development of specialized tourism in the area, necessitating collaboration between the reserve management Board, private sector, universities, and local governments to devise a comprehensive development strategy. Working groups and consultants are actively formulating plans for sustainable and appealing ecosystem services within the GSK-BB BR.

The promotion of natural and cultural tourism serves as the third hallmark of the GSK-BB BR, fostering the sustainable utilization of living natural resources and their ecosystems. It is envisaged as a catalyst for boosting ecotourism, leveraging the allure of nature and culture to enhance the well-being of communities in the vicinity. "Experience it all: nature, culture, and adventure in the Giam Siak Kecil - Bukit Batu Biosphere Reserve."

3.10. Monitoring and Enforcement

Monitoring and enforcement in a Biosphere Reserve according to the MAB-UNESCO guidelines involve several key components to ensure the protection and sustainable management of these areas:

a. **Integrated Management Plans**: Each biosphere reserve must develop and implement a comprehensive management plan that outlines conservation objectives, sustainable use practices, and development goals. This plan is created in consultation with local communities, stakeholders, and scientists to ensure it is both practical and effective.

b. **Regular Monitoring**: Continuous monitoring of the biosphere reserve's ecological, socio-economic, and cultural conditions is essential. This includes tracking changes in biodiversity, assessing the health of ecosystems, and evaluating the impact of human activities. Advanced technologies like remote sensing, GIS, and field surveys are often employed for accurate data collection.

c. **Scientific Research**: Ongoing scientific research is crucial for understanding the dynamics of the biosphere reserve. Research initiatives focus on ecology, climate change, species behavior, and the socio-economic aspects of the reserve. Findings from research projects guide adaptive management practices and policy decisions.

d. **Community Involvement**: Effective monitoring and enforcement require the active involvement of local communities. Community members are often engaged in monitoring activities and are educated about sustainable practices. Their participation ensures that conservation efforts are culturally appropriate and economically beneficial to the local population.

e. **Enforcement of Regulations**: Biosphere reserves operate under a set of rules and regulations designed to protect the environment and promote sustainable use of resources. Enforcement mechanisms include patrolling, inspections, and penalties for non-compliance. Local authorities, reserve managers, and sometimes even community groups are responsible for enforcing these regulations.

f. **Periodic Review and Reporting**: Biosphere reserves undergo periodic reviews to assess their performance against established criteria. These reviews are conducted by external experts and involve stakeholder consultations. The results are reported to UNESCO, ensuring transparency and accountability.

g. **Adaptive Management**: The management approach is adaptive, meaning it evolves based on monitoring results and scientific research. Adaptive management allows for adjustments in strategies and practices to better address emerging challenges and opportunities.

h. **Capacity Building**: Training programs and capacity-building initiatives are implemented for reserve managers, local authorities, and community members. These programs enhance the skills and knowledge needed for effective monitoring, enforcement, and sustainable management.

By adhering to these guidelines, biosphere reserves can achieve their goals of conserving biodiversity, promoting sustainable development, and supporting local communities, while ensuring compliance with MAB-UNESCO standards.

3.11. Integrated Management Plan of Core Areas

3.11.1. Management Guidelines for Core area

The primary objective of one or more core zones is to conserve biodiversity through comprehensive and stringent protection measures, akin to those applied in nature reserve and conservation areas. Human activities involving the utilization of natural resources are strictly regulated, although scientific endeavors such as long-term monitoring or management practices based on ecological balance principles are permissible. Occasionally, the core area may coincide with or encompass an area that receives absolute full protection, such as a designated nature reserve.

In Indonesia, various conservation areas exist, including Nature Reserve Areas (Nature Reserves and Wildlife Sanctuaries) and Nature Conservation Areas (National Parks, Grand Forest Parks, Nature Tourism Parks). The Management Guidelines for Biosphere Reserves should underscore the interaction between buffer zones, transition areas, and core areas, as well as the relationship between the Biosphere Reserve as a whole and the surrounding areas. For instance, if there are migration routes, they should be situated sufficiently far from the core area.

