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Utilizing Geographic Information Systems to Analyze Physical Conditions for Policymaking in Kapuas Hulu for Sustainable Development Goals

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Abstract - The Kapuas Hulu, situated in the heart of Kalimantan, is home to the Betung Kerihun National Park and Danau Sentarum. These areas play a crucial role in mitigating global climate change. The presence of sufficient forests is essential for maintaining ecosystem balance, but forest conservation is increasingly threatened by development pressures. Therefore, development policies in Kapuas Hulu must take into account the region's physical conditions, ecological boundaries, and functional limits to achieve the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land). This study uses Geographic Information Systems with a superimpose method to analyze variables such as environmental carrying capacity, ecoregions, disaster risks, and land cover. The analysis offers guidance for more holistic and integrated policy-making. It reveals that Kapuas Hulu has ecological and functional boundaries that extend beyond its administrative limits, making it a critical buffer zone, especially due to its location at the headwaters of the Kapuas River and within the Meratus Structural Complex Mountain Ecoregion. Based on the analysis, the recommended policies prioritize improving rural and urban settlement management, reducing disaster risks, enhancing conservation area and biodiversity management, and reducing air and water pollution levels.

Keywords: GIS, Physical Conditions, Policy-Making, Kapuas Hulu.

1 Introduction

Kapuas Hulu, situated in the upstream of West Kalimantan, holds significant ecological value due to the presence of Betung Kerihun National Park and Danau Sentarum. These conservation areas are critical in mitigating global climate change, serving as carbon sinks and preserving biodiversity [1], [2]. These conservation areas also the critical water catchment area for the Kapuas River, the longest river in Indonesia [3]. However, Kapuas Hulu face threats from development pressures, deforestation, natural resources exploitation, and land-use changes, all of which jeopardize environmental balance and the sustainability of natural resources, impacting the future. Such challenges are generally faced

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by West Kalimantan, where the expansion of plantation land, illegal logging, and deforestation have caused significant environmental degradation [4], [5].

As a developing region, Kapuas Hulu must harness its natural resources without exceeding its biophysical limits to prevent ecosystem degradation both now and in the future. This aligns with sustainable development, which balances economic growth, environmental protection, and social well-being to preserve natural resources for future generations [6]. Development policies in Kapuas Hulu must be carefully designed to meet the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land). SDG 11 emphasizes resilient and sustainable settlements, crucial for rural areas like Kapuas Hulu. SDG 13 highlights the region's role in climate mitigation through its forests, while SDG 15 stresses the protection of terrestrial ecosystems threatened by land conversion and human activities.

While existing studies have addressed deforestation and land-use change in Kalimantan, few have specifically focused on integrating spatial ecological data to inform SDG-oriented development policies in Kapuas Hulu. Although numerous thematic spatial datasets—such as: land cover, disaster risk, ecoregions, and ecosystem services—are available but these datasets are often analyzed in fragmented or presented at national or provincial scales making it lacking integrated interpretation and policy relevance. This fragmentation limits their usefulness for supporting sustainable development planning. This lack of integrative spatial analysis for local-level decision-making constitutes a significant research gap.

To ensure that development policies in Kapuas Hulu align with the SDGs, it is crucial to have a comprehensive understanding of the region's physical and ecological conditions. This necessitates data-driven approaches to capture the intricate relationship between human activities and environmental capacity. Geographic Information Systems (GIS) offer a robust tool for analyzing spatial data, thereby supporting holistic policymaking that balances conservation, disaster risk and development through spatial analysis [7], [8], [9]. This research aims to provide a thorough analysis of Kapuas Hulu's physical conditions by focusing on environmental carrying capacity, land cover, disaster risks, and ecological boundaries, with the goal of offering comprehensive environmentally-based policy recommendations. This research utilizes GIS by employing the superimposition method [10]. The integration of various spatial data allows for in-depth analysis, facilitating evidence-based policymaking.

2 Materials and methods

This desk-study research, conducted in 2024, focuses on Kapuas Hulu, West Kalimantan. This research employs a quantitative descriptive approach and Geographic Information Systems (GIS)-based spatial analysis to evaluate the physical conditions of Kapuas Hulu in the context of sustainable development planning and the achievement of SDGs. The research process comprises several key stages: data collection, spatial analysis, and policy recommendation formulation. Detailed below are the methods and materials used in this study:

2.1 Data Collection

The spatial analysis in this study utilized the most recent and officially published datasets available at the regency level. These datasets were selected based on their thematic relevance to the region's biophysical characteristics and the credibility of the issuing institutions, thereby ensuring both analytical validity and potential for inter-sectoral coordination. These include:

a. Administrative map (2023) from BAPPEDA Kapuas Hulu, used to delineate the official boundaries;
b. Land cover maps (1996, 2006, 2016, 2022) issued by the Ministry of Environment and Forestry (KLHK), used to analyze temporal trends in land use and vegetation cover;
c. Ecoregion map (2018) based on Ministerial Decree No. SK.8/MENLHK/SETJEN/PLA.3/1/2018 about the Determination of Indonesian Ecoregion Boundaries, used to define specific ecological zoning;
d. Landscape and natural vegetation characteristics maps (2021) based on Ministerial Decree No. SK.1272/MENLHK/SETJEN/PLA.3/12/2021 about the Determination of Landscape Characteristics and Natural Vegetation Characteristics of Indonesian Ecoregion Maps at a scale of 1:250,000, used to identify the dominant landscape structure, substrate composition, natural vegetation types, and to determine ecological boundaries;
e. Kapuas River Basin map (2012) produced by Balai Wilayah Sungai Kalimantan I and BAPPEDA West Kalimantan, used to define the watershed extent and determine ecological boundaries;
f. Disaster hazard and vulnerability map (for 2020–2024) from the West Kalimantan Provincial Government, used to assess exposure and resilience to natural hazards;
g. Ecosystem services map (2021–2022) derived from the Environmental Protection and Management Plan Document (DDDTLH) of Kapuas Hulu Regency, used to evaluate the ecosystem's capacity to provide essential services and human benefits.

2.2 Spatial Analysis Using GIS

The analysis was conducted using ArcGIS. The superimpose method was applied to integrate various layers of spatial data [11]. This approach allows for integrating various spatial data, providing a comprehensive overview of the region's environmental capacity and potential risks, and serving as a basis of spatially-informed policies for sustainable development planning.

