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Analysis of batu city's carrying capacity for land development and utilization for disaster-mitigation based tourism

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Abstract

Batu City, known as the "City of Tourism," faces significant environmental challenges due to its reliance on tourism and rapid urbanization. This study aims to analyze the carrying capacity and suitability for tourism development within the framework of disaster mitigation, utilizing Cloud-based Web Geographic Information Systems (GIS). By examining factors such as natural disaster potential, land capability, erosion risks, and drainage suitability, the research reveals that 86% of the city's land is classified as having low natural disaster potential, positioning it favorably for eco-tourism and adventure tourism. However, 14% of the area presents moderate risks, necessitating careful planning and risk mitigation strategies. The findings highlight the importance of developing sustainable infrastructure and integrating stakeholder engagement in the planning process. Additionally, the study emphasizes the critical role of carrying capacity in ensuring that tourism growth does not exacerbate environmental degradation. Ultimately, the research contributes to the establishment of the Information System for Land Capacity and Suitability Distribution Based on Disaster Mitigation (SIMAMBA), aimed at guiding policymakers in fostering sustainable tourism while preserving Batu City's natural resources for future generations. This study provides a comprehensive framework for integrating spatial analysis with sustainable tourism planning, offering valuable insights for similar regions facing the dual challenges of urbanization and environmental sustainability.

Keywords: Carrying Capacity; Sustainable Tourism; Geographic Information System

Abstrak

Kota Batu, yang dikenal sebagai "Kota Wisata," menghadapi tantangan lingkungan yang signifikan akibat ketergantungan pada pariwisata dan urbanisasi yang cepat. Studi ini bertujuan untuk menganalisis daya dukung dan kesesuaian pengembangan pariwisata dalam kerangka mitigasi bencana dengan memanfaatkan Sistem Informasi Geografis (SIG) berbasis Cloud Web. Dengan mengkaji faktor-faktor seperti potensi bencana alam, kemampuan lahan, risiko erosi, dan kesesuaian drainase, penelitian ini mengungkapkan bahwa 86% lahan di kota ini diklasifikasikan memiliki potensi bencana alam yang rendah, sehingga cocok untuk pengembangan ekowisata dan wisata petualangan. Namun, 14% wilayah memiliki risiko sedang, sehingga membutuhkan perencanaan hati-hati dan strategi mitigasi risiko. Hasil penelitian menekankan pentingnya membangun infrastruktur berkelanjutan dan mengintegrasikan keterlibatan pemangku kepentingan dalam proses perencanaan. Selain itu, studi ini menyoroti peran krusial daya dukung dalam memastikan pertumbuhan pariwisata tidak memperburuk degradasi

lingkungan. Pada akhirnya, penelitian ini berkontribusi pada pendirian Sistem Informasi Kapasitas dan Distribusi Kesesuaian Lahan Berbasis Mitigasi Bencana (SIMAMBA) yang bertujuan memandu pembuat kebijakan dalam mendorong pariwisata berkelanjutan sambil melestarikan sumber daya alam Kota Batu untuk generasi mendatang. Studi ini menyediakan kerangka kerja komprehensif untuk mengintegrasikan analisis spasial dengan perencanaan pariwisata berkelanjutan, serta menawarkan wawasan berharga bagi wilayah lain yang menghadapi tantangan ganda urbanisasi dan keberlanjutan lingkungan.

Kata Kunci: Daya Dukung; Pariwisata Berkelanjutan; Geographic Information System

INTRODUCTION

Batu City, renowned as the "City of Tourism," is celebrated for its rich array of natural, artificial, and cultural attractions. However, the city's heavy reliance on tourism has brought about significant environmental challenges. The construction boom to meet growing tourist demand has led to ecosystem destruction, disrupted river flows, and deforestation, which in turn negatively impact agriculture and degrade land quality. Additionally, while tourism generates substantial revenue for the government and local communities, it comes with environmental costs. Increased travel has elevated the city's carbon footprint, and tourist activities contribute to significant waste generation, further straining the environment.

