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Zoning of Nature Tourism Parks Based on Ecological and Socio-Economic Sensitivity: Case Study of Grojogan Sewu Nature Tourism Park

Evi Heriyaningtyas [1], Maryono [2], Fuad Muhammad [3]

[1] Master of Environmental Science, school of postgraduate studies, Diponegoro University, Semarang, Indonesia

[2] Departemen Urban and Regional Planning, Faculty Engineering, Diponegoro University, Semarang, Indonesia

[3] Biology, Faculty Science and Mathematics, Diponegoro University, Semarang, Indonesia

Email: heriyaningtyas.evi@gmail.com, maryono@live.undip.ac.id, fuad.muh@gmail.com

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Abstract

Grojogan Sewu Nature Tourism Park, covering an area of 64,124 hectares, has undergone environmental and spatial changes that no longer align with its original management zoning plan. This study aims to redesign the management blocks based on ecological and socio-economic sensitivities through the use of spatial multi-criteria evaluation combined with a hierarchical decision-making process and geographic information system-based analysis. The objectives of the study are to determine management zones using ecological sensitivity criteria, including vegetation cover, land cover, slope classification, geological sensitivity, and distribution of flora and fauna. Additionally, socio-economic sensitivity is assessed using criteria such as accessibility to potential areas of utilization, zones of tourism activities, and water resource usage areas. The findings of this study indicate a revised spatial division of the nature park into two main management blocks: the protection block and the utilization block. The protection block accounts for approximately 36,966 hectares or 57.65 percent of the total area, while the utilization block comprises about 27,158 hectares or 42.35 percent. The proposed zoning scheme is expected to support effective conservation strategies and enhance integrated spatial planning for sustainable nature tourism management in Grojogan Sewu.

Keywords: *ecological sensitivity 1, socio-economic sensitivity 2, spatial planning 3, conservation management 4, nature tourism 5*

INTRODUCTION

Grojogan Sewu Nature Tourism Park, located in Karanganyar Regency, is one of Indonesia's officially designated conservation areas. The area currently faces significant challenges due to environmental and land-use changes not accounted for in previous planning documents. These shifts have made existing spatial and management frameworks outdated and less responsive to current conditions. Grojogan Sewu plays an essential role in conserving biodiversity while also serving as a prominent nature-based tourism destination. Despite its importance, management strategies have not fully addressed the park's ecological potential or socio-economic context. Many biophysical features of the park remain underutilized in conservation and tourism planning. In addition, the socio-economic needs of surrounding communities have not been properly integrated. This has led to ineffective resource allocation and management conflicts. Moreover, existing tourism activities are often disconnected from ecological zoning priorities. These challenges necessitate a comprehensive re-evaluation of management zones.

The objective of this study is to design a new zoning model based on ecological and socio-economic sensitivity. This model integrates Geographic Information System (GIS) tools with Spatial Multi-Criteria Analysis/Evaluation (SMCA/E) and the Analytical Hierarchy Process (AHP). The integration of these methodologies supports a spatially precise and context-sensitive approach to zone planning. SMCA/E allows the inclusion of multiple criteria, each weighted based on expert judgment, to reflect varying degrees of importance (Hamidun, 2012). The AHP method is employed to systematize the decision-making process for determining criterion weights (Saaty, 1980). GIS spatial analysis is then used to apply these weights across the study area. This method helps visualize spatial distributions of ecological and socio-economic sensitivities. By combining these tools, zoning design becomes more adaptive and evidence-based. The new zoning is expected to enhance both conservation effectiveness and community benefits. It also contributes to long-term sustainable tourism development.

In this study, ecological sensitivity is defined as the vulnerability of the natural environment to anthropogenic pressures. It includes factors such as slope steepness, vegetation cover, geological stability, and the distribution of flora and fauna. High ecological sensitivity areas are considered to have a strong environmental carrying capacity for supporting wildlife and maintaining ecosystem services (Zhang et al., 2015). On the other hand, areas with lower sensitivity may be more appropriate for human use or tourism. Socio-economic sensitivity is assessed based on factors such as accessibility, existing tourism infrastructure, and potential for resource use. These indicators help evaluate the value and pressure placed on the landscape by human activity. The integration of both ecological and socio-economic analyses allows for a holistic understanding of land suitability. This dual perspective ensures that zoning decisions are both environmentally sustainable and socially inclusive. The goal is to identify areas where ecological protection and economic utilization can be effectively balanced (Kunarso et al., 2019).

Zoning, also referred to as spatial allocation or functional division, is a core strategy in conservation area management. The Regulation of the Minister of Forestry Number 28 of 2011 outlines the basic structure and terminology for zoning in protected areas. This regulatory approach aligns with the concept of territorialization, where land is organized based on function and authority (Vandergeest, 1996; Vandergeest & Peluso, 1995). In forest planning, zoning is used to assign spatial functions based on biophysical capacity and social demand. Erdi et al. (2017) emphasize the role of zoning in reconciling environmental and socio-economic factors in forest management. By doing so, it helps ensure that forests continue to serve as essential life-support systems. These systems include water regulation, habitat preservation, and carbon storage. Without proper zoning, these functions are at risk due to unmanaged land use. Theoretical grounding in political ecology and environmental governance strengthens the legitimacy of the zoning process. It underscores the need for participatory and adaptive approaches in land management.

Indonesia's forest management has undergone significant transformation in the context of regional autonomy. However, existing legal frameworks, particularly Law Number 41 of 1999, have struggled to accommodate ongoing changes. This has led to fragmented forest governance, ineffective conservation efforts, and rising land-use conflicts. One consequence is the increasing vulnerability of forests to degradation and exploitation. To address these challenges, the government introduced Government Regulation Number 6 of 2007 concerning Forest Management and Forest Utilization Planning. This regulation emphasizes adaptive planning, stakeholder involvement, and zoning as key components. It aims to bring coherence and flexibility to forest governance. In practice, zoning becomes a strategic tool to allocate space based on

ecological and social criteria. Forest management now must account for dynamic socio-environmental changes, rather than rely on static regulations. The case of Grojogan Sewu demonstrates the pressing need for updated spatial planning aligned with these new legal and ecological realities.

METHODS

2.1. Study Area (Word style: MK Heading 2)

This research was conducted in the Grojogan Sewu Nature Tourism Park. Geographically, the study area is located between 7°39'15.6" – 7°39'47.61" South Latitude and 111°07'23.8" – 111°08'46.9" East Longitude. Administratively, the Grojogan Sewu Nature Tourism Park is situated within Tawangmangu Village, Tawangmangu District, Karanganyar Regency, Central Java Province, Indonesia. The research was carried out over a three-month period, from January to March 2025.