Management guidelines for core areas can be delineated through steps or phases, which are not sequential stages but rather conceptual outlines, as follows:

Phase 1: Knowledge Inventory

- Survey of areas with legal protection, customary regulations, and types of protection
- Collection of data on flora, fauna, habitats, ecosystems, etc., including an inventory of research findings
- Compilation of Natural Resources (biodiversity): cataloging current species by taxonomic group
- Assessment of Cultural (including local knowledge) and landscape resources: inventorying sites and features of particular significance
- Review and analysis of existing literature and research
- Analysis of historical land use patterns
- Evaluation of past human activities' impact (from the onset of a particular era/time)
- Assessment of current human activities' impact (over the past 10 years)
- Examination of interplay between zones/areas

The compilation of research findings and literature analysis will be particularly beneficial if the GSK-BB Biosphere Reserve manager directs efforts towards establishing a comprehensive database.

Phase 2: Evaluation

- Knowledge Evaluation

Effective management of a Biosphere Reserve requires a solid foundation of knowledge about the area. Current and past research findings should be carefully evaluated to identify any gaps and enhance existing knowledge. This evaluation is crucial and the findings can serve as valuable guidance materials.

- Assessment of Protected Value and Rarity

  This step involves identifying sites, locations, or features of special significance within the core area and assessing their relative importance. A ranking system is established to prioritize the protection of species and habitats based on their rarity and importance.

- Evaluation of Protection Activities

  An assessment of the effectiveness of existing protection activities is necessary to address potential threats and vulnerabilities to the area's resources. It is important to evaluate standardized protection measures and determine their long-term viability. Additionally, activities with negative impacts should be relocated to buffer zones or other areas, while strategies to enhance protection in the core area should be prioritized.

Phase 3: Setting Goals

Clear objectives must be established for various management sub-units based on different ecosystems or units within a Cluster Biosphere Reserve. Considering the GSK-BB Biosphere Reserve's composition, it can be categorized as a Group Biosphere Reserve, comprising two Wildlife Reserves (Bukit Batu and Giam Siak Kecil) and non-converted Industrial Plant Forest (HTI) concession forests.

- Identification of Biodiversity Knowledge and Human Activity Impact Objectives

  Additional research programs, studies, and inventories may be required to supplement existing information. An environmental monitoring system should be established in the core area, aligned with national-level programs. Coordination between relevant institutions, such as the Directorate General of Conservation of Natural Resources and Ecosystem (KSDAE) and BRIN, is essential. Special attention should be given to research on resource use practices and quantifying the impacts of human activities.

- Identification of Management Objectives

  a. Define ideal goals.

  b. Identify resource actors and users and their sustainability goals for the core area.

  c. Identify obstacles, such as land tenure and land use issues, historical factors, and natural disasters.

  d. Identify resource use conflicts and areas of common interest.

  e. Define achievable objectives in consultation with stakeholders, informing resource users of priorities for natural resource protection projects.

  f. Finalize the necessary area delimitations.

- Identification of Nature Protection Goals

  Precisely defining the purpose of protecting natural resources is crucial. Long-term protective strategies should be prioritized over short-term policies to ensure effective conservation efforts.

Phase 4: Work Plan

Each objective related to management, research, and protected status must be detailed into a list of activities. These activities are then scheduled in a work plan, which includes estimated costs and a list of responsible agencies for funding. Additionally, the Biosphere Reserve manager's task is to engage partners to achieve these goals. Partners include various stakeholders such as central and local governments, including the Ministry of Environment and Forestry/Directorate General of Conservation of Natural Resources and Ecosystem (KSDAE), BRIN (National Research and Innovation Agency), BAPPENAS (National Development Planning Agency), Regional Development Planning Agency (BAPPEDA), Regional Research and Development Agency (BALITBANGDA), Ministry of Marine Affairs and Fisheries, Ministry of Home Affairs/Director General of Regional Development, Ministry of Education, Culture, Research and Technology, Ministry of Tourism, UNESCO, universities and research institutes, private sector/entrepreneurs, non-governmental organizations, and local traditional leaders. Before the work plan evaluation can be conducted, it is essential to elaborate on the work mechanism.

Phase 5: Work Plan Evaluation

An evaluation is conducted to assess the progress of each initiated activity and its alignment with specific objectives. This evaluation involves reviewing the progress of each activity, analyzing reasons for both success and failure, and determining what is needed to complete each activity. Ecological, sociological, technical, and economic insights are considered during evaluation. Ecological insights focus on changes in species and habitats over time, while sociological insights examine social changes and the impacts of various activities. Technical insights address specific management issues based on technical specifications, and economic insights assess the financial and human resources required to achieve goals. With a feedback mechanism in place, management can adjust objectives considering unforeseen events beyond their control, such as natural disasters or extreme weather events.