These changes have heightened the city's vulnerability to natural disasters, as illustrated by one of the tourist destinations in Batu City, the Taman Langit tourist destination in Bumiaji District. Developed on a site designated as a Protected Forest Area, Taman Langit offers scenic views but has experienced the construction of permanent structures, leading to landslides and erosion. Recognizing the importance of environmental sustainability, it is crucial to establish a comprehensive evaluation and land-use limitation plan. This plan should integrate with spatial planning documents and incorporate the concept of environmental carrying capacity. Such measures can enable Batu City to promote sustainable tourism while preserving its natural resources for future generations.

The aim of this research is to evaluate the carrying capacity and suitability of land for tourist destinations in Batu City, focusing on disaster mitigation and environmental sustainability. Given the city's reliance on tourism, which has led to significant environmental challenges, the study seeks to develop a comprehensive land-use limitation plan that integrates the concept of environmental carrying capacity. By utilizing innovative tools like Cloud-based Web Geographic Information Systems (GIS), the research will contribute to the Information System for Land Capacity and Suitability Distribution Based on Disaster Mitigation (SIMAMBA), supporting sustainable tourism while preserving natural resources.

1.1. Geographic Information Systems (GIS)

Spatial analysis using Geographic Information Systems (GIS) has become an increasingly important tool for decision-making across various disciplines (Karnatak et al., 2007; Bhermana & Susilawati, 2023). GIS enables the capture, storage, analysis, and management of spatial data, facilitating the identification of patterns and relationships (Torres-Román et al., 2018; Ihsan et

al., 2021). This technology has been applied in urban planning, environmental impact assessments, traffic analysis, and disease surveillance, among other areas (Bhermana & Susilawati, 2023; Irawan, 2022). By generating spatial information and performing clustering analyses, GIS provides valuable insights that enhance informed decision-making (Bhermana & Susilawati, 2023; Ihsan et al., 2021).

Building on the capabilities of GIS, the concept of carrying capacity plays a crucial role in sustainable land development, particularly in disaster-mitigation-based tourism (Jossi et al., 2022; Setyawati, 2023; Zhou et al., 2021). Carrying capacity refers to the ability of land resources to support human activities without leading to environmental degradation (Han et al., 2021; Yang et al., 2019). Assessing this capacity is essential for ensuring that land use does not exacerbate natural disaster risks, and integrating this analysis with spatial planning helps identify suitable areas for tourism development while minimizing the impact on disaster-prone regions (Jossi et al., 2022; Erwindy et al., 2021).

1.2. Carrying Capacity

Various evaluation methods for carrying capacity, such as ecological footprint analysis and index system approaches, consider factors like population, resources, and socio-economic development (Yongfu et al., 2015; Jiang et al., 2015; Han et al., 2021; Yang et al., 2019; Cheng et al., 2015). For example, a study in Palu City, Indonesia, revealed that while 74.56% of the area is earthquake-prone, 78.79% of land use aligns with its carrying capacity, particularly in protected regions (Jossi et al., 2022). This emphasizes the need for effective land use planning to mitigate disaster risks.

In the Yangtze River Delta of China, research highlighted the significance of energy and green spaces for ecological carrying capacity, while infrastructure also plays a critical role (Liu, 2012). Such insights are vital for ensuring that land use and infrastructure support disaster-resilient tourism. By integrating land carrying capacity analysis with spatial planning and disaster risk management, policymakers can align tourism growth with environmental, social, and economic capacities, thereby enhancing resilience for local communities and the tourism industry (Jossi et al., 2022; Erwindy et al., 2021). This holistic approach underscores the complementary nature of GIS and carrying capacity assessments in fostering sustainable tourism development.

METHOD

This research employs a qualitative method, with data actively collected in the field through direct observation, mapping, photography, and secondary data sourced from the Public Works and Spatial Planning Department and the Tourism Department of Batu City. The qualitative approach was chosen as it effectively supports the achievement of the research objectives. As noted by Risfandini and Putri (2023), a key strength of qualitative methods is

their ability to provide rich, detailed information from a relatively small number of participants and cases, enhancing the understanding of the research topic.