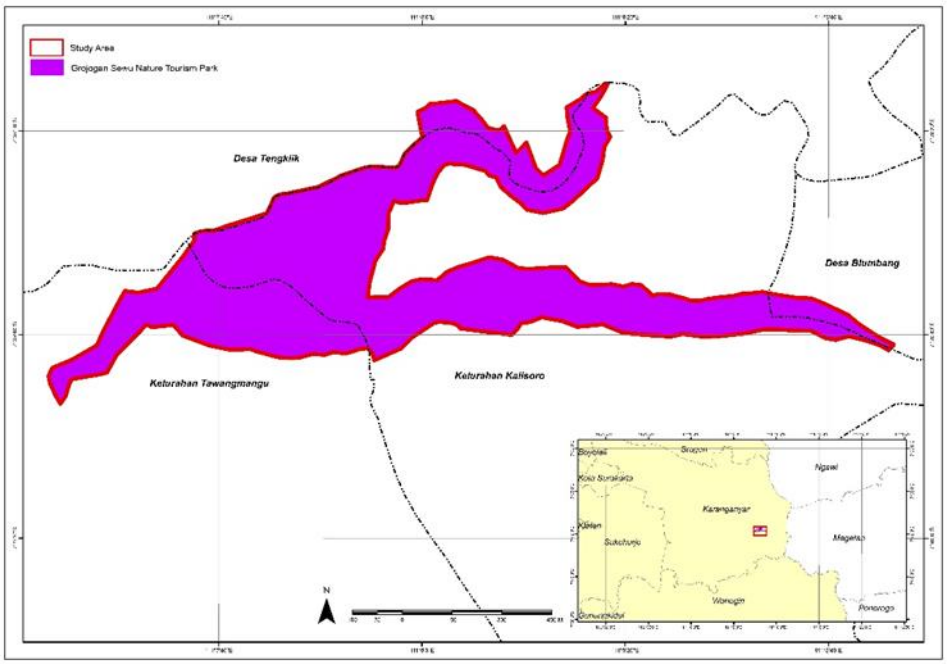

Figure 1. Sketch of the research in Grojogan Sewu Nature Tourism Park

2.2. Data collection

Data collection was conducted through field surveys by mapping areas based on ecological and socio-economic criteria. The data utilized in this study comprised ecological biophysical spatial data, including vegetation conditions, fauna distribution, topography, soil types, and hydrological characteristics. Socio-economic data included areas of natural tourism activities and water utilization. Spatial data for each criterion were processed using buffering techniques in accordance with the specific requirements of each data. In addition, spatial distribution maps of flora, fauna,

and other relevant features were verified through ground-checking to ensure data accuracy and completeness.

2.3. Data analysis

Data analysis was conducted spatially using Geographic Information System (GIS) techniques by integrating biophysical and socio-economic datasets. The Spatial Multi-Criteria Analysis/Evaluation (SMCA/E) approach was employed to assess various criteria based on ecological and socio-economic sensitivity. Additionally, the Analytical Hierarchy Process (AHP) was used to determine the weighting of each criterion in the decision-making process. The integration of spatial and attribute data generated a comprehensive database for each thematic map. All data were digitized and converted into computer-based maps, which were then analyzed spatially using the overlay method. This process enabled the generation of a zoning map for the management of Grojogan Sewu Nature Tourism Park.

RESULTS AND DISCUSSION

3.1. Ecological Sensitivity

The determination of criteria included in ecological sensitivity is a crucial step in zoning the Grojogan Sewu Nature Tourism Park. The arrangement of management blocks within the park must consider ecological sensitivity, as certain parts of the area are utilized for nature tourism activities whose management directly impacts the ecological balance. Ecological conditions that are highly sensitive require careful and sustainable management of tourism activities (Istiadi, 2014). Therefore, the classification of tourism zones based on ecological parameters is essential, alongside socio-economic considerations. The analysis of ecological sensitivity levels within an ecosystem can be used to predict its potential responses to disturbances. Sensitivity is interpreted as the ratio between external forces that can cause changes in the ecosystem and the internal capacity of the ecosystem to maintain its equilibrium. Areas identified as ecologically sensitive are typically those with high biodiversity or serve as habitats for significant flora and fauna species, including endemic, rare, or endangered species (Royana, 2013). The ecological sensitivity approach provides a scientific basis for delineating zoning and management blocks within Grojogan Sewu Nature Tourism Park to ensure the preservation of ecological integrity. The ecological sensitivity criteria for Grojogan Sewu Nature Tourism Park include vegetation cover condition, land cover, slope class, rock sensitivity classification, and the distribution of protected flora and fauna.

3.2. Vegetation Cover Condition

The land cover condition of Grojogan Sewu Nature Tourism Park was analyzed using the Normalized Difference Vegetation Index (NDVI) classification approach. Based on NDVI values, vegetation cover is categorized into four density classes: open vegetation (NDVI < 0.22), sparse vegetation (NDVI 0.22–0.42), moderate vegetation (NDVI 0.42–0.72), and dense vegetation (NDVI 0.72–1.00). The vegetation structure within the park is dominated by dense vegetation, which covers approximately 91.87% of the total area or 58.90 hectares. These dense vegetation zones are predominantly located in the central part of the park—particularly in tourist-accessible zones—and north of the South Samin River.Moderate vegetation areas constitute

around 7.48% or 4.79 hectares of the total park area. These are typically found adjacent to dense vegetation zones, particularly along the Samin River corridor and in parts of the northern section of the park. Sparse and open vegetation zones are less extensive and are primarily distributed in the northern and southern regions of Grojogan Sewu Nature Tourism Park. The area classified as sparse vegetation covers approximately 0.398 hectares (0.62%), while open vegetation occupies only 0.02 hectares (0.03%). The vegetation types in these sparsely covered and open areas are generally dominated by shrubs and early successional plant species, indicating lower ecological resilience and higher exposure to anthropogenic or natural disturbances.