The first analysis was to localize all datasets by overlaying them with the administrative boundaries of Kapuas Hulu. This localization is crucial for ensuring that all spatial data corresponds to the same geographic region, thus improving the consistency and precision of subsequent analysis. This provides an initial overview of the biophysical conditions within Kapuas Hulu and elaborate on the main environmental issues.

The next analysis involved delineating the ecological boundaries, which were derived from the ecoregion map (SK.1272/MENLHK/SETJEN/PLA.3/12/2021) and the Kapuas River Basin (DAS) map. This approach enables identification of the region's ecological influence, considering how changes occurring within Kapuas Hulu may affect surrounding areas with similar ecological characteristics. Such integration supports a more comprehensive understanding of ecological functions and environmental dynamics beyond administrative limits.

Further overlays were conducted in relation to selected Sustainable Development Goals (SDGs). For SDG 15 (Life on Land), land cover changes and ecosystem services maps were used to examine forest conditions and the availability of natural resources. For SDG 13 (Climate Action), analysis focused on disaster risk maps and ecosystem services related to climate hazards. For SDG 11 (Sustainable Cities and Communities), spatial overlays helped identify settlement areas that require management interventions to ensure ecological and social sustainability. This multi-layered approach supports holistic spatial-based policy recommendations aligned with regional SDG targets.

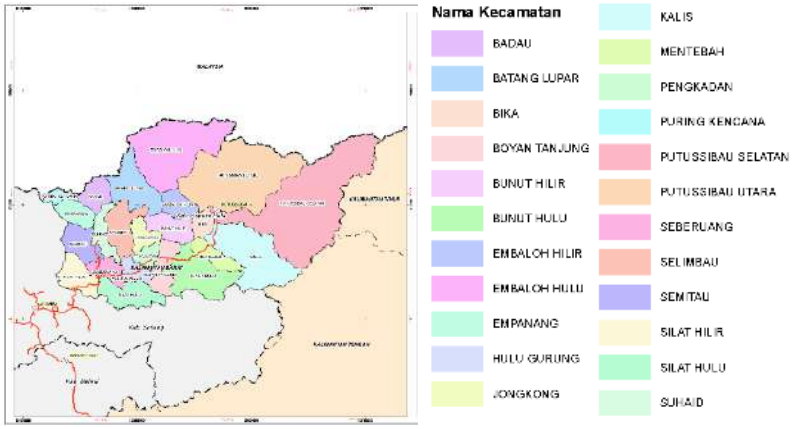
2.3 Policy Recommendation Formulation

Policy recommendations were developed based on the findings from the spatial analysis and refined through focus group discussions (FGDs), which helped prioritize issues relevant to the physical characteristics of the region. The spatial integration of ecological boundaries, land cover changes, disaster vulnerabilities, and ecosystem service capacities provided a comprehensive basis for identifying priority intervention zones. This ensured that the proposed actions are not only grounded in empirical data but also responsive to local needs and stakeholder perspectives. The primary focus of these policies includes improving settlement management, reducing disaster risks, enhancing conservation area management, and controlling air and water pollution. These recommendations are designed to contribute directly to the achievement of SDG 11, SDG 13, and SDG 15, by aligning environmental planning with sustainable development targets at the local scale.

3 Results and discussion

3.1 Administrative Area

Kapuas Hulu Regency is situated in the easternmost region of West Kalimantan Province, bordered to the north by Sarawak (Eastern Malaysia), to the east by Central Kalimantan Province and East Kalimantan Province, to the south by Central Kalimantan Province, Sintang Regency, and Melawi Regency, and to the west by Sintang Regency. Kapus Hulu is the largest regency in West Kalimantan covers 21.30% of the province's area, with a total area of 31,318.25 km² (3,131,824.61 Ha). Approximately 390,000 Ha (3,900 km²) consists of water areas, while the remaining about 2,594,200 Ha (25,942 km²) is land. According to the Decree of the Minister of Home Affairs Number 100.1.1-6117 of 2022, Kapuas Hulu consists of 23 districts divided into 4 sub-districts and 278 villages.



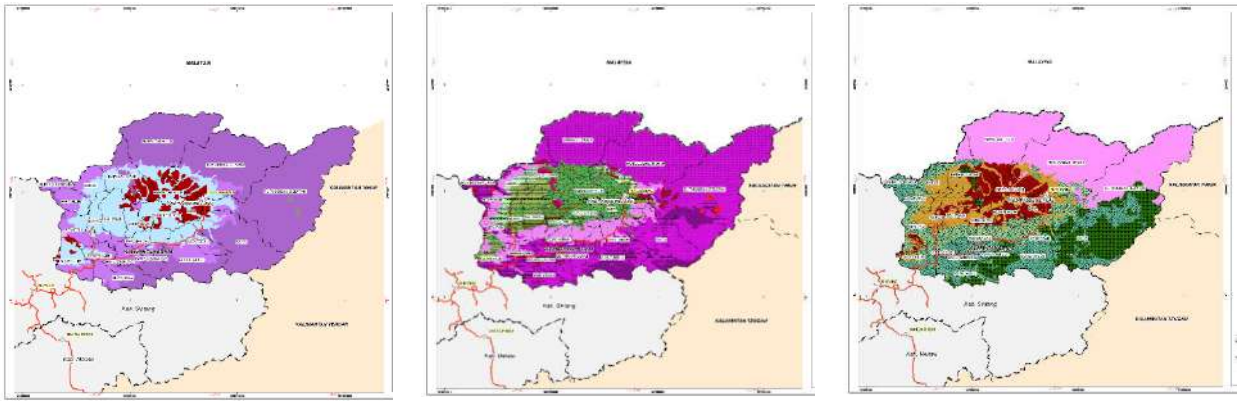
Source: Map of Administrative Boundaries of Districts/Cities in West Kalimantan Province, Scale 1:50,000, Bappeda West Kalimantan, 2023
Fig. 1. Administrative Map of Kapuas Hulu Regency in 2023

3.2 Ecological Area

Understanding the characteristics of landscapes involves various terms and approaches, such as land systems, bioregions, and ecoregions. Langgeng [12] emphasizes the importance of landform approaches in defining ecoregions. In Indonesia, the Ministry of Environment and Forestry has delineated the country's ecoregions through Ministerial Decree Number SK.8/MENLHK/SETJEN/PLA.3/1/2018. Specifically, Kapuas Hulu Regency comprises six ecoregions, with the Structural Mountains of the Meratus Complex being the largest at 1,750,223.55 hectares (55.76%). This is followed by the Kalimantan Fluvial Plain, covering 678,501.16 hectares

(21.62%), and the Structural Hills of the Meratus Complex, with an area of 506,672.82 hectares (16.14%). The Peatland Plain of the Kahayan–Kapuas–Mahakam Complex comprises 191,559.14 hectares (6.10%), while the Intrusive Mountains of Old Igneous Rocks of Kalimantan and the Structural Plain of the Meratus Complex cover 7,156.85 hectares (0.23%) and 4,537.68 hectares (0.14%), respectively. The region also features diverse landscapes, primarily lowland areas with lakes and swamps, while the highland areas consist of narrow swamps surrounded by hills, affected by seasonal inundation.