To achieve these objectives, a qualitative research method is employed, emphasizing active data collection in the field. The methodology involves multiple components. For data collection, spatial data is gathered using GIS to analyze land use, natural disaster risks, erosion, drainage, and urbanization patterns, with sources including satellite imagery, government reports, and local surveys. Complementing this, field surveys are conducted to validate GIS data, providing qualitative insights into land conditions and tourism potential through direct observation, mapping, and photography. In the land capability analysis, GIS is utilized to assess factors such as soil quality, topography, and existing infrastructure, identifying areas with high, moderate, and low potential for tourism development. The disaster risk assessment examines natural disaster risks using historical data and predictive models to map and categorize areas prone to disasters like floods and landslides. Additionally, a carrying capacity evaluation is performed to determine the sustainable tourism development potential of different areas by analyzing environmental impacts, resource availability, and community needs. Spatial analysis employs advanced GIS techniques to visualize spatial relationships and patterns, identifying suitable areas for tourism while considering disaster risks and environmental sustainability. The findings contribute to the development of SIMAMBA, a platform integrating data and analyses to assist policymakers in effective land management. Finally, stakeholder engagement involves collaboration with local government officials, tourism operators, and community members to ensure the research findings are practical, align with community needs, and refine strategies for successful implementation.

RESULT AND DISCUSSION

A. *Result*

Batu City has a total land area of 19,418 hectares, divided into two natural disaster potential categories. The Moderate Natural Disaster Potential category covers 2,629 hectares or approximately 14% of the area, indicating that a small portion of the region has a higher disaster risk. This area may require disaster risk mitigation measures if developed for tourism, especially for projects involving intensive infrastructure and activities. Mitigation efforts may include the construction of disaster-resilient infrastructure and the establishment of clear evacuation routes, ensuring tourist safety.

Meanwhile, the Low Natural Disaster Potential category encompasses 16,789 hectares or 86% of the total land area. The majority of this region has a low natural disaster risk, making it safer and more suitable for tourism development. This includes attractions such as natural tourism (plantations, mountains), as well as cultural and culinary tourism. These conditions support sustainable tourism development in Batu City, enabling safer and more diverse tourism activities, such as eco-tourism or adventure tourism. With its low disaster potential, this area

presents significant opportunities to attract long-term visitors and contribute to the growth of the local economy.

Land Cover Development

The following map presents an analysis of land use in Batu City from 2014 to 2024. This analysis aims to provide an overview of the dynamics of land cover changes over the past 10 years, as well as their potential impacts on the environment and the tourism sector.

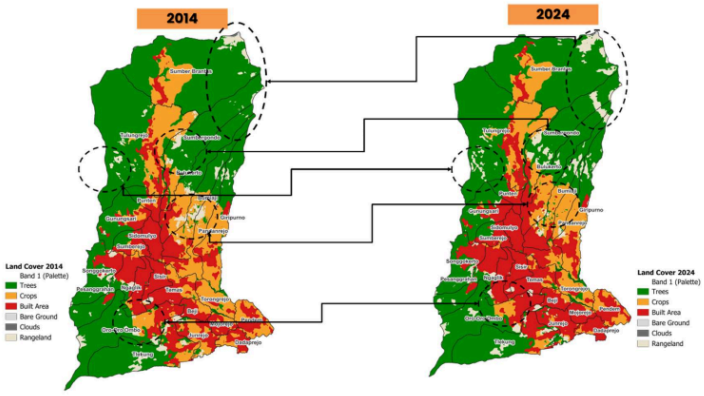

Figure 1: Land Cover Map of Batu City 2014–2024

Source: RBI accessed in 2024

In the 2014 map on the left, various land use categories are displayed in different colors: dark green for trees (forests), light green for agricultural land, yellow for grasslands, red for built-up areas, and orange for vacant land. The map shows that most of the area was still dominated by forest and agricultural land, particularly in the northern and central parts. Built-up areas in 2014 were relatively limited and concentrated in specific regions, primarily in the southern and lower central areas.

In contrast, the 2024 map on the right illustrates a shift in land use. Built-up areas, marked in red, have noticeably expanded, especially in areas previously occupied by agricultural land or trees. This expansion indicates an increase in development activities and urbanization over the past ten years. Green areas or tree cover in the northern and central parts remain dominant but appear slightly fragmented compared to the 2014 map, suggesting possible land conversion for infrastructure or residential development.