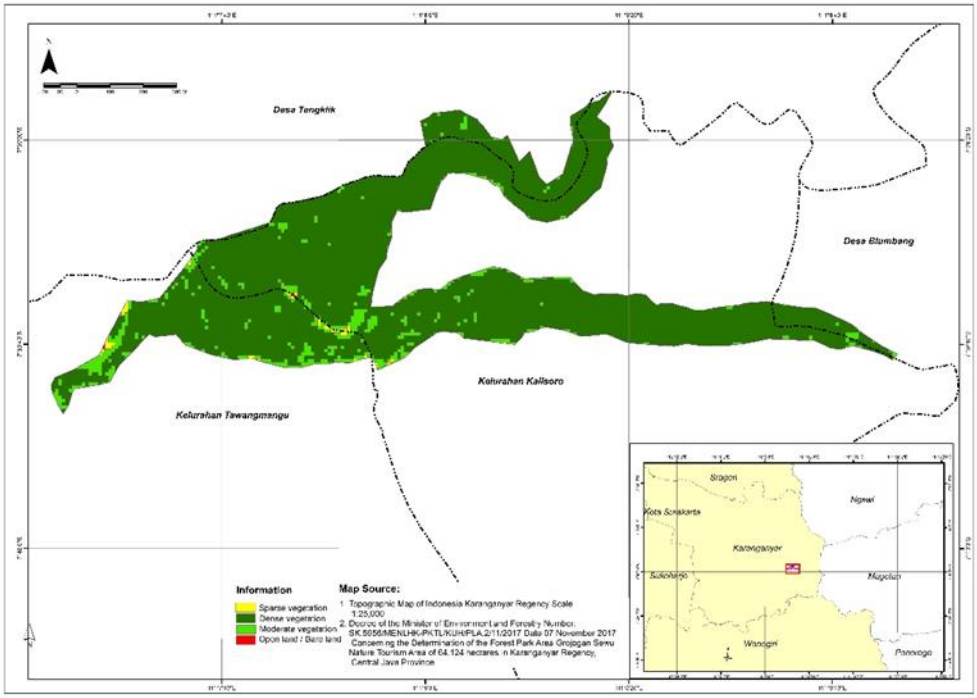

Figure 2. Vegetation cover map of Grojogan Sewu Nature Tourism Park

3.3. Land Cover

The results of this classification provide valuable information regarding the distribution of land cover within the Grojogan Sewu Nature Tourism Park area. This classification is essential for supporting ecological assessments, spatial planning processes, and environmental conservation strategies. Understanding the spatial extent and density of vegetation cover contributes to better decision-making in managing the park's natural resources.

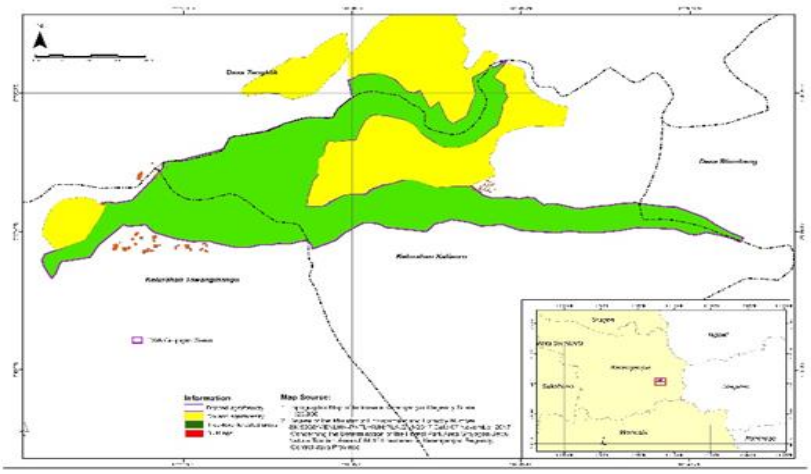

Figure 3. Land Cover Map of Grojogan Sewu Nature Tourism Park

As Grojogan Sewu Nature Tourism Park is a designated conservation area within a forested landscape, the dominant land cover is tree-level vegetation. Accordingly, there are no permanent buildings or man-made structures within the area, ensuring the preservation of its natural forest characteristics

3.4. Slope class

This classification provides an overview of the distribution of slopes in the Grojogan Sewu Nature Tourism Park area. This information is important for ecological analysis, conservation planning, and environmental management. The slope class in the Grojogan Sewu Nature Tourism Park is divided into five slopes, namely Flat (0-8%), Gently (8-15%), Slightly Steep (15-25%), Steep (25-45%) and Very Steep (> 45%).

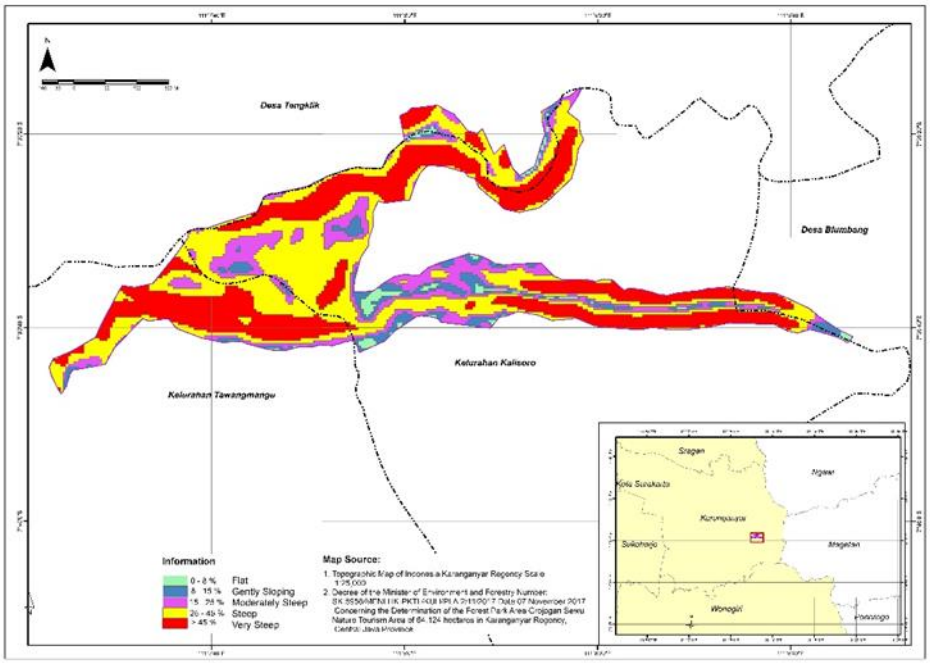

Figure 4. Map of the slope of Grojogan Sewu Nature Tourism Park

The Grojogan Sewu Nature Tourism Park is situated at an elevation ranging from 925 to 1,240 meters above sea level. The majority of the area, approximately 58%, features a very steep

topography with slopes exceeding 45%. About 25% of the park consists of steep slopes between 25% and 45%, characterized by hilly terrain. Additionally, 11% of the area has moderately steep slopes ranging from 15% to 25%, with slightly hilly and undulating landforms. The remaining 6% comprises flat to gently sloping terrain with gradients below 15%. These flatter areas are primarily located around the Samin River, near the base of the waterfall. The Grojogan Sewu waterfall itself stands approximately 81 meters tall and cascades down a vertical cliff with distinctive rock formations. This striking feature is one of the park's main natural attractions. Due to the rugged topography, the development of tourism infrastructure is limited and concentrated in accessible areas. As a result, visitor facilities are minimal and adapted to the park's challenging landscape conditions.