To enhance ecological understanding, the landscape of Kapuas Hulu was classified into 14 types based on the Decree of the Minister of Environment and Forestry Number SK 1272/MENLHK/SETJEN/PLA.3/12/2021, with structural fold hills of metamorphic rocks dominating at 1,032,802.18 hectares (32%). These hills, shaped by tectonic activity, provide essential surface water and natural tourism sites. Additionally, structural fold hills composed of non-carbonate sedimentary rocks make up 16.49% of the landscape. Vegetation in Kapuas Hulu includes nine types, with ultrabasic rock forest vegetation covering approximately 1,034,308.49 hectares (33%). This unique plant community thrives in nutrient-poor soils derived from serpentinite, supporting diverse flora and playing a vital role in water retention and soil stabilization. [13]. Overall, Kapuas Hulu exhibits a rich tapestry of ecoregions and landscapes, highlighting its ecological diversity and resilience.



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Source: Results of the analysis to the Minister of Environment and Forestry's Decree No. SK.8/MENLHK/SETJEN/PLA.3/1/2018 and SK 1272/MENLHK/SETJEN/PLA.3/12/2021 regarding the Establishment of Landscape Characteristics and Natural Vegetation Characteristics of the Indonesian Ecoregion Map at a scale of 1:250,000

Fig. 2. (a) Ecoregions Map of Kapuas Hulu Regency 2018 (b) Map of Landscape Characteristics of Kapuas Hulu Regency 2021 (c) Map of Natural Vegetation Characteristics in Kapuas Hulu Regency 2021.

3.3 Ecological Boundaries

In addition to administrative boundaries, the functional boundaries of Kapuas Hulu Regency were also considered in an effort to identify potential impacts of the development plans for Kapuas Hulu Regency on neighboring areas and/or the possible impacts of development plans in neighboring regions on Kapuas Hulu, particularly in relation to the regional environmental ecosystem. Functional areas are determined based on watershed boundaries, with the rationale that watersheds indicate whether the study area is an impacted region or a region that controls the impacts. Functional boundaries also serve as ecological limits, which are boundaries within which ecosystems can function sustainably without causing significant environmental damage.

The ecological boundaries in Kapuas Hulu Regency are reflected in the characteristics of the ecoregion (based on the Decree of the Minister of Environment and Forestry Number SK

1272/MENLHK/SETJEN/PLA.3/12/2021, while the functional boundaries are reflected by the watershed boundaries (based on the Map of the Kapuas Watershed, Ministry of Public Works, Kalimantan River Basin Office I, and the Provincial Development Planning Board of West Kalimantan, 2012).

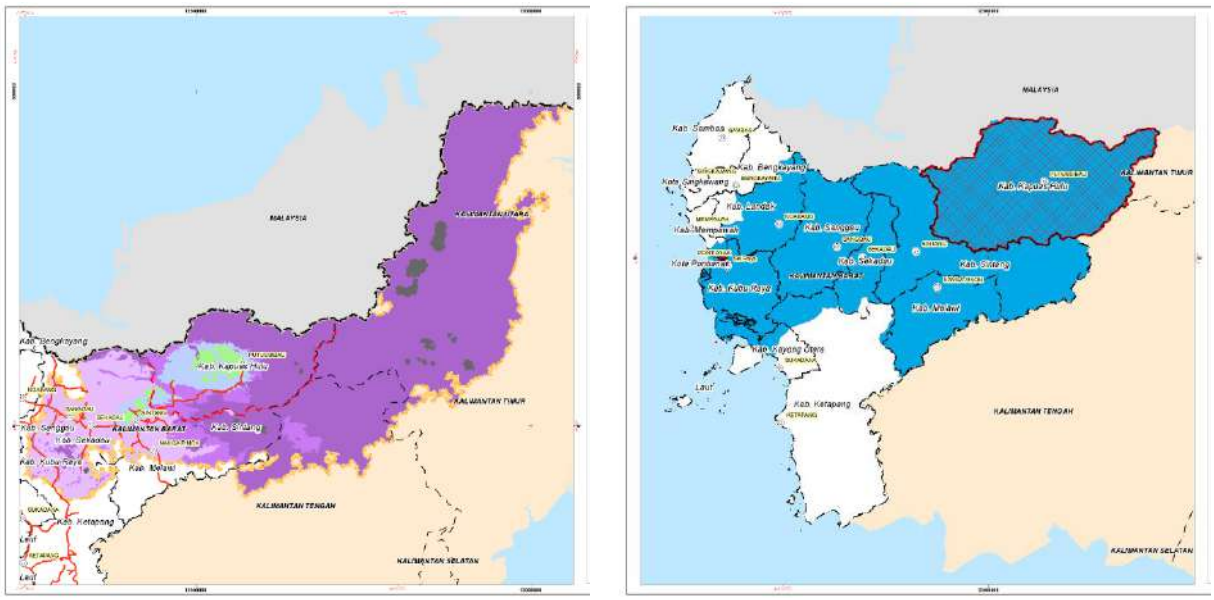
Based on its landscape characteristics and watershed boundaries, the ecological boundaries of Kapuas Hulu extend into the Melawi and Sintang regions, as well as the regencies in Central and East Kalimantan, which directly border Kapuas Hulu. Their interconnected landscape features suggest that any changes in one area are likely to affect the others. In addition to these regions, Sekadau, Sanggau, Ketapang, and several regencies in North Kalimantan also share similar environmental characteristics, though the influence of environmental changes in these regions may be less pronounced compared to those in direct proximity to Kapuas Hulu.