These changes in land cover have potential implications for the region's tourism sector, both in terms of tourism development and environmental conservation efforts. As a city that relies heavily on tourism as its main attraction, these land-use changes present both challenges and opportunities. On one hand, the expansion of built-up areas can support the development

of tourism facilities and infrastructure. On the other hand, it risks reducing natural areas that serve as the main draw for eco-tourism.

Vegetation Density Development (NDVI)

The following map illustrates the development of vegetation density in Batu City from 2014 to 2024 using the Normalized Difference Vegetation Index (NDVI) analysis. The NDVI map displays vegetation density with a color scale, where green indicates high vegetation density, while lighter colors or shades closer to red signify lower density.

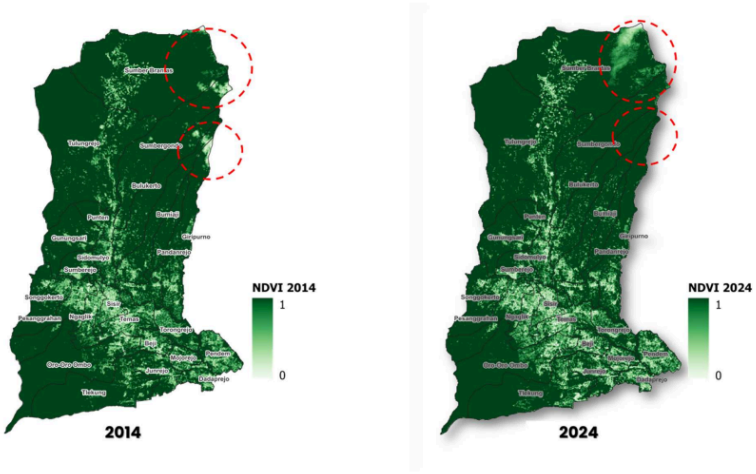

Figure 2: NDVI Analysis Map of Batu City 2014–2024
Source : EO-Browser, accessed 2024

In 2014, Batu City displayed relatively high vegetation density, particularly in areas marked with dark green. Regions with very dense vegetation were observed in several forested areas, showing NDVI values ranging from 0.78 to 1, indicating lush and healthy vegetation. This dense vegetation was predominantly located in forested areas, which were likely part of the city's natural tourism attractions. However, the 2024 map reveals changes in vegetation density in some areas marked in red, particularly in the northern region outlined with a red circle on the map. This indicates a decline in vegetation density in these areas over the past ten years, which could be attributed to various factors such as land-use conversion, tourism activities, or development projects. These changes are significant as Batu City has substantial potential for nature-based tourism. By maintaining high vegetation density, the city can preserve the ecological balance that serves as a major draw for tourists. Therefore, this map not

only functions as a tool for monitoring vegetation conditions but also highlights the importance of sustaining the ecosystem in this area to optimize the benefits of its natural tourism attractions.

Land Capability Analysis

1. Morphological Land Capability Unit Analysis

The Morphological Land Capability Unit analysis in Batu City categorizes land areas based on their suitability for development, using morphology and slope maps. The city's total area of 19,418 hectares is divided into five categories of land development capability. The largest category, "Moderately High Development Capability," spans 7,189 hectares (37%), suitable for intensive development like residential or cultivation zones. The smallest category, "Medium Development Capability," covers 2,629 hectares (14%), offering moderate development potential. Other categories include "Low Development Capability" (2,358 hectares, 12%) and "Very Low Development Capability" (3,739 hectares, 19%), with the latter being less suitable for development due to complex topography, making it better for conservation or nature tourism. The analysis highlights that most of Batu City's land has development potential, while more complex areas are suited for environmental protection. Based on the analysis results, the Morphological Land Capability in Batu City is as follows.