3.5. Classification of rock sensitivity

This classification provides important information about the sensitivity of soil types to landslides in the Grojogan Sewu TWA area. This information is useful for environmental risk analysis and conservation planning.

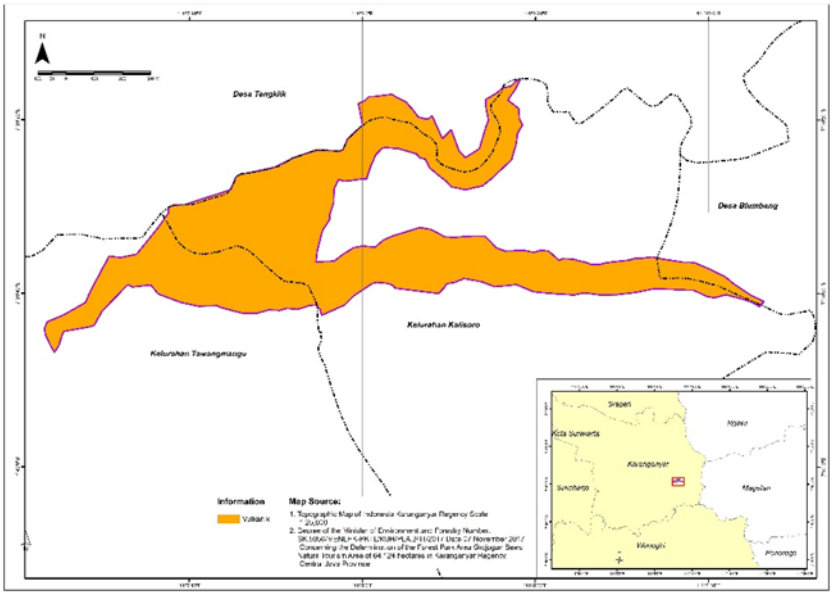

Figure 5. Map of rock types of Grojogan Sewu Nature Tourism Park

According to the 1971 Java-Madura Soil Geology map and data from the Bogor Soil Research Institute, the Grojogan Sewu Nature Tourism Park is situated within a young geological formation. The area belongs to the Alluvium and Quaternary geological groups, which are characteristic of relatively recent earth structures. The dominant rock types in this region are young volcanic rocks originating from Mount Lawu. These include andesitic basalt, a volcanic rock commonly found in mountainous areas with recent volcanic activity. The presence of these rocks indicates a dynamic geological history shaped by volcanic processes. In terms of soil classification, the park features primarily andosol soils, which are typical of volcanic regions. These soils are further divided into yellowish brown andosol and brown andosol, both known for their fertility and ability to support dense vegetation. Additionally, lithosol is also present in certain parts of the area. Lithosol is generally shallow and stony, often found on steep slopes or rocky terrain. The combination of volcanic rock and diverse soil types contributes to the ecological richness of the park.

3.6. Distribution of protected Flora Fauna

This classification helps determine the priority of protection for protected flora and fauna

in the Grojogan Sewu Nature Tourism Park area . With this approach, areas with high ecological sensitivity can be optimally managed for conservation purposes.

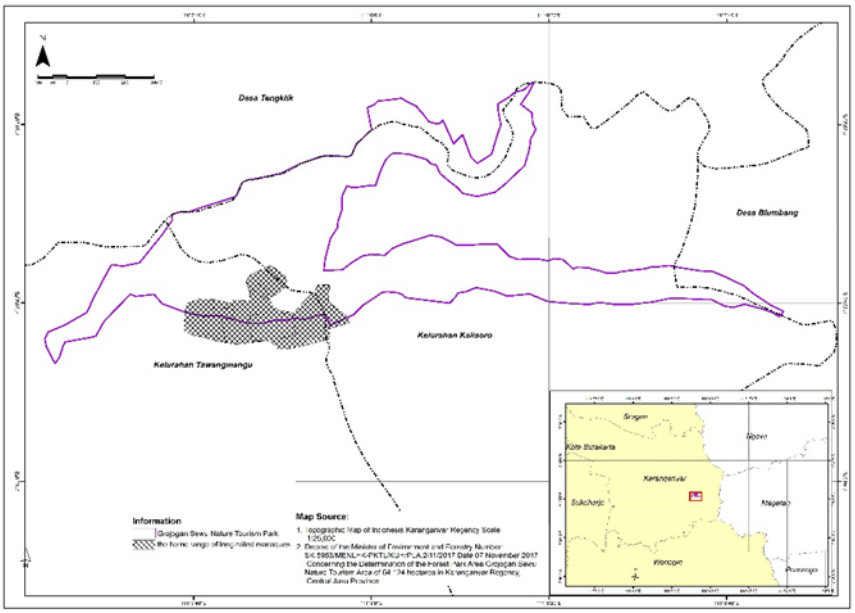

Figure 6. Map of the distribution area of long-tailed macaque

The dominant fauna species in the Grojogan Sewu Nature Tourism Park is the long-tailed macaque (Macaca fascicularis). These primates are commonly observed near the ticketing area and other locations frequented by tourists. Their adaptability to human presence makes them a prominent and easily encountered species in the park. In addition to the macaques, several other wildlife species inhabit the area. Among the notable birds of prey is the black eagle (Ictinaetus malayensis), which occupies higher forest canopies. Small mammals such as squirrels (Tupaia sp.) and the common palm civet (Paradoxurus hermaphroditus) are also present. The park supports a variety of avian species, reflecting its ecological diversity. These include the ivory starling (Sturnus poliocephalus), the Java sparrow (Pycnonotus aurigaster), and the drongo (Dicrurus macrocercus). Other frequently sighted birds are the tailorbird (Prinia familiaris), the sunbird (Aethopyga duyvenbodei), and the collared kingfisher (Todiramphus chloris). The presence of these diverse faunal species highlights the park's role as a habitat for both resident and migratory wildlife.