Table 1. Ecological Boundaries Kapuas Hulu

Region	Landscape Characteristics	Ha	%
Kapuas Hulu	Fluvial Plain of Kalimantan	678.534,88	3,92%
	Peatlands of the Kahayan–Kapuas–Mahakam Complex	191.564,98	1,11%
	Structural Plain of the Meratus Complex	4.537,70	0,03%
	Intrusive Mountains of Ancient Igneous Rocks of Kalimantan	7.156,85	0,04%
	Structural Mountains of the Meratus Complex	1.750.380,25	10,12%
	Structural Hills of the Meratus Complex	506.731,72	2,93%
Ketapang	Structural Plain of the Meratus Complex	429.046,03	2,48%
	Intrusive Mountains of Ancient Igneous Rocks of Kalimantan	2.201,55	0,01%
	Structural Mountains of the Meratus Complex	19.220,85	0,11%
	Structural Hills of the Meratus Complex	30.313,43	0,18%
Melawi	Fluvial Plain of Kalimantan	11,68	0,00%
	Structural Plain of the Meratus Complex	243.560,38	1,41%
	Denudational Mountains of Kalimantan	0,06	0,00%
	Structural Mountains of the Meratus Complex	24.412,20	0,14%
	Structural Hills of the Meratus Complex	50.290,95	0,29%
Sanggau	Fluvial Plain of Kalimantan	0,00	0,00%
	Structural Plain of the Meratus Complex	714.482,29	4,13%
	Structural Mountains of the Meratus Complex	19.388,03	0,11%
	Denudational Hills of Kalimantan	26.798,48	0,15%
	Structural Hills of the Meratus Complex	32.599,59	0,19%
Sekadau	Fluvial Plain of Kalimantan	6.833,59	0,04%
	Structural Plain of the Meratus Complex	477.471,73	2,76%
	Intrusive Mountains of Ancient Igneous Rocks of Kalimantan	3.486,00	0,02%
	Structural Mountains of the Meratus Complex	23.449,27	0,14%
	Structural Hills of the Meratus Complex	29.813,43	0,17%
Sintang	Fluvial Plain of Kalimantan	139.447,36	0,81%
	Peatlands of the Kahayan–Kapuas–Mahakam Complex	49.790,67	0,29%
	Structural Plain of the Meratus Complex	772.081,93	4,46%
	Intrusive Mountains of Ancient Igneous Rocks of Kalimantan	21.943,28	0,13%
	Structural Mountains of the Meratus Complex	709.257,17	4,10%
	Structural Hills of the Meratus Complex	348.037,08	2,01%
Regency at North, East, and Central Kalimantan	Structural Plain of the Meratus Complex	103,24	0,00%
	Denudational Mountains of Kalimantan	208,61	0,00%
	Intrusive Mountains of Ancient Igneous Rocks of Kalimantan	265.181,63	1,53%
	Structural Mountains of the Meratus Complex	9.557.833,37	55,24%

Region	Landscape Characteristics	Ha	%
	Karst Hills of Kalimantan	595,18	0,00%
	Structural Hills of the Meratus Complex	164.179,61	0,95%
Grand Total		**17.300.945,04**	**100,00%**

Source: Results of the analysis to the Minister of Environment and Forestry's Decree No. SK.8/MENLHK/SETJEN/PLA.3/1/2018 and SK 1272/MENLHK/SETJEN/PLA.3/12/2021 regarding the Establishment of Landscape Characteristics and Natural Vegetation Characteristics of the Indonesian Ecoregion Map at a scale of 1:250,000



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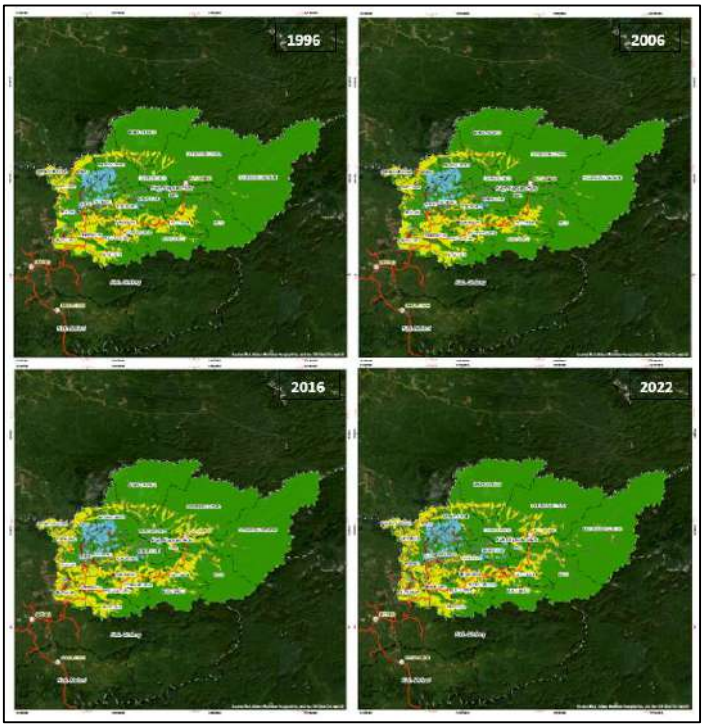
Source : Results of the analysis to the Minister of Environment and Forestry's Decree No. SK.8/MENLHK/SETJEN/PLA.3/1/2018 and SK 1272/MENLHK/SETJEN/PLA.3/12/2021 regarding the Establishment of Landscape Characteristics and Natural Vegetation Characteristics of the Indonesian Ecoregion Map at a scale of 1:250,000 and The results of the analysis of the Kapuas River Basin Map, Ministry of Public Works, Kalimantan River Basin Authority I, and the Regional Development Planning Agency (Bappeda) of West Kalimantan Province, 2012.

Fig. 3. Ecological Boundary Map of Kapuas Hulu Regency and Functional Area Map of Kapuas Hulu Regency.

3.4 Landcover

The land in Kapuas Hulu Regency is primarily dry land, utilized by farmers for plantation and agricultural activities. Land use reflects the pattern of human interaction with natural resources to meet their needs. However, this can significantly impact the region's environmental carrying capacity and sustainability. According to the 2022 land cover map from the Ministry of Environment and Forestry (KLHK) for Kapuas Hulu Regency, land use is predominantly covered by Primary Dryland Forest, spanning 1,444,805.29 hectares (46% of the total area).