Table 1: Morphological Land Capability of Batu City

No	Morphological Land Capability	Area Ha	Percentage
1.	Medium Land Capability	2.629	14%
2.	Moderately High Development Capability	7.189	37%
3.	Low Development Capability	2.358	12%
4.	Very Low Development Capability	3.739	19%
5.	Very High Development Capability	3.503	18%
Grand Total		**19.418**	**100%**

Source: Researchers Analysis, 2024

2. Land Capability Units for Natural Disaster

The Land Capability Units analysis for natural disasters in Batu City assesses the land's ability to withstand geological disasters to minimize risks and casualties. With a total area of 19,418 hectares, Batu City is divided into two categories based on natural disaster potential. The "Moderate Natural Disaster Potential" category covers 2,629 hectares (14%), indicating a higher disaster risk that may require mitigation measures like disaster-resistant infrastructure and clear evacuation routes, especially for tourism development. The larger "Low Natural Disaster Potential" category, covering 16,789 hectares (86%), has minimal risk, making it safer and more suitable for various tourism activities, such as eco-tourism and adventure tourism. This area supports sustainable tourism development, offering long-term economic benefits for the region.

Table 2: Natural Disaster Land Capability

No	Natural Disaster Land Capability	Area (Ha)	Percentage
1	Moderate Natural Disaster Potential	2.629	14 %
2	Low Natural Disaster Potential	16.789	86%

Grand Total	19.418	100%

Source: Researchers Analysis, 2024

3. Land Capability Unit analysis for Drainage

The Land Capability Unit analysis for drainage in Batu City evaluates the land's ability to naturally channel rainwater and prevent flooding. With a total area of 19,418 hectares, Batu City is divided into three drainage capability categories. The largest category, "High Drainage Capability," covers 10,692 hectares (55%), making it ideal for tourism development, particularly outdoor activities, with minimal risk of waterlogging. The "Low Drainage Capability" category spans 6,097 hectares (31%), where drainage limitations may pose a risk of local flooding, requiring additional infrastructure for tourism development. The "Moderate Drainage Capability" category covers 2,629 hectares (14%), where tourism can be supported but may need careful drainage planning during periods of heavy rainfall. Overall, most of Batu City has high drainage capability, supporting sustainable tourism, while areas with moderate or low drainage require additional planning for infrastructure.

Table 3: Drainage Land Capability

No	Drainage Land Capability	Area (Ha)	Percentage
1	Moderate Drainage Capability	2.629	14%
2	Low Drainage Capability	6.097	31%
3	High Drainage Capability	10.692	55%
	Grand Total	19.418	100 %

Source: Researchers Analysis, 2024

4. Land Workability Capability

The Land Workability Capability analysis in Batu City assesses the ease of land excavation or preparation for development. The city, with a total area of 19,418 hectares, is divided into four workability categories. The largest category, "Moderately Easy to Work," covers 7,189 hectares (37%) and is ideal for tourism development requiring basic infrastructure. The "Less Easy to Work" category spans 5,861 hectares (30%) and may face challenges like topographic or soil conditions, requiring special construction techniques. The "Moderately Easy to Work" category, covering 2,629 hectares (14%), has potential for development but needs careful planning. The "Very Easy to Work" category, covering 3,739 hectares (19%), is optimal for tourism development with minimal excavation challenges. Overall, Batu City has significant potential for tourism development, with most areas being easy to work with for sustainable planning.

Table 4: Land Capability for Workability

No	Land Capability for Workability	Area (Ha)	Percentage
1	Moderate Workability	7.189	37%
2	Low Workability	5.861	30%
3	Medium Workability	2.629	14%
4	High Workability	3.739	19%

Grand Total	19.418	100%

Source: Researchers Analysis, 2024

5. Land Capability for Foundation Stability

The Land Capability for Foundation Stability analysis in Batu City evaluates the land's ability to support heavy buildings and determine suitable foundation types for urban development. With a total area of 19,418 hectares, the land is categorized into three foundation stability levels. The largest category, "Poor Foundation Support & Stability," covers 2,629 hectares (56%) and is unsuitable for heavy infrastructure, making it ideal for nature-based tourism with minimal land alteration, such as hiking trails or camping. The "Low Foundation Support & Stability" category spans 5,861 hectares (30%) and can support medium-scale developments like recreational parks or ecotourism with lightweight structures. The "High Foundation Support & Stability" category, covering 10,928 hectares (14%), offers excellent stability, suitable for intensive tourism infrastructure like hotels and attractions. Overall, Batu City's varied foundation stability supports both environmentally friendly and large-scale tourism development, promoting sustainable growth.