3.7. Socio-Economic Sensitivity

Socio-economic sensitivity is an important consideration in determining the zoning and management of conservation areas. This concept generally refers to the extent to which social and economic factors influence or are influenced by specific systems or conditions, such as environmental changes or development infrastructure. It involves evaluating the adaptability, resilience, and vulnerability of communities and local economies to these external influences (Rathore et al., 2023). Socio-economic sensitivity goes beyond observable socio-economic indicators and includes more complex, less tangible variables. For instance, the concept of happiness sensitivity was introduced to capture variations in national average subjective well-being that cannot be fully explained by economic or social conditions. Intrinsic factors such as personality traits, cultural values, and demographic characteristics contribute significantly to this sensitivity. These factors differ across individuals and populations and may affect how people perceive and respond to similar socio-economic situations. As a result, some communities may

exhibit higher or lower sensitivity to environmental or policy changes, regardless of comparable economic indicators. Understanding these subtleties is crucial for designing socially inclusive and adaptive management strategies. Therefore, integrating socio-economic sensitivity into conservation planning ensures that both ecological and human dimensions are adequately addressed (Mizobuchi, 2017). In the Grojogan Sewu Nature Tourism Park, the criteria for socio-cultural sensitivity consist of three main components: accessibility of potential utilization areas, tourist activity zones, and water resource utilization areas within the region.

3.8. Accessibility of potential utilization

The area can be categorized as a utilization zone, special zone, or another designated management area. In regions experiencing high ecological pressure, spatial analysis is used to identify potential zones for utilization. One method involves distance-based analysis using the buffer tool in ArcGIS. Buffer zones are created at various distances from the utilization area to determine potential levels of use. According to Farizal (2021), these distances can be classified into three categories: 0–50 meters indicates high utilization potential, 50–100 meters indicates medium potential, and distances beyond 100 meters represent low utilization potential. This classification provides a useful framework for spatial planning and resource management. It enables the identification of zones where human activity can be more intensively directed without causing excessive ecological disruption. Applying this approach in the Grojogan Sewu Nature Tourism Park aids in prioritizing areas for tourism infrastructure or visitor access. The use of GIS-based spatial modeling ensures that planning decisions are grounded in measurable data. Ultimately, this supports sustainable management by balancing utilization with the need to mitigate ecological stress.

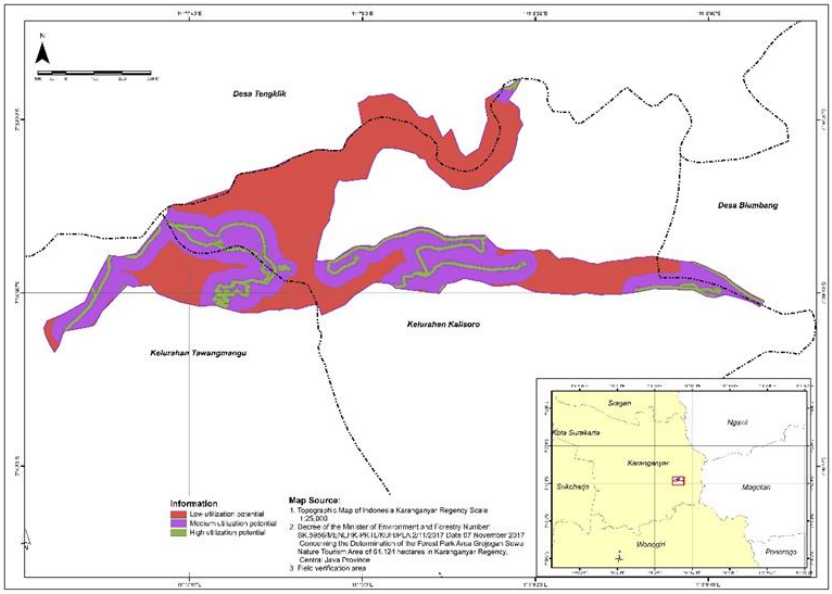

Figure 7. Map of potential utilization of Grojogan Sewu Nature Tourism Park

Grojogan Sewu Nature Tourism Park is divided into three categories of potential utilization based on the distance of community accessibility. These categories reflect how intensively different parts of the area can be used, especially in relation to tourism and water resource access. Areas with high utilization potential are located within approximately 0–50 meters from major tourist routes and water sources. These zones are the most frequently accessed and used by visitors and local communities. Medium utilization potential areas are situated at

distances of about 50–100 meters from the same routes. These areas are still accessible but are less intensively used than those in the high potential category. Low utilization potential refers to areas that lie beyond 100 meters and are not traversed by tourist pathways or used for water access. These zones tend to experience minimal human activity and are often left in a more natural state. This classification provides a basis for managing spatial use within the park according to ecological sensitivity and accessibility. Incorporating such zoning into park planning supports sustainable tourism while minimizing environmental degradation.

3.9. Tourist Activity Area

The tourism utilization area can be classified as a human activity zone, in addition to areas identified through surveys as having potential for human activity and high ecological pressure. To support spatial planning, geospatial processing is conducted using ArcGIS to determine zones with potential for tourism utilization. This process allows for the identification and classification of areas based on their suitability and level of ecological impact. Tourism activities within the park are categorized into three distinct levels. Low activity areas are characterized by the absence of tourist attractions and supporting facilities. These zones generally experience minimal human presence and are maintained in a more natural state. Moderate activity areas contain one to two tourist attractions or infrastructure facilities. These areas receive occasional visitor flow but remain within manageable ecological limits. High activity areas are defined by the presence of more than two tourist objects or facilities, indicating a higher frequency of human use. This classification assists in aligning tourism development with environmental carrying capacity and conservation goals.

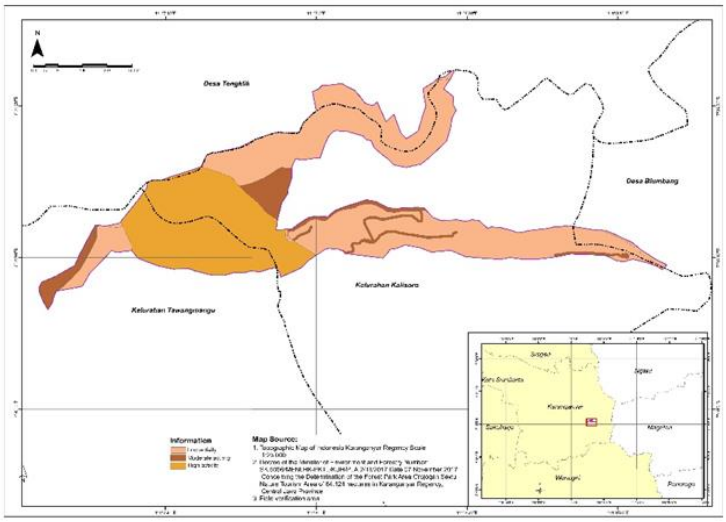

Figure 8. Map of tourist activities in Grojogan Sewu Nature Tourism Park

The Nature Tourism Park, managed by PT Duta Djaya Lestari, covers a total area of approximately 20 hectares. Within this area, the zone categorized as high activity includes various natural tourism attractions and supporting facilities. This zone serves as the primary destination for visitors due to its concentration of tourism infrastructure and scenic features. Facilities such as gazebos, rest areas, and information boards are commonly found in this section. In contrast, the medium activity zone consists mainly of the visitor pathway, which includes a horse-riding track and access routes to the main tourist site. This area functions primarily as a transitional space connecting high activity zones. Meanwhile, the low activity zone encompasses areas that

are not utilized for tourism purposes. These parts of the park lack both visitor facilities and tourism attractions. As a result, they remain relatively undisturbed and are often characterized by more natural and less-managed vegetation. The delineation of activity levels in the park reflects both the intensity of human presence and the degree of infrastructure development.