Data from the KLHK land cover maps for the years 1996, 2006, 2016, 2019, and 2022 indicate significant reductions in Secondary Dryland Forest (previously logged areas), with a decrease of 154,436.39 hectares between 1996 and 2022, and a reduction of 63,558.18 hectares in Primary Swamp Forest. Meanwhile, there were substantial increases in Primary Dryland Forest, which expanded by 107,365.23 hectares, and in plantation areas, which grew by 97,684.42 hectares.



Source: Land Cover Map, Appendix on Environmental Services, Ministry of Environment and Forestry Scale 1:250,000, Year 2019, Year 2023.
Fig. 4. Transition of Land Cover Changes in Kapuas Hulu Regency in 1996, 2006, 2016, and 2022

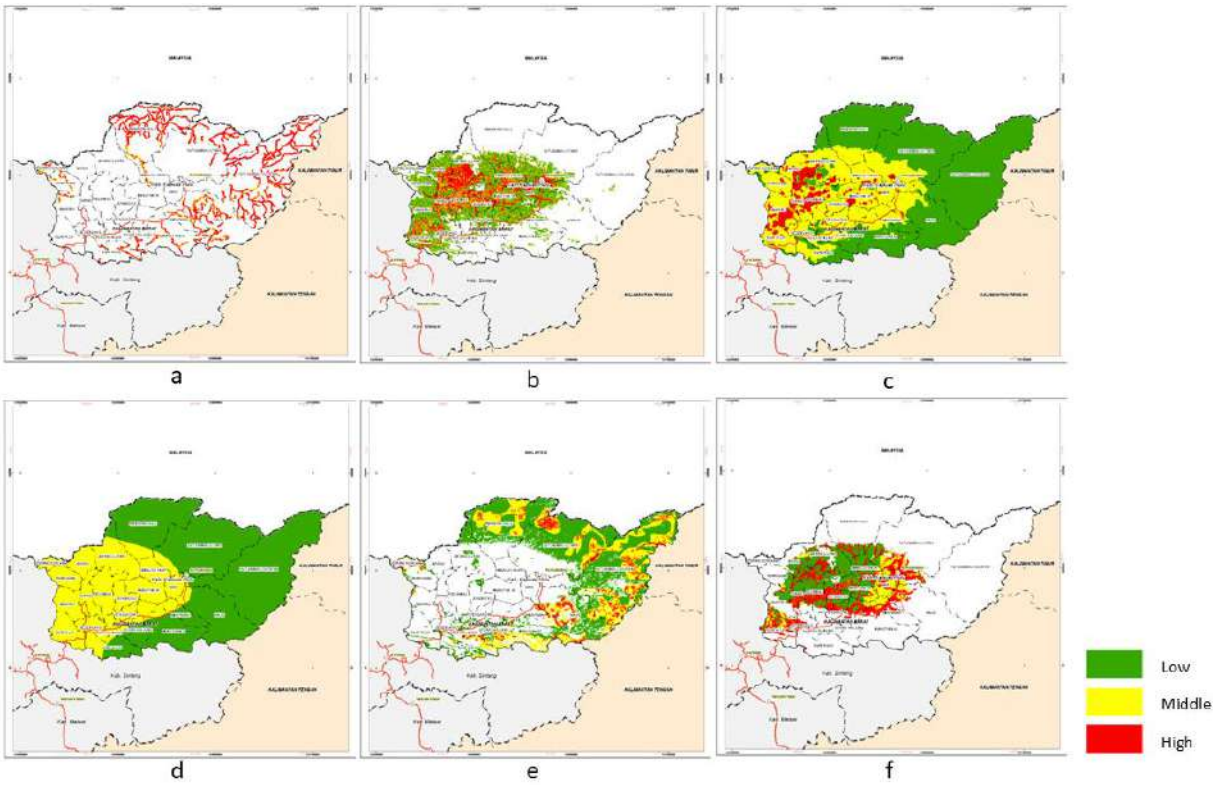
3.5 Disaster Risk

Based on the disaster hazard and vulnerability map for 2020–2024 from the West Kalimantan Provincial Government, Kapuas Hulu Regency demonstrates a strong capacity to manage various disasters, although some areas remain vulnerable. The majority of the region exhibits resilience, with 98.43% not prone to flooding and 65.30% safe from flash floods, despite seasonal flooding potentially reaching water levels of up to 2 meters. In terms of forest and land fires, 59.09% of the area is classified as low vulnerability, and while the occurrence of such fires is relatively low compared to other districts in Kalimantan Barat, 1,390 hectares were recorded burned in 2019. Additionally, 63.19% of the area is in the low vulnerability category for drought, with 50.05% safe from landslides, and 72.38% unaffected by extreme weather, underscoring the overall resilience of Kapuas Hulu to various environmental risks.

Table 2. Distribution of Disaster Hazards and Vulnerabilities in Kapuas Hulu Regency in 2020

No.	Disaster	Low		Middle		High		Not Vulnerable	
		Ha	%	Ha	%	Ha	%	Ha	%
1	Flash Flood	1.326,89	0,04%	10.754,09	0,34%	37.028,95	1,18%	3.082.714,68	98,43%
2	Flood	517.589,98	16,53%	312.229,68	9,97%	256.898,99	8,20%	2.045.105,96	65,30%
3	Forest And Land Fires	1.850.519,59	59,09%	1.110.713,96	35,47%	163.113,58	5,21%	7.477,49	0,24%
4	Drought	1.978.858,41	63,19%	1.152.099,02	36,79%	-	-	867,19	0,03%
5	Landslides	912.114,12	29,12%	509.370,97	16,26%	143.013,58	4,57%	1.567.325,94	50,05%
6	Extreme Weather	375.622,98	11,99%	158.576,77	5,06%	330.915,86	10,57%	2.266.709,01	72,38%

Source: Analyzed from disaster hazard and vulnerability map for 2020–2024 from the West Kalimantan Provincial Government



Source: analyzed from disaster hazard and vulnerability map for 2020–2024 from the West Kalimantan Provincial Government

Fig. 5. Distribution of Disaster Hazards and Vulnerabilities in Kapuas Hulu Regency in 2020: (a) Flash Flood (b) Flood (c) Forest and Land Fires (d) Drought (e) Landslide (f) Extreme Weather

3.6 Environmental Service

Kapuas Hulu is endowed with abundant natural resources and robust ecological services, which play a crucial role in supporting both local livelihoods and broader environmental sustainability. The region offers substantial provisioning services, including water, food, and fiber, essential for both human well-being and ecosystem stability. In terms of regulating services, Kapuas Hulu is vital for climate regulation, disaster prevention, and water purification, contributing to regional resilience and environmental health. The region's supporting functions are also strong, promoting biodiversity, soil health, and long-term ecosystem sustainability. Additionally, cultural services in Kapuas Hulu are significant, enhancing aesthetic, recreational, and cultural heritage values, further enriching the local community, and contributing to eco-tourism opportunities. The synthesis of the ES index values for Kapuas Hulu Regency in 2019, based on the DDDTLH documents for 2021–2022, is as follows.