Table 5: Land Capability for Foundation Stability

No	Land Capability for Foundation Stability	Area (Ha)	Percentage
1	Low Bearing Capacity & Foundation Stability	2.629	56 %
2	Poor Bearing Capacity & Foundation Stability	5.861	30%
3	High Bearing Capacity & Foundation Stability	10.928	14%
	Grand Total	19.418	100%

Source: Researchers Analysis, 2024

6. Land Suitability Analysis for Water Availability

Batu City, with a total land area of 19,418 hectares, is categorized into four water availability zones. The largest category, Medium Water Availability, covers 37% of the land, supporting various tourism developments like recreation parks and homestays that require moderate water supply. About 31% of the city has Very Low Water Availability, which limits water-dependent tourism but still offers potential for dry destinations such as hiking trails and historical sites. Areas with Low Water Availability (18%) require careful water management, making them suitable for water-efficient tourism like agroecotourism or camping. The remaining 18% of the land has High Water Availability, ideal for tourism projects with high water demands, such as water parks and resorts. Overall, most of Batu City's land has moderate to low water availability, necessitating water-conscious tourism planning, with nature-based activities suited for areas with limited water resources and larger developments in water-rich areas.

Table 6: Land Capability for Water Availability

No	Land Capability for Water Availability	Area (Ha)	Percentage

1	Low Water Availability	2.629	18%
2	Very Low Water Availability	6.097	31%
3	Moderate Water Availability	7.189	37%
4	High Water Availability	3.503	18%
	Grand Total	19.418	100%

Source: Researchers Analysis, 2024

7. Analysis of Land Capability for Waste Disposal Units

The Land Capability Analysis for Waste Disposal in Batu City identifies areas suitable for waste treatment and disposal. With a total area of 19,418 hectares, Batu City is divided into three categories based on waste disposal suitability. The largest category, "Sufficient Land Suitability for Waste Disposal," covers 10,692 hectares (55%), making it ideal for tourism facilities like restaurants and hotels, with proper waste management supporting intensive tourism activities. The "Insufficient Land Suitability for Waste Disposal" category spans 6,097 hectares (31%) and requires strict waste management, making it more suitable for nature-based tourism that minimizes waste, such as eco-tourism. The "Moderate Land Suitability for Waste Disposal" category covers 2,629 hectares (14%), supporting medium-scale tourism developments like tourist parks with manageable waste volumes. Overall, most of Batu City has sufficient capacity for waste disposal, supporting sustainable tourism, while areas with limited capacity are best suited for environmentally friendly tourism.

Table 7: Land Capability for Waste Disposal

No	Land Capability for Waste Disposal	Area (Ha)	Percentage
1	Moderate Land Capability for Waste Disposal	10.692	55%
2	Low Land Capability for Waste Disposal	6.097	31%
3	Medium Land Capability for Waste Disposal	2.629	14%
	Grand Total	19.418	100%

Source: Researchers Analysis, 2024

8. Land Capability Analysis for Erosion

The Soil Erosion Suitability Analysis in Batu City categorizes land based on erosion levels to assess its stability for development. The city, covering 19,418 hectares, has five erosion categories. The largest, "Very Low Erosion," spans 7,189 hectares (37%) and is ideal for nature-based tourism like recreational parks or eco-tourism. The "Moderate Erosion" category, covering 2,629 hectares (14%), requires careful environmental management for tourism development. "Fairly High Erosion" covers 2,358 hectares (12%) and is suited for eco-friendly tourism, like conservation or educational tourism. The "High Erosion" category, covering 3,739 hectares (19%), is better for protected areas or low-impact nature tourism. Finally, 3,503 hectares (18%) of land are not affected by erosion, offering flexible development potential. Overall, Batu City offers great tourism potential, with erosion-prone areas being more suitable for eco-tourism and conservation-focused activities.

