JURNAL PARIWISATA PESONA

Volume 10 No. 1, Juni 2025
Print-ISSN: 1410-7252 | Online-ISSN: 2541-5859

Page: 81-90

# Analysis of Batu City's carrying capacity for land development and utilization for disaster-mitigation based tourism

**Andini Risfandini[1]*, Ayu Fitriatul Ulya[1], Annisa Hamidah Imaduddina[2], Irwan Yulianto[1]**
[1]Diploma of Tourism Universitas Merdeka Malang
Jalan Bandung No.1 Malang 65113, Indonesia
[2]Faculty of Urban and Regional Planning, Malang National Institute of Technology
Jalan Sigura-Gura No. 2 Malang 65152, Indonesia

**ARTICLE INFO**

**Keywords:**
carrying capacity, geographic information system, sustainable tourism

**Katakunci:**
*daya dukung,* geographic information system, *pariwisata berkelanjutan*

**DOI:**
https://doi.org/10.26905/jpp.v10i1.15093

Received **December 18, 2024**
Review **December 18, 2024**
Accepted **June 30, 2025**

**Corresponding Author:**
Andini Risfandini
andini.risfandini@unmer.ac.id

**HOW TO CITE ITEM**

Risfandini, A., Ulya, A. F., Imadiddina, A. H., & Yulianto, I. (2025). Analysis of Batu City's carrying capacity for land development and utilization for disaster-mitigation based tourism. *Jurnal Pariwisata Pesona*, *10*(1). https://doi.org/10.26905/jpp.v10i1.15093

**ABSTRACT**

Batu City, widely known as the "City of Tourism," faces mounting environmental pressures due to its dependence on tourism and rapid urban development. This study aims to assess land suitability and tourism carrying capacity within a disaster mitigation framework using Cloud-based Web Geographic Information Systems (GIS). The analysis considers multiple spatial and environmental variables, including natural disaster risk, land capability, erosion potential, and drainage suitability. The results indicate that 86% of the city's land has low natural disaster risk, making it well-suited for eco-tourism and adventure tourism development. Conversely, 14% of the area shows moderate risk levels, underscoring the need for targeted planning and mitigation efforts. These findings highlight the importance of balancing development with environmental safeguards and involving stakeholders in sustainable infrastructure planning. As a practical output, the study supports the development of the SIMAMBA (Information System for Land Capacity and Suitability Distribution Based on Disaster Mitigation), designed to aid policymakers in guiding tourism development that respects ecological, social, and economic limits. In conclusion, the research reinforces the complementary roles of GIS and carrying capacity assessments in promoting sustainable tourism. Their integration offers a strategic pathway to enhance the resilience of Batu City's tourism sector while conserving its natural resources for future generations.

***ABSTRAK***

*Kota Batu, yang dikenal sebagai "Kota Wisata," menghadapi tekanan lingkungan yang semakin besar akibat ketergantungannya pada sektor pariwisata dan pesatnya urbanisasi. Penelitian ini bertujuan untuk menganalisis kesesuaian lahan dan daya dukung pariwisata dalam kerangka mitigasi bencana dengan memanfaatkan sistem informasi geografis berbasis web cloud (Cloud-based Web GIS). Analisis dilakukan dengan mempertimbangkan berbagai variabel spasial dan lingkungan, termasuk potensi bencana alam, kemampuan lahan, risiko erosi, dan kesesuaian drainase. Hasil penelitian menunjukkan bahwa 86% wilayah Kota Batu memiliki potensi bencana alam yang rendah, sehingga sangat cocok untuk pengembangan ekowisata dan wisata petualangan. Namun, 14% wilayah lainnya menunjukkan tingkat risiko sedang, yang memerlukan perencanaan dan strategi mitigasi yang cermat. Temuan ini menekankan pentingnya pembangunan infrastruktur berkelanjutan dan pelibatan para pemangku kepentingan dalam proses perencanaan. Sebagai output praktis, penelitian ini mendukung pengembangan SIMAMBA (Sistem Informasi Sebaran Kapasitas dan Kesesuaian Lahan Berbasis Mitigasi Bencana), yang dirancang untuk membantu pengambil*