3.10. Water resource utilization areas within the region

The Nature Tourism Park has significant potential as a source of water, which is utilized by the surrounding community to fulfill their daily needs. In accessing these water resources, residents often pass through conservation areas along specific routes. This interaction illustrates the socio-economic sensitivity of the local population toward the conservation area. Based on the intensity of use, the classification of water source utilization is divided into three categories: low activity areas, where water sources are used by fewer than 100 households; moderate activity areas, where usage ranges between 100 and 150 households; and high activity areas, where more than 150 households rely on the water sources.

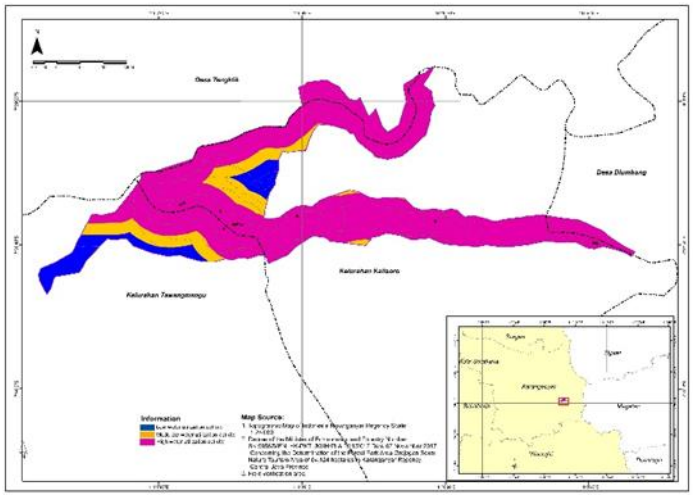

Figure 9. Map of water utilization activities in the Grojogan Sewu Nature Tourism Park

Grojogan Sewu Nature Tourism Park is home to nine natural springs that serve as vital water sources for the surrounding communities. These springs play a crucial role in meeting the daily water needs of residents in several nearby villages. Based on the intensity of use, the areas surrounding these springs can be categorized into three levels of activity: high, medium, and low. High-activity areas are characterized by the utilization of water sources by more than 150 households, predominantly located in Nglebak Village and parts of Tawangmangu Village. These areas indicate a significant dependence on spring water, which may exert pressure on the natural environment. Medium-activity areas, found primarily in Tengklik Village, involve the use of water sources by approximately 100 to 150 households. These areas represent a moderate level of dependency, often balancing between environmental sustainability and socio-economic needs. Low-activity areas, where fewer than 50 households rely on spring water, are distributed in certain parts of Tawangmangu and Tengklik Villages. These areas typically exert minimal pressure on the springs, although they still contribute to the overall utilization pattern. The spatial distribution of these activities reflects both the geographical accessibility of the springs and the varying needs of each village..

DISCUSSION

After identifying the criteria that fall under ecological sensitivity and socio-economic sensitivity, the weighting process can be carried out using the Analytical Hierarchy Process (AHP) method, guided by the Pairwise Comparison Matrix (PCM). The PCM is a technique commonly applied in multi-criteria decision making (MCDM) to systematically evaluate and compare various criteria or alternatives in pairs. This approach enables decision makers to express their preferences between two criteria at a time, which are then compiled into a structured matrix. By quantifying subjective judgments, the PCM supports the derivation of relative weights for each criterion. This method is widely recognized and frequently applied in both the AHP and the Analytical Network Process (ANP), as noted by Kou et al. (2016). In the context of the Grojogan Sewu Nature Tourism Park, this approach was used to analyze the sensitivity-based zoning or management blocks within the area. The weight values derived from the PCM reflect the relative importance of ecological and socio-economic factors in spatial planning. These weights are essential in guiding conservation strategies and sustainable tourism development. The final output of this analysis is presented in Table 9, which displays the results of the Spatial Multi-Criteria Analysis (SMCA). The SMCA table summarizes the calculated weightings for both ecological and socio-economic sensitivity using the Pairwise Comparison Matrix method.

Table 1. SMCA/E matrix for determining the zoning of Grojogan Sewu Nature Tourism Park

Goal	Sub-Goals	Criteria	Weight (AHP)	Class	Score
Zoning Directions	Ecological Sensitivity	Vegetation cover	26.3	Water body/no vegetation	2
				Very sparse vegetation/open land	4
				Sparse vegetation	6
				Moderate vegetation	8
				Dense vegetation	10
		Land cover	11.8	Built up areas and open land	2
				Shrubs – bushes – fields	4
				Plantation crops / forest at stake level	6
				Body of water	8
				Tree-lined forest area2983	10
		Slope Class	12.4	Flat	2
				Sloping	4
				A bit steep	6
				Steep	8
				Very Steep	10
		Classification of rock sensitivity	6.6	Low sensitivity	3
				Medium sensitivity	6
				High sensitivity	10
		Flora & fauna sensitivity	42.8	Low protection	30
				Medium protection	20
				High protection	10
			58.9	Low utilization potential	3

	Socio-Economic Sensitivity	Accessibility of potential utilization		Medium utilization potential	6
				High utilization potential	10
		Tourist Activity Area	25.2	Low activity	3
				Moderate activity	6
				High activity	10
		Water resource utilization areas within the region		Low activity	3
				Moderate activity	6
				High activity	10

The application of the Analytical Hierarchy Process (AHP) integrated with Spatial Multi-Criteria Analysis (SMCA) was utilized to support spatial zoning and land-use decisions in Grojogan Sewu Nature Tourism Park. This decision-support approach is particularly suitable for addressing complex spatial planning problems that require the integration of ecological, socio-economic, and physical parameters (Malczewski, 1999; Saaty, 1980). The results indicate that socio-economic criteria exert the greatest influence in the determination of spatial priorities. The accessibility of potential utilization emerged as the most significant factor, contributing 58.9% of the total weight. This suggests that areas with higher levels of accessibility are deemed more suitable for development, particularly for tourism and recreational purposes. The tourist activity area criterion followed with a weight of 25.2%, highlighting the role of existing or potential tourism infrastructure in shaping zoning decisions. From the ecological perspective, vegetation cover was the most influential criterion, weighted at 26.3%, emphasizing the importance of vegetative integrity in maintaining ecosystem function and biodiversity. Other ecological variables such as slope class (12.4%), land cover (11.8%), and rock sensitivity classification (6.6%) were also considered, representing the biophysical sensitivity and ecological vulnerability of different zones. These parameters are crucial for informing conservation-oriented zoning, in line with sustainable landscape management practices (Geneletti, 2002).