3.11.2. Buffer Zone Management Guidelines

The buffer zone serves a dual purpose of protecting the core area while ensuring the sustainable utilization of natural resources. Within this zone, activities should align with biodiversity conservation, possess economic and social value, and allow for experimental endeavors. Consequently, a range of ecologically responsible activities, including research, education, recreation, and sustainable resource use, can take place. Long-term ecological monitoring and the testing of alternative resource management practices are also integral to the buffer zone's function.

Aligned with Article 16 paragraph (2) of Law no. 5 of 1990, the UNESCO buffer zone concept designates an area outside the nature reserve that maintains its integrity. Management responsibility for the buffer zone rests with rightful landowners, with compliance to government regulations being imperative.

Phase 1: Identification

- Assess the status of knowledge concerning resource use practices and their impact on biodiversity, alongside current regulations governing land use and spatial planning.

- Conduct an inventory of resource utilization and management practices, encompassing various activities such as agriculture, forestry, tourism, and hunting.
- Catalog existing regulations at national, provincial, and regional levels governing land use and spatial planning.
- Identify stakeholders involved in the buffer zone, including resource managers, users, and institutional partners.
- Compile a list of environmental training and education activities tailored to adults, children, and resource users.

Phase 2: Evaluation

- Conduct an ecological impact evaluation to review land use practices in terms of environmental quality and biodiversity preservation efforts.
- Perform an economic impact evaluation to measure the actual income generated from natural resource utilization activities.
- Undertake a social impact evaluation to identify beneficiaries of human activities and assess the overall quality of life.
- Analyze resource use practices in terms of social and generational equity and evaluate global equity considerations.
- Evaluate the alignment of land use plans with existing practices, considering implementation challenges.

Phase 3: Issue Resolution

- Disclose conflicts of interest/use and propose solutions among stakeholders, addressing conservation goals.
- Align interests between land users and managers to foster collaboration and effective management.
- Evaluate the effectiveness of consultations between Biosphere Reserve management and other partners.
- Assess the need for advanced knowledge to measure the ecological, socio-economic, and cultural impacts of various activities.
- Inventory land use suitability based on spatial plans to ensure compatibility.

Phase 4: Activity Proposals

- Define the ideal objective to outline compatible activities for maintaining biodiversity and conserving natural resources in the buffer zone.
- Propose management strategies that integrate new ideas and local knowledge, identifying partners, outlining protocols, selecting implementation areas, creating work and cost plans, establishing monitoring systems, and validating activities for broader application.

3.11.3. Management Guidelines for Transition Areas

The transition areas is intricately linked to the development zone, where Biosphere Reserve managers must apply sustainable development approaches. It serves as a hub for collaborative efforts among researchers, managers, local residents, and stakeholders to pilot projects addressing everyday challenges like waste management, water purification, sanitation, and transportation.

Clarity regarding the boundary map of the transition area is crucial, especially for training purposes, as activities conducted beyond these boundaries may still impact the Biosphere Reserve. External factors can significantly influence Biosphere Reserve management, exemplified by coastal and marine reserves susceptible to upstream catchment basin quality or industrial proximity.

Guidelines for managing transition areas align closely with sustainable development plans. Research efforts in these zones should prioritize sustainability, accompanied by educational initiatives to disseminate information about Biosphere Reserves. Initial engagement with residents in transition areas is vital to garner support and demonstrate the mutual benefits of the Reserve's presence. Collaboration among relevant institutions is essential, particularly when urban areas intersect with or adjoin the Biosphere Reserve.

Phase 1: Identification

- Inventory resource use and management practices such as agriculture, forestry, tourism, and industry.
- Assess the sustainability of these practices and their impact on biodiversity through ecological and socio-economic studies.
- Identify environmental challenges, especially those affecting buffer zones and core areas.
- Identify stakeholders, including local communities, land managers, users, and institutions like public bodies, professionals, educators, scientists, and associations.
- Document training, education, and informational activities targeting diverse demographics.
- Catalog cultural events and activities within the area.

Phase 2: Evaluation

Evaluation mirrors that of the buffer zone, tailored to promote sustainable development. After identifying relevant practices, their impact can be assessed using appropriate analytical tools, akin to those used for buffer zones.