*kebijakan dalam mengarahkan pembangunan pariwisata yang selaras dengan batas ekologis, sosial, dan ekonomi. Sebagai kesimpulan, penelitian ini menegaskan peran saling melengkapi antara GIS dan penilaian daya dukung dalam mendukung pengembangan pariwisata berkelanjutan. Integrasi kedua alat ini memberikan pendekatan strategis untuk memperkuat ketahanan sektor pariwisata Kota Batu sekaligus melestarikan sumber daya alamnya bagi generasi mendatang.*

## INTRODUCTION

Batu City, widely recognized as the "City of Tourism," offers a rich diversity of natural, artificial, and cultural attractions. The shift from farmland to tourism development highlights growing tension between economic growth and environmental preservation, calling for careful sustainability planning (Abbas et al., 2021). Urbanization and tourism development in Batu City have altered land use, reduced green spaces, and increased temperatures, contributing to land degradation and higher greenhouse gas emissions (Candra et al., 2024; Sumarmi et al., 2022; Rahmawati et al., 2023; Sari, 2021).

According to Central Bureau of Statistics Batu City, 2021 there were 103 landslides and 25 floods occurred between 2009 and 2019, reflecting environmental risks linked to increased tourism and urban growth ( Rahmawati et al., 2023; Sari, 2021). While tourism benefits the economy, it also increases carbon emissions and waste, intensifying environmental stress (UNWTO, 2020). This strain has made the city more vulnerable to natural disasters, as seen in the Taman Langit site in Bumiaji District, where construction in a Protected Forest Area has led to landslides and erosion (Budiarti et al., 2022).

By employing cloud-based Web GIS technologies, the study supports the development of SIMAMBA (Information System for Land Capacity and Suitability Distribution Based on Disaster Mitigation), a decision-support tool for guiding sustainable tourism planning (Binh et al., 2020; Li et al., 2023). These technologies enhance stakeholder decision-making by identifying areas suitable for development while protecting ecologically sensitive zones, thereby reducing disaster risk (Rosyida et al., 2022; Al-Ghorayeb et al., 2023).

Spatial analysis using GIS has become an essential tool in decision-making across disciplines (Karnatak et al., 2007; Bhermana & Susilawati, 2023), enabling data collection, storage, analysis, and management to uncover patterns and relationships (Torres-Román et al., 2018; Ihsan et al., 2021). GIS has been applied in urban planning, environmental assessments, transportation studies, and public health surveillance (Bhermana & Susilawati, 2023; Irawan, 2022). Through spatial information and clustering analyses, GIS provides insights that enhance evidence-based planning (Bhermana & Susilawati, 2023; Ihsan et al., 2021).

Complementing GIS, the concept of carrying capacity is vital for sustainable land development, especially in tourism driven by disaster-mitigation needs (Jossi et al., 2022; Setyawati, 2023; Zhou et al., 2021). Carrying capacity refers to a land's ability to support human activity without causing environmental harm (Han et al., 2021; Yang et al., 2019). Its assessment is crucial in avoiding development in disaster-prone zones and guiding tourism to suitable areas (Jossi et al., 2022; Erwindy et al., 2021).

Various evaluation approaches—such as ecological footprint analysis and index systems—consider 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 instance, a study in Palu City found that while 74.56% of land is earthquake-prone, 78.79% of current land use conforms to its carrying capacity, especially in protected areas (Jossi et al., 2022). Similarly, research in the Yangtze River Delta emphasized the importance of energy, green space, and infrastructure for ecological carrying capacity (Liu, 2012). These findings reinforce the need for land use planning that aligns with disaster risk management and sustainability goals. Integrating GIS with carrying capacity assessments offers a robust framework for policymakers to ensure that tourism development supports environmental, social, and economic resilience (Jossi et al., 2022; Erwindy et al., 2021). This research aims to evaluate the carrying capacity and land suitability for tourism development in Batu City, with an emphasis on disaster mitigation and environmental sustainability. It seeks to develop an integrated land-use restriction plan that aligns with spatial planning regulations and is based on the principles of environmental carrying capacity.