The water resource utilization area—a socio-economic factor—was weighted at 15.9%, indicating the importance of freshwater availability in both ecological functioning and local community support. Although the specific weight of flora and fauna sensitivity was not explicitly defined in the model, it remains a key consideration in the ecological evaluation of the park, consistent with the biodiversity protection goals outlined in protected area management (Phillips, 2002). Each criterion was evaluated using a standardized scoring scale from 2 to 10, allowing for consistent comparative assessments. Areas characterized by dense forest vegetation, steep slopes, or high conservation value were assigned higher scores (8–10), signifying greater ecological importance or development constraints. Conversely, built-up areas, flat terrains, or sparsely vegetated land received lower scores (2–4), indicating zones with higher development feasibility. Overall, the integration of AHP and SMCA offers a structured, transparent, and evidence-based approach to support spatial decision-making in conservation areas. In the context of Grojogan Sewu Nature Tourism Park, the method enables the formulation of zoning policies that balance ecological protection with sustainable tourism development, thereby contributing to long-term environmental stewardship and socio-economic viability (Saaty, 2008; Malczewski & Rinner, 2015).

The next step in the analysis involved determining the spatial zoning allocation through a weighted overlay process using ArcMap. This procedure was carried out by multiplying each

standardized criterion score with its respective weight—previously derived through the Analytical Hierarchy Process (AHP)—to produce a composite score for each spatial unit. The spatial layers (shapefiles) representing ecological sensitivity (e.g., vegetation cover, slope, land cover, rock sensitivity) and socio-economic sensitivity (e.g., accessibility, water resource utilization, and tourist activity zones) were integrated through an overlay operation. The results of this overlay analysis yielded two principal zoning categories: the Protection Block and the Utilization Block. Areas with high composite sensitivity scores—indicating fragile ecological conditions, steep terrain, or critical vegetation cover—were classified as Protection Blocks. In contrast, areas exhibiting lower ecological sensitivity but higher accessibility and socio-economic potential were designated as Utilization Blocks.

The spatial distribution of these zones is illustrated in Figure 10. The Protection Block, shown in red, encompasses approximately 38.966 hectares and covers regions deemed unsuitable for development due to their ecological vulnerability. Meanwhile, the Utilization Block, shown in green, spans around 27.158 hectares and includes areas with development potential that can support sustainable tourism activities. These zones are located across several administrative units, including Kelurahan Tawangmangu, Kelurahan Kalisoro, and parts of Desa Tengklik and Desa Blumbang. This zoning arrangement aligns with national conservation directives as defined in the Ministerial Decree SK.5566/MENLHK-PKTL/KUH/PLA.2/11/2017, which formalizes the status and extent of the Grojogan Sewu Nature Tourism Park. The zoning map serves not only as a spatial decision-support tool but also as a foundation for future policy development, conservation planning, and sustainable tourism management.

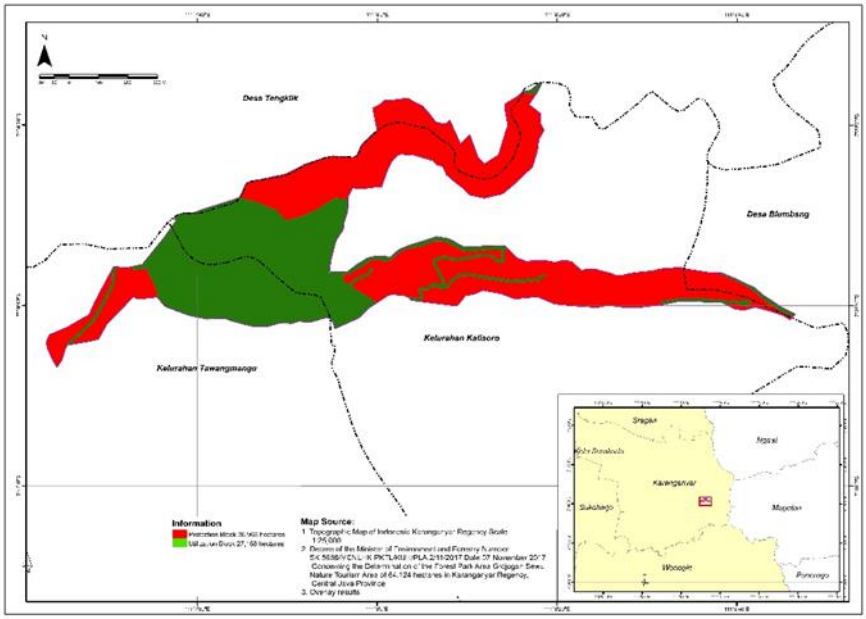

Figure 10. Zoning map of Grojogan Sewu Nature Tourism Park based on AHP/SMCA overlay analysis. Red areas represent the Protection Block (38.966 ha), and green areas represent the Utilization Block (27.158 ha). Source: Topographic Map of Indonesia, Ministerial Decree SK.5566/MENLHK-PKTL/KUH/PLA.2/11/2017, and overlay results.

Based on the results of the spatial analysis and discussion, the Grojogan Sewu Nature Tourism Park is divided into two primary management zones: the Protection Block and the Utilization Block. These zones were delineated based on ecological and socio-economic sensitivity factors, as identified through the AHP-SMCA analysis.

1. Protection Block

The Protection Block covers approximately 36.966 hectares, which constitutes 57.65% of the total park area. This zone is dominated by very steep slopes (greater than 45%) and features vegetation ranging from dense forest to more open cover types. Several considerations led to the classification of this area as a protection zone: (1) topographical conditions characterized by steep cliffs, (2) limited human activity, (3) its position as a riverbank protection area, and (4) its high vulnerability to landslides. To mitigate environmental risks and enhance ecological resilience, habitat restoration efforts, such as the strategic planting of tree species adapted to slope and soil sensitivity, are recommended.