Table 3. Synthesis of the ES for Kapuas Hulu Regency in 2019

No.	ES Classification		1. Very Low	2. Low	3. Moderate	4. High	5. Very High
Provisioning Function							
1	P1	Water Supplier	19.538,81	473.824,57	973.480,69	**1.604.140,83**	60.839,71
2	P2	Food Supplier	650,85	33.011,09	609.449,06	**2.352.279,79**	136.433,83
3	P3	Supplier of Fiber, Fuel, and Other Materials	76.423,42	456.253,43	624.200,00	**1.381.793,91**	593.153,86
4	P4	Genetical Resources Supplier	73.608,25	254.342,39	540.324,79	**1.558.885,97**	704.663,23
Regulating Function							
5	R1	Air Quality Regulation	5.762,17	60.790,39	270.489,89	989.354,90	**1.805.427,26**
6	R2	Climate Regulation	9.565,96	246.590,23	412.640,33	766.387,84	**1.696.640,26**
7	R3a	Prevention and Protection of Flood Disasters	9.422,73	13.947,05	187.217,23	1.012.549,58	1.908.688,02
	R3b	Prevention and Protection of Landslides	10.597,47	135.293,95	643.707,60	545.834,00	1.796.391,59

No.	ES Classification		1. Very Low	2. Low	3. Moderate	4. High	5. Very High
	R3c	Prevention and Protection of Forest and Land Fire Disasters	11.052,87	59.099,22	675.650,44	825.609,03	1.560.413,06
8	R4	Water Regulation	19.542,12	383.510,47	499.797,08	657.538,47	**1.571.436,47**
9	R5	Water Purification and Waste Treatment		343.168,34	522.681,21	471.846,47	**1.794.128,59**
10	R6	Natural Pollination Regulation	383.662,63	267.837,96	491.457,55	**1.772.848,68**	216.017,80
11	R7	Pest and Disease Control	256.164,83	416.349,00	**1.596.418,24**	862.892,55	
Supporting Function							
12	S1	Habitat and Biodiversity Supporters	62.475,62	414.838,23	385.928,17	**1.531.119,83**	737.462,77
13	S2	Soil Formation and Regeneration	82,50	142,54	454.219,51	977.520,10	**1.699.859,96**
14	S3	Primary/Biomass Production		399.987,12	464.544,03	**1.844.226,28**	423.067,19
15	S4	Nutrient Cycle	1.692,64	553.385,55	727.264,64	**1.849.481,79**	
Cultural Function							
16	C1	Aesthetics (Appreciation of Natural Scenery)		1.883,91	593.225,51	**2.536.715,20**	
17	C2	Recreation (Opportunities for Tourism and Recreation Activities)		209.177,72	**1.957.876,16**	964.770,73	
18	C3	Cultural Heritage and Identity		2.576,91	386.876,89	**2.731.539,09**	10.831,72

Source: processed from DDDTLH Document of Kapuas Hulu Regency 2021–2022

Monetization of environmental services is an effort to assign economic value to natural ecosystem services, such as the provision of clean water, carbon sequestration, and flood control, to integrate environmental values into the economic system. Dryland forest cover absorbs 0.43 tons of C ha^{-1} $year^{-1}$ [14], peat swamp forests absorb 2.7 tons of C ha^{-1} $year^{-1}$ [15], mangrove forests absorb between 0.23 to 23.54 tons of C ha^{-1} $year^{-1}$ [16], [17], [18], [19], and plantation forests absorb between 2.15 to 32.99 tons of C ha^{-1} $year^{-1}$ [20]. In Kapuas Hulu Regency, about 53% to 80% of the land provides high-value environmental services, including water, food, and fiber. Carbon sequestration as a climate regulation service also shows high potential economic value, with estimated carbon absorption reaching 86 million tons of CO2 by 2024. With carbon prices in the international market at USD 0.5 per ton of CO2 equivalent, the potential economic value of carbon sequestration services in Kapuas Hulu is estimated to reach 689 billion Rupiah. Efforts to increase vegetation cover and utilize renewable energy are key to achieving net zero emissions by 2060.

3.7 Discussion

3.7.1 Issue 1 (Suboptimal management of natural resources and biodiversity)

The management of natural resources and biodiversity in Kapuas Hulu Regency remains suboptimal despite the existence of progressive local regulations such as the Regional Regulation No. 20 of 2015, which officially designates the area as a Conservation District, and the Regional Spatial Plan (RTRW) 2018–2038 as outlined in Regulation No. 3 of 2018. While these policies provide a formal legal framework for conservation, their implementation appears insufficient in halting environmental degradation. Data from the Ministry of Environment and Forestry (KLHK) in 2022 show a significant increase in plantation areas (up to 97,684.42 hectares) and a decline in secondary dryland forests and primary swamp forests, indicating ongoing deforestation and biodiversity loss. Moreover, although the RTRW identifies protected zones, enforcement and monitoring remain weak, and land-use changes often contradict the spatial plan's conservation intent. The region’s complex ecoregion—characterized by ultrabasic forest vegetation and structural fold hills—requires adaptive and community-based conservation strategies, which are not yet clearly operationalized in the current regulatory framework. This gap undermines efforts to achieve SDG 15 (Life on Land) and SDG 11

(Sustainable Cities and Communities), as continued degradation could diminish biodiversity, weaken ecosystem resilience, and reduce the long-term livability and economic potential of the region.