## METHOD

This research adopts a qualitative approach, which allows for in-depth exploration of land use, disaster risks, and tourism suitability in Batu City. As highlighted by Risfandini and Putri (2023), qualitative methods are particularly valuable for generating rich, contextual insights from a relatively small number of cases, enhancing the understanding of complex environmental and socio-spatial dynamics. Field data were actively collected through direct observation, mapping, photography, and interviews, complemented by secondary data from the Department of Public Works and Spatial Planning and the Tourism Department of Batu City. The qualitative approach is further strengthened through the use of spatial analysis techniques via Geographic Information Systems (GIS).

Spatial data were obtained from satellite imagery, government databases, and field surveys. These were used to analyze land use patterns, erosion levels, drainage systems, natural disaster risks, and urbanization trends. Field surveys served to validate GIS outputs, providing grounded, qualitative assessments of local land conditions and tourism potential through on-site observation and documentation. For the land capability analysis, GIS was applied to assess topography, soil quality, and infrastructure availability, which allowed the identification of zones with high, moderate, or low potential for sustainable tourism development. In parallel, a disaster risk assessment was conducted by integrating historical disaster records and predictive spatial models to map and categorize areas vulnerable to floods, landslides, and other hazards. The study also performed a carrying capacity evaluation, measuring the sustainable threshold of tourism activities based on environmental impacts, natural resource availability, and community needs. Spatial analysis using advanced GIS techniques enabled the visualization of spatial relationships and patterns, supporting the identification of suitable areas for tourism that align with disaster mitigation and environmental sustainability goals.

All results feed into the development of SIMAMBA (Information System for Land Capacity and Suitability Distribution Based on Disaster Mitigation)—a strategic platform designed to support local policymakers in sustainable land-use planning. Lastly, the research integrates stakeholder engagement, including consultations with local government officials, tourism operators, and community members to ensure the applicability and alignment of findings with on-the-ground realities and policy needs.

## RESULT AND DISCUSSION

Batu City covers a total area of 19,418 hectares and is classified into two natural disaster risk zones. The Moderate Risk Zone covers 2,629 hectares (14%), where tourism development should include disaster mitigation strategies, such as resilient infrastructure and evacuation routes to ensure tourist safety. The remaining 16,789 hectares (86%) fall under the Low Risk Zone, making them safer and more suitable for tourism activities. This area supports various tourism types, including natural tourism (plantations, mountains), cultural, and culinary tourism, with potential for eco-tourism and adventure tourism. These conditions favor sustainable tourism development and offer opportunities to attract long-term visitors, contributing to the local economy.

### Land Cover Development

The map on figure 1 shows changes in land use in Batu City from 2014 to 2024. This analysis provides insights into land cover dynamics over the past decade and highlights their potential impact on the environment and tourism sector.