2. Utilization Block

The Utilization Block encompasses approximately 27.158 hectares, or 42.35% of the park. The topographic gradient in this zone ranges from flat to very steep slopes (less than 15% to more than 45%). Despite the challenging terrain, this block includes areas suitable for both tourism and limited community use, such as water intake points and grass harvesting areas for livestock. The Utilization Block features several attractions, including the Grojogan Sewu Waterfall, a playground, a swimming pool, shelters, lush tree canopies, and scenic viewpoints that contribute to visitor enjoyment and ecological tourism. Additionally, this area is home to a population of long-tailed macaques (Macaca fascicularis), particularly along the main tourist route between Ticket Counter I and the waterfall. While the presence of these animals adds to the natural experience, their frequent interactions with visitors can pose management challenges, requiring targeted strategies to ensure both visitor safety and wildlife conservation.

Figure 11. The Grojogan Sewu Waterfall area located within the Utilization Block of the park. The site features rich vegetation, natural rock formations, and constructed paths that facilitate visitor access. It serves as the main tourist destination and ecological landmark within the Grojogan Sewu Nature Tourism Park.

CONCLUSION

This study demonstrates that an integrated approach combining ecological and socio-economic sensitivity analysis using AHP and SMCA methods within a GIS environment provides a robust basis for zoning management in nature tourism areas. In the case of Grojogan Sewu Nature Tourism Park, the resulting zoning scheme—comprising a Protection Block and a Utilization Block—reflects a spatial arrangement that aligns with the park's biophysical characteristics and community interaction patterns. By identifying areas of high ecological sensitivity, such as steep slopes, dense vegetation, and geologically fragile zones, alongside regions with high accessibility and tourism potential, the study offers a zoning strategy that balances conservation imperatives with sustainable tourism development. This spatial framework not only enhances the ecological integrity of the park but also supports equitable resource use and visitor management, offering a replicable model for adaptive spatial planning in other protected areas facing similar landscape pressures.

The zoning or block arrangement of Grojogan Sewu Nature Tourism Park, developed through the integration of the Analytical Hierarchy Process (AHP) and Spatial Multi-Criteria Analysis/Evaluation (SMCA/E), based on ecological and socio-economic sensitivity, resulted in the delineation of two primary management zones: the Protection Block and the Utilization Block. The Protection Block covers approximately 36.966 hectares, accounting for 57.65% of the total area, and is characterized by high ecological sensitivity requiring strict conservation measures. In contrast, the Utilization Block spans 27.158 hectares, or 42.35% of the park's area, and is designated for tourism and limited community-based use. This zoning framework reflects a balanced approach that supports both biodiversity conservation and sustainable nature tourism development.

REFERENCE

1. Erdi, M.A., E. Fataei, M.E. Ramezani, dan H. R. Nakhjavani. 2017. "Spatial-Systematic Analysis Approach for Conservation Purposes." Journal of Wildlife and Biodiversity. 1 (1): 37-46. Doi:10.22120/jwb.2017.27578.
2. Farizal, A. 2001. Analisis Perencanaan Penataan Kawasan Suaka Margasatwa Gunung Tunggangan, Sragen, Jawa Tengah Dengan Pendekatan Sensitivitas Ekologis Dan Tekanan Ekologis Menggunakan Sistem Informasi Geografis (SIG). Tesis. Semarang: Sekolah Pascasarjana Universitas Diponegoro.
3. Geneletti, D. (2002). Ecological evaluation for environmental impact assessment. Ecological Engineering, 16(1), 1–8. https://doi.org/10.1016/S0925-8574(00)00173-1.
4. Hamidun, M.S. 2012. Zonasi Pengelolaan Taman Nasional Dengan Pendekatan Ekowisata (Kasus Calon Taman Nasional Nantu-Boliyohuto di Provinsi Gorontalo). Desertasi. Bogor: Sekolah Pasca Sarjana. Institut Pertanian Bogor.
5. Istiadi Y. 2014. Pengaruh Strategi Karyawisata Dan Sensitivitas Ekologis Terhadap Apresiasi Siswa Tentang Pelestarian Satwa. EDUSAINS. 6(02):186 – 190.

6. Kou, G., Ergu, D., Lin, C., & Chen, Y. (2016). Pairwise comparison matrix in multiple criteria decision making. Technological and economic development of economy, 22(5), 738-765.
7. Kunarso, A., T.A.A. Syabana, S. Mareti, F. Azwar, T. Kharis, dan Nuralamin. 2019. "Analisis Spasial Tingkat Kerusakan Kawasan Suaka Margasatwa Padang Sugihan Sumatera Selatan." Jurnal Penelitian Hutan dan Konservasi Alam. 16(2): 191-207.
8. Malczewski, J. (1999). GIS and multicriteria decision analysis. New York: John Wiley & Sons.
9. Malczewski, J., & Rinner, C. (2015). Multicriteria decision analysis in geographic information science. New York: Springer.
10. Mizobuchi, H. (2017). Measuring socio-economic factors and sensitivity of happiness. Journal of Happiness Studies, 18, 463-504.
11. Phillips, A. (2002). Management guidelines for IUCN Category V protected areas: Protected Landscapes/Seascapes. IUCN.
12. PP No.6 tahun 2007. Peraturan Pemerintah RI Nomor 6 Tahun 2007 tentang Tata Hutan Dan Penyusunan Rencana Pengelolaan Hutan, Serta Pemanfaatan Hutan. Jakarta: Pemerintah Republik Indonesia.
13. Rathore, A., Kumar, A., & Patidar, N. P. (2023). Techno-socio-economic and sensitivity analysis of standalone micro-grid located in central India. International Journal of Ambient Energy, 44(1), 1490-1511
14. Royana, R. 2013. Panduan Kelestarian Ekosistem untuk Pemanfaatan Panas Bumi. Jakarta: WWF-Indonesia.
15. Saaty, T. L. (1980). The analytic hierarchy process: Planning, priority setting, resource allocation. New York: McGraw-Hill.
16. Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83–98. https://doi.org/10.1504/IJSSCI.2008.017590.
17. UU No.41 tahun 1999. Undang-Undang (UU) nomor 41 tahun 1999 tentang Kehutanan. Jakarta: Pemerintah Republik Indonesia.
18. Vandergeest, P., & Peluso, N. L. 1995. Territorialization and state power in Thailand. Theory and society, 385-426.
19. Vandergeest, Peter. 1996. Mapping Nature: Territorialization of Forest Rights in Thailand. Society & Natural Resources: An International Journal, 9:2, 159-175.
20. Zhang, X., Z. Wang, dan J. Lin. 2015. "GIS Based Measurement and Regulatory Zoning of Urban Ecological Vulnerability." Sustainability. 7: 9924-9942. doi:10.3390/su7089924.