3.7.2 Issue 2 (Climate change and the risk of natural disasters)

The increasing impacts of climate change and disaster risks in Kapuas Hulu Regency, evidenced by recurrent seasonal floods, forest and land fires, landslides, and droughts, underscore the need for a more robust and integrated policy response. While the West Kalimantan Regional Action Plan for Greenhouse Gas Emission Reduction (RAD-GRK) includes Kapuas Hulu in its efforts to reduce emissions in the forestry, agriculture, and energy sectors, the plan largely emphasizes emission accounting and lacks localized adaptation strategies tailored to the region's specific vulnerabilities. Similarly, the REDD+ program, implemented to protect forests and promote sustainable livelihoods, has shown potential in reducing deforestation but faces challenges in ensuring long-term community engagement and institutional coordination. The region's unique biophysical characteristics dominated by watershed boundaries and hilly terrain, require cross-sectoral disaster risk reduction measures that go beyond current sectoral policies. Without stronger institutional integration and climate-resilient spatial planning, existing frameworks may fall short of achieving SDG 13 (Climate Action) and SDG 11 (Sustainable Cities and Communities). A critical gap remains in aligning mitigation goals with concrete adaptation actions, such as early warning systems, resilient infrastructure development, and inclusive local disaster preparedness programs.

3.7.3 Issue 3 (Environmental vulnerability to degradation and increased pollution risk)

The growing environmental vulnerability to degradation and pollution in Kapuas Hulu Regency reflects a gap between development pressures and the effectiveness of current regulatory and community-based measures. Although the Spatial Plan (RTRW) 2014–2034 identifies zones prone to environmental damage and provides spatial guidelines for prevention, implementation remains limited due to weak enforcement and insufficient integration with local development initiatives. Likewise, the Village-Based Renewable Energy and Ecotourism Program aims to promote sustainable resource use and pollution reduction through community participation, but its coverage and long-term impact remain unclear. These policy efforts, while conceptually aligned with SDG 11 (Sustainable Cities and Communities) and SDG 15 (Life on Land), require stronger monitoring, coordination, and scalability to counterbalance the environmental pressure caused by land-use change, urban expansion, and harmful agricultural practices such as slash-and-burn. Without a more robust policy framework and cross-sectoral collaboration, the risk of irreversible degradation and ecosystem loss may continue to rise.

Environmental issues that are vulnerable to damage and the increasing risk of pollution in Kapuas Hulu Regency are becoming more serious along with the rise in human activities, particularly in the agriculture and plantation sectors. These activities exert pressure on the environment and heighten the risk of soil, water, and air pollution. Frequent forest and land fires, mainly due to land clearing by burning, worsen the situation by increasing air pollution, resulting in haze disasters and damaging ecosystems. Additionally, urbanization and infrastructure development without proper environmental management further exacerbate environmental degradation and increase the risk of pollution that related to SDG 13 (Climate Action). The impact of these issues is related to SDG 11 (Sustainable Cities and Communities), where environmental pollution can lower the quality of life

and public health, as well as reduce community sustainability. This issue is also linked to SDG 15 (Life on Land), which states that pollution and environmental damage threaten natural habitats and biodiversity, while reducing the capacity of ecosystems to support life.

Table 4. Policy Direction Formulation

Sustainable Development Goals	Related Issues	Main Target	Policy Direction
SDG 11: Sustainable Cities and Communities	• Issue 1 (Suboptimal management of natural resources and biodiversity) • Issue 2 (Climate change and the risk of natural disasters) • Issue 3 (Environment vulnerable to damage and increased pollution risk)	Improvement of rural and urban settlement management and disaster risk management.	a. Ensure decent, safe, and affordable housing, along with basic services, and improve slum areas. b. Reduce urban per capita environmental impacts that are detrimental, particularly by paying special attention to air quality, including the management of residential waste. c. Substantially increase the number of settlements implementing integrated policies and planning, resource efficiency, climate change mitigation and adaptation, disaster resilience, and holistic disaster risk management across all sectors.
SDG 13: Climate Action	• Issue 1 (Suboptimal management of natural resources and biodiversity) • Issue 2 (Climate change and the risk of natural disasters)	Increase in the quantity and quality of preparedness training programs and disaster mitigation efforts for communities and governments.	d. Enhance the capacity and preparedness of communities and governments in facing disasters. e. Develop and implement an effective disaster early warning system. f. Improve mitigation and adaptation efforts in response to climate change. g. Reduce greenhouse gas (GHG) emissions by adopting clean and environmentally friendly technologies.
SDG 15: Life on Land	Issue 1 (Suboptimal management of natural resources and biodiversity)	Utilization of conservation areas in a responsible and sustainable manner.	a. Protect and preserve biodiversity. b. Improve the quality of air, water, and soil.

Source: Analysis, 2024

4 Conclusion

Kapuas Hulu's diverse landscape and rich ecoregions support a variety of ecosystems and services essential for sustainable development. However, the region faces challenges from land use changes, environmental risks, and the need for careful management of its ecological boundaries to balance development and conservation efforts. Integrated policy approaches to address key strategic issues related to natural resource management, biodiversity, climate change, and environmental vulnerability in line with the Sustainable Development Goals (SDGs). For SDG 11 (Sustainable Cities and Communities), improving rural and urban settlement management and disaster risk mitigation is essential, with a focus on providing safe, affordable housing, reducing environmental impacts, and enhancing disaster resilience. For SDG 13 (Climate Action), efforts should be concentrated on enhancing preparedness and mitigation through effective early warning systems, clean technologies, and reducing greenhouse gas emissions. Lastly, SDG 15 (Life on Land) highlights the importance of

responsibly managing conservation areas, protecting biodiversity, and improving environmental quality for sustainable land use.

Kapuas Hulu's diverse physical characteristics and rich ecoregions support critical ecosystem services that are foundational for sustainable development. However, ongoing land-use changes and environmental pressures pose serious risks to ecological stability and regional resilience. Through GIS-based spatial analysis, this study has identified both opportunities and vulnerabilities within the district's biophysical context. Key findings reveal declining secondary forests, expansion of plantations, and the presence of ecological boundaries that extend beyond administrative limits. These spatial dynamics emphasize the need for planning those accounts for environmental thresholds and cross-jurisdictional ecological influence. Policy implications drawn from the analysis are directly aligned with SDG 11, 13, and 15. For SDG 11, improvements in rural and urban settlement management and disaster resilience are essential. Under SDG 13, the region must strengthen climate risk preparedness through spatial hazard mapping. SDG 15 highlights the urgency of biodiversity protection and land use control.