Table 8: Land Capability for Erosion

No	Land Capability for Erosion	Area (Ha)	Percentage
1	Moderately High Erosion	2.358	12%
2	Very Low Erosion	7.189	37%
3	Moderate Erosion	2.629	14%
4	High Erosion	3.739	19%
5	No Erosion	3.503	18%
	Grand Total	19.418	100%

Source: Researchers Analysis, 2024

9. Land Capability Classification

Determining the land capability in the research area is one of the main objectives of this study. Several stages are required to understand the existing land capability conditions in the area. The parameters used to determine land capability are outlined in the Minister of Public Works Regulation No. 20 of 2007. There are 9 (nine) land capability indicators, which are: (1) morphology; (2) ease of work; (3) slope stability; (4) foundation stability; (5) drainage; (6) water availability; (7) erosion; (8) waste; and (9) natural disasters. The analysis of land capability is carried out by processing spatial data in GIS through overlay analysis

Table 9 Land Capability of Batu City

Class of Land Capability	Status of Land Capability	Area
Class A	Very Low Development Capability	3.503
Class B	Low Development Capability	2.358
Class C	Moderate Land Capability	2.629
Class D	Fairly High Development Capability	7.189
Class E	Very High Development Capability	3.739
	Total	19.418

Source: Researchers Analysis, 2024

The land capability analysis in Batu City, based on the Minister of Public Works Regulation No. 20 of 2007, uses nine indicators such as morphology, slope stability, drainage, and natural disasters. The analysis shows that Batu City is classified as Class D, which indicates moderately high development potential, covering 7,189 hectares (37% of the total area). This class includes areas primarily in Bumiaji District and is suitable for various development activities, including residential areas with medium density, commercial services, agriculture, and light industrial activities. Specific conditions, such as the use of wastewater treatment plants for industrial and high-density residential areas, are required for sustainable development. The area can also accommodate activities like protected forests, public services, and wetland agriculture with necessary infrastructure such as irrigation channels.

The overlay analysis of land capability with tourist sites in Batu City aims to assess the suitability of land for tourism development while ensuring environmental and economic sustainability. The results show that 37% of the tourist areas fall under very low development

capability, primarily due to high disaster risks from steep slopes, unstable soil, and river basins, requiring careful disaster risk mitigation. Areas with moderate (27%) and low (19%) development capability also face potential risks, necessitating attention to geological and hydrological factors for safe tourism development. Only 17% of the areas have moderately high development capability, offering lower disaster risks, but even here, development should proceed cautiously to avoid increasing environmental vulnerabilities.

B. Discussion

Batu City, with a total land area of 19,418 hectares, presents both opportunities and challenges for tourism development. The land is categorized based on various factors such as natural disaster potential, land capability, erosion risks, and drainage suitability. A significant portion of the city (86%) falls within low natural disaster potential, making it safer and more suitable for tourism, including eco-tourism and adventure tourism. However, 14% of the area has moderate natural disaster risks, which may require additional mitigation efforts. Land capability analyses show that most areas, including those with moderately high development potential (37%), can support a range of tourism activities, from eco-tourism to residential developments, with appropriate infrastructure. Nevertheless, certain areas with high erosion or poor drainage may be more suitable for nature-based tourism and require careful planning. The land cover analysis from 2014 to 2024 indicates increasing urbanization, which may affect eco-tourism, but also offers opportunities for building tourism infrastructure. Overall, Batu City's land capability analysis supports sustainable tourism development by identifying areas best suited for different types of tourism, while ensuring that environmental and disaster risks are managed appropriately.

The findings of this research on Batu City underscore the significant role of Geographic Information Systems (GIS) in facilitating informed decision-making for sustainable tourism development. As highlighted by previous studies, GIS has emerged as an essential tool across various disciplines, enabling the capture, storage, analysis, and management of spatial data (Karnatak et al., 2007; Bhermana & Susilawati, 2023). By identifying patterns and relationships within spatial data, GIS enhances our understanding of the interactions between tourism development and environmental factors (Torres-Román et al., 2018; Ihsan et al., 2021).