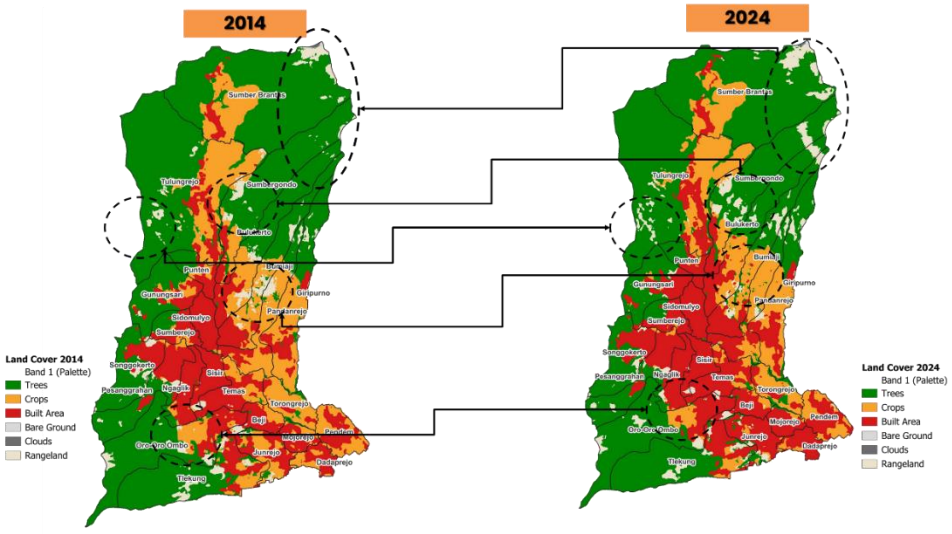


**Figure 1**. Land Cover Map of Batu City 2014–2024
Source: RBI accessed in 2024

The 2014 map (left) shows land use in Batu City with color-coded categories:

- Dark green for forests
- Light green for agricultural land
- Yellow for grasslands
- Red for built-up areas
- Orange for vacant land

At that time, forests and agricultural areas dominated, especially in the north and central regions. Built-up areas were limited and mostly concentrated in the southern and lower central zones. In the 2024 map (right), built-

up areas (red) have expanded significantly, replacing parts of agricultural and forested land. Although forests remain in the north and central areas, they appear more fragmented, suggesting land conversion for infrastructure or housing. These land cover changes have direct implications for tourism. The growth of built-up areas may support tourism infrastructure, but also threatens natural attractions that are vital for eco-tourism. Batu City must balance development with environmental conservation to maintain its tourism appeal.

**Vegetation Density Development (NDVI)**

The map figure 2 shows vegetation density changes in Batu City from 2014 to 2024, based on NDVI (Normalized Difference Vegetation Index) analysis.

- Green areas indicate high vegetation density.
- Lighter shades and red tones indicate lower vegetation cover.

This analysis helps identify areas experiencing vegetation loss, which is essential for planning sustainable tourism and environmental management.

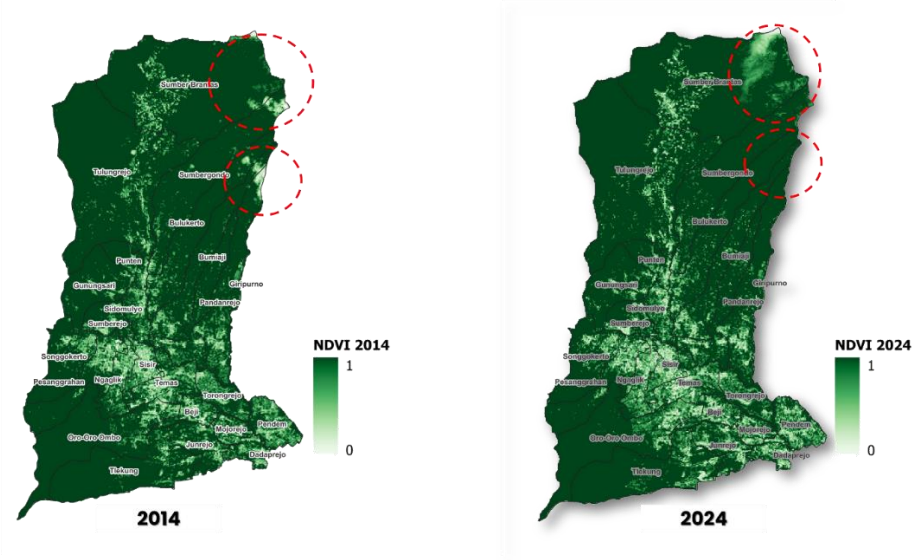


**Figure 2**. NDVI Analysis Map of Batu City 2014–2024
Source : EO-Browser, accessed 2024

In 2014, Batu City had **high vegetation density**, especially in areas marked dark green on the map. NDVI values between **0.78 and 1** indicate **dense, healthy vegetation**, mostly located in **forested zones** that support nature tourism. By 2024, several areas—especially in the **northern region (circled in red)**—show a **decline in vegetation density**, indicated by red-colored zones. This decline may result from **land-use changes**, **tourism expansion**, or **development projects**. These findings are critical for Batu City, which relies on **nature-based tourism**. Maintaining dense vegetation is essential for **ecological balance** and sustaining the area's tourism appeal. The NDVI map serves both as a **monitoring tool** and a **reminder of the need to protect ecosystems** that support long-term tourism benefits.