Phase 3: Work Plan

Biosphere Reserves gain community acceptance when viewed as entities bolstering the local economy. Thus, in addition to sustainable development activities, management should:

- Support local economy initiatives, such as promoting local products or piloting projects, and facilitating quality labelling.
- Encourage environmentally responsible practices among institutional and public stakeholders to mitigate pollution.
- Establish platforms for showcasing sustainable activities like waste management, energy, transportation, agriculture, forestry, and ecotourism demonstrations.

IV. SUMMARY

Based on the desk study review of the biophysical data update for the Giam Siak Kecil Bukit Batu Biosphere Reserve (GSK-BB BR), derived from literature over the past 5-10 years, it is clear that the biophysical data obtained is not comprehensive, and logistical support for research and innovation has not been fully optimized. Research on peatland ecosystems requires substantial investment and specialized support for researchers, including expertise in flora, fauna, and forest microbes, necessitating competent research resources and advanced laboratory facilities. Socio-economic research in the transitional areas of the biosphere reserve is also crucial to understand the dynamics of communities with minimal awareness of the reserve's benefits. Daily economic pressures and the influence of individuals or groups seeking to convert forest land into plantation areas present significant challenges to the sustainable management of the GSK-BB BR.

The initial step recommended from the analysis and synthesis of this review is to address institutional reforms for the execution of GSK-BB BR management coordination. This involves promptly establishing a simple organization with leadership mandates from the Riau province to facilitate daily coordination of management activities with various community and industrial partners. This should be based on the biosphere reserve management plan document drafted for the 2022-2026 period. If any content in the document is deemed irrelevant, the management Board should promptly revise it in accordance with mutual agreement. A common issue is the election cycle for provincial and district leaders, which occurs every five years. The change in regional leadership represents a significant weakness in the management of biosphere reserves. New provincial or district leaders may not understand or support the ongoing management activities of biosphere reserves in Indonesia, potentially disrupting continuity and progress.

Strengthening the database with biophysical and socio-economic information is key to the successful sustainable development of the GSK-BB Biosphere Reserve in Riau province. To manage wildlife priorities in the GSK-BB BR effectively, consider the following recommendations, to conduct comprehensive surveys to assess the current population status of key wildlife species. This includes documenting population sizes, demographic structures, and reproductive success rates. Regular monitoring will help track changes over time and identify trends that require management intervention. To study and map the activity patterns and movement pathways of wildlife within the biosphere reserve. Use GPS tracking and camera traps to gather data on migration routes, feeding grounds, and breeding sites. Understanding these patterns is crucial for managing habitats and mitigating human-wildlife conflicts. To identify and analyze both external (e.g., climate change, human encroachment) and internal (e.g., disease, genetic diversity) factors that influence wildlife populations and behavior. Develop strategies to mitigate negative impacts, such as habitat restoration projects and anti-poaching measures. Document incidents of human-wildlife conflict, including the types of wildlife involved, locations of conflicts, and the extent of damage or injuries. Use this data to create conflict maps and develop targeted mitigation strategies to reduce these conflicts. To review and evaluate the effectiveness of previous wildlife management activities. This includes assessing the outcomes of conservation programs, habitat restoration efforts, and anti-poaching measures. Identify successful strategies and areas needing improvement. To sssess the current state of wildlife habitats and their carrying capacities. This involves analyzing habitat quality, availability of resources, and spatial requirements of different species. Use this information to guide habitat management and restoration efforts. To evaluate the application of scientific research and technology in wildlife management. This includes the use of remote sensing, GIS, and biotelemetry. Determine the effectiveness of these tools and explore opportunities for incorporating new technologies. To examine the potential for further development of wildlife management practices both in-situ (within natural habitats) and ex-situ (in captivity or controlled environments). Develop plans for breeding programs, reintroduction projects, and habitat enhancements. To identify and evaluate the roles of various stakeholders involved in wildlife management, including government agencies, local communities, NGOs, and researchers. Foster collaboration and ensure all stakeholders are engaged in the management process. To develop and implement standard operating procedures (SOPs) for preventing

and mitigating human-wildlife conflicts. These SOPs should include guidelines for community education, early warning systems, and rapid response teams to handle conflict situations. To establish SOPs for the translocation of wildlife, which should include criteria for selecting individuals for translocation, methods for capture and transport, and protocols for post-release monitoring. Ensure that translocation efforts are scientifically justified and ethically conducted. These recommendations aim to provide a comprehensive framework for managing wildlife priorities in the GSK-BB BR, ensuring sustainable conservation and minimizing conflicts with human activities.

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