Urgent adoption of GIS-based, data-informed policies at the district level is critical to ensure inter-sectoral coordination and localized sustainability outcomes. Future research should integrate socio-economic layers and evaluate the long-term effectiveness of spatially guided policy interventions.

5 References

[1] Y. Li, Z. Xiang, K. Chen, and X. Wang, "An improved spatial subsidy approach for ecological compensation in coastal seascapes for resilient land-sea management," *J. Environ. Manage.*, vol. 276, no. September, p. 111305, 2020, doi: 10.1016/j.jenvman.2020.111305.

[2] S. E. G. Findlay, "Organic Matter Decomposition," *Fundam. Ecosyst. Sci. Second Ed.*, pp. 81–102, Jan. 2021, doi: 10.1016/B978-0-12-812762-9.00004-6.

[3] L. A. Putri, A. A. Akbar, and Romiyanto, "The impact of traditional gold mining on land use changes and vegetation index in Mandor Subwatershed, West Kalimantan," *J. Degrad. Min. Lands Manag.*, vol. 10, no. 2, pp. 4219–4232, Jan. 2023, doi: 10.15243/JDMLM.2023.102.4219.

[4] H. Takagi, M. Esteban, T. Mikami, M. B. Pratama, V. P. B. Valenzuela, and J. E. Avelino, "People's perception of land subsidence, floods, and their connection: A note based on recent surveys in a sinking coastal community in Jakarta," *Ocean Coast. Manag.*, vol. 211, no. April 2020, p. 105753, 2021, doi: 10.1016/j.ocecoaman.2021.105753.

[5] B. Rangga, A. A. Akbar, and H. Herawati, "The impact of soil and rock mining on freshwater provisioning services in Peniraman Village, Mempawah Regency, West Kalimantan," *J. Degrad. Min. Lands Manag.*, vol. 10, no. 1, pp. 3905–3919, Oct. 2022, doi: 10.15243/JDMLM.2022.101.3905.

[6] S. Subanti and A. Hakim, "EKONOMI REGIONAL PROVINSI SULAWESI TENGGARA: Pendekatan Sektor Basis dan Analisis Input-Output," *J. Ekon. Stud. Pembang. (Jurusan Ekon. Pembang. Fak. Ekon. Univ. Negeri Malang)*, vol. 10, no. 1, pp. 13–33, 2009, doi: 10.18196/jesp.10.1.1281.

[7] B. Jamali, R. Löwe, P. M. Bach, C. Urich, K. Arnbjerg-Nielsen, and A. Deletic, "A rapid urban flood inundation and damage assessment model," *J. Hydrol.*, vol. 564, pp. 1085–1098, 2018, doi: 10.1016/j.jhydrol.2018.07.064.

[8] L. M. Bott, T. Schöne, J. Illigner, M. Haghshenas Haghighi, K. Gisevius, and B. Braun, "Land subsidence in Jakarta and Semarang Bay – The relationship between physical processes, risk perception, and household adaptation," *Ocean Coast. Manag.*, vol. 211, 2021, doi: 10.1016/j.ocecoaman.2021.105775.

[9] I. Buchori, A. Pramitasari, A. Sugiri, M. Maryono, Y. Basuki, and A. W. Sejati, "Adaptation to coastal flooding and inundation: Mitigations and migration pattern in Semarang City, Indonesia," *Ocean Coast. Manag.*, vol. 163, no. July, pp. 445–455, 2018, doi: 10.1016/j.ocecoaman.2018.07.017.

[10] I. Rudiarto, W. Handayani, and B. Pigawati, "Zona Peri-Urban Semarang Metropolitan : Perkembangan," *Tata Loka*, vol. 15, no. 2, pp. 116–128, 2013.

[11] H. Latief, M. R. Putri, F. Hanifah, I. N. Afifah, M. Fadli, and D. O. Ismoyo, "Coastal Hazard Assessment in Northern part of Jakarta," *Procedia Eng.*, vol. 212, pp. 1279–1286, 2018, doi: 10.1016/j.proeng.2018.01.165.
[12] W. Langgeng, *Bentang Lahan (Landscape) untuk Pengenalan Fenomena Geosfer*. Yogyakarta: Fakultas Geografi, 2008.
[13] Kementerian Lingkungan Hidup dan Kehutanan, *Deskripsi Peta Wilayah Ekoregion Indonesia*. Jakarta: Direktorat Jenderal Planologi dan Tata Lingkungan, 2020.
[14] L. Qie *et al.*, "Long-term carbon sink in Borneo's forests halted by drought and vulnerable to edge effects," *Nat. Commun.*, vol. 8, no. 1, p. 1966, 2017, doi: 10.1038/s41467-017-01997-0.
[15] D. Murdiyarso, M. F. Saragi-Sasmito, and A. Rustini, "Greenhouse gas emissions in restored secondary tropical peat swamp forests," *Mitig. Adapt. Strateg. Glob. Chang.*, vol. 24, no. 4, pp. 507–520, Apr. 2019, doi: 10.1007/s11027-017-9776-6.
[16] K. Analuddin *et al.*, "Aboveground biomass, productivity and carbon sequestration in rhizophora stylosa mangrove forest of southeast sulawesi, indonesia," *Biodiversitas*, vol. 21, no. 4, pp. 1316–1325, 2020, doi: 10.13057/biodiv/d210407.
[17] R. Wiarta, Y. Indrayani, F. Mulia, and D. Astiani, "Carbon sequestration by young Rhizophora apiculata plants in Kubu Raya district, West Kalimantan, Indonesia," *Biodiversitas*, vol. 20, no. 2, pp. 311–315, 2019, doi: 10.13057/biodiv/d200202.
[18] D. M. Alongi, "Carbon sequestration in mangrove forests," *Carbon Manag.*, vol. 3, no. 3, pp. 313–322, 2012, doi: 10.4155/cmt.12.20.
[19] M. A. Kusumaningtyas *et al.*, "Carbon sequestration potential in the rehabilitated mangroves in Indonesia," *Ecol. Res.*, vol. 37, no. 1, pp. 80–91, 2022, doi: https://doi.org/10.1111/1440-1703.12279.
[20] M. Iskandar, I. Z. Siregar, and H. Krisnawati, "Potential of carbon sequestration enhancement through intensive silvicultural techniques using Shorea leprosula plantation in Central Kalimantan, Indonesia," *Biodiversitas*, vol. 24, no. 8, pp. 4699–4513, 2023, doi: 10.13057/biodiv/d240852.