In Batu City, the application of GIS has revealed that 86% of the land has low natural disaster potential, making it favorable for eco-tourism and adventure tourism. This aligns with findings from past research that emphasize the importance of safety in attracting tourists, as areas with low disaster risk are more likely to encourage visitation. However, the 14% of land classified with moderate risks necessitates careful planning and the implementation of mitigation strategies, reinforcing the need for proactive risk assessment protocols (Jossi et al., 2022; Erwindy et al., 2021).

The concept of carrying capacity further supports the sustainable development framework in Batu City. Previous studies define carrying capacity as the ability of land

resources to accommodate human activities without leading to environmental degradation (Han et al., 2021; Yang et al., 2019). This research's carrying capability analysis, which indicates that a substantial portion of the city can support various tourism activities, reflects the principles established in earlier works. For instance, the identification of areas with moderately high development potential (37%) allows for diverse tourism opportunities, provided that adequate infrastructure is developed to support this growth sustainably.

Moreover, the findings highlight the challenges posed by urbanization, as the analysis from 2014 to 2024 shows increasing urban sprawl that could threaten essential eco-tourism areas. This situation mirrors concerns raised in previous studies regarding the impact of urbanization on natural spaces vital for tourism (Liu, 2012). The current research emphasizes the need for strategic urban planning that prioritizes sustainability and integrates disaster risk management with land use planning.

In summary, the current study builds on the foundations laid by previous research, demonstrating the complementary relationship between GIS and carrying capacity assessments in fostering sustainable tourism development. By effectively integrating these tools, policymakers can enhance the resilience of Batu City's tourism sector, ensuring that growth aligns with environmental, social, and economic capacities. This holistic approach is crucial in navigating the complexities of urbanization and natural hazards, ultimately paving the way for a sustainable tourism model that benefits both the local economy and the environment. Continuous monitoring and adaptive management will be essential in this endeavor, as highlighted by the collective insights from both this study and earlier research.

Recommendations for Batu City

To enhance sustainable tourism development, several key recommendations are proposed. First, integrate GIS in urban planning by utilizing Cloud-based Web GIS to monitor land use, natural disaster risks, and tourism potential. Regular updates to spatial data will enable policymakers to make informed decisions that balance tourism growth with environmental sustainability. Second, develop comprehensive risk mitigation plans by establishing protocols for areas with moderate disaster risks. These should include emergency response plans, risk assessment frameworks, and community awareness programs to build resilience and ensure visitor safety. Third, promote sustainable infrastructure development by focusing on eco-tourism and adventure tourism while minimizing environmental impact. This involves adopting sustainable building practices and ensuring new developments harmonize with the natural landscape.

In addition, enhance community engagement by involving local stakeholders, including community members, tourism operators, and government officials, in the planning process. Their insights will guide effective land use strategies and create a sense of ownership over local tourism initiatives. To further strengthen environmental preservation, prioritize nature-based tourism by identifying areas with high erosion or poor drainage for such activities. This

approach encourages responsible tourism that respects and enhances local ecosystems. Finally, implement continuous monitoring and adaptive management through ongoing assessments of land use, environmental impacts, and tourism trends. This will allow Batu City to adapt strategies in response to changing conditions, ensuring long-term sustainability.

Recommendations for Future Research

To support these initiatives, future research should focus on several areas. Conducting longitudinal studies will assess the long-term impacts of tourism development on ecosystems and community resilience, providing insights into the effectiveness of implemented strategies. Additionally, comparative studies with other tourist destinations facing similar challenges can help identify best practices in sustainable tourism and disaster risk management. Research into the impact of climate change on Batu City's natural resources and tourism infrastructure is also essential, with a focus on adaptive strategies to mitigate risks associated with climate variability.

Moreover, community perception studies should be conducted to understand local attitudes toward tourism development and its impacts. These insights will help align tourism strategies with community values, fostering social sustainability. Lastly, exploring technological innovations such as remote sensing and machine learning can enhance GIS applications for spatial analysis, improving data accuracy and decision-making processes. By implementing these recommendations, Batu City can achieve a balanced approach to sustainable tourism development, ensuring economic growth, environmental preservation, and community well-being. Future research will play a vital role in refining these strategies and adapting to evolving challenges.

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PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16