**Land Capability Analysis**

The Morphological Land Capability Unit analysis as seen on table 1 classifies Batu City's 19,418 hectares based on morphology and slope into five categories.

**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

The largest, "Moderately High Capability," covers 7,189 hectares (37%) and is suitable for intensive use like housing or agriculture. "Medium Capability" spans 2,629 hectares (14%) with moderate development potential, while "Low Capability" (2,358 hectares or 12%) offers limited suitability. "Very Low Capability," covering 3,739

hectares (19%), is least suitable due to steep terrain and is better preserved for conservation or nature-based tourism. Overall, much of Batu City supports development, while lower-capability areas are ideal for environmental protection.

**Land Capability Units for Natural Disaster**

The Land Capability Units analysis on table 2 shows that 14% (2,629 ha) of Batu City's land has moderate disaster risk, requiring mitigation for tourism development. The remaining 86% (16,789 ha) has low disaster potential, making it safer and more suitable for sustainable tourism, with strong potential for long-term economic growth.

**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

**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 (table 3). 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.

**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

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.

**Land Workability Capability**

The Land Workability Capability analysis in Batu City divides its 19,418 hectares into four categories as seen on table 4. The largest, "Moderately Easy to Work" (7,189 ha or 37%), is suitable for basic tourism infrastructure. "Less Easy to Work" (5,861 ha or 30%) may require special construction due to terrain or soil. "Very Easy to Work" (3,739 ha or 19%) offers minimal development challenges, while 14% (2,629 ha) requires careful planning. Overall, most of the land is suitable for tourism development with manageable workability.

**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

**Land Capability for Foundation Stability**

The Foundation Stability analysis in Batu City (table 5) assesses land suitability for supporting structures across 19,418 hectares. "Poor Stability" (2,629 ha or 56%) is best for low-impact tourism like hiking or camping. "Low Stability" (5,861 ha or 30%) suits lightweight structures such as parks or ecotourism facilities. "High Stability" (10,928 ha or 14%) supports intensive tourism development like hotels. This variation enables both eco-friendly and large-scale tourism, supporting 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

**Land Suitability Analysis for Water Availability**

Batu City, with a total land area of 19,418 hectares, is categorized into four water availability zones (Table 6). 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

**Analysis of Land Capability for Waste Disposal Units**

The Waste Disposal Capability analysis in Batu City categorizes its 19,418 hectares into three levels (Table 7). "Sufficient Suitability" (10,692 ha or 55%) supports intensive tourism with proper waste systems. "Moderate Suitability" (2,629 ha or 14%) fits medium-scale tourism like parks. "Insufficient Suitability" (6,097 ha or 31%) is better for low-impact, eco-friendly tourism. Overall, most of the city can support sustainable tourism with effective waste management.

**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

**Land Capability Analysis for Erosion**

The Soil Erosion Suitability Analysis in Batu City divides its 19,418 hectares into five categories (Table 8). "Very Low Erosion" (7,189 ha or 37%) and "No Erosion" (3,503 ha or 18%) offer high potential for various tourism activities. "Moderate" (2,629 ha or 14%) and "Fairly High Erosion" (2,358 ha or 12%) require careful planning, suited for eco-friendly tourism. "High Erosion" (3,739 ha or 19%) is best for conservation or low-impact tourism. Overall, areas with low erosion support broader tourism development, while erosion-prone zones suit nature-based tourism.

**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

**Land Capability Classification**

Determining the land capability in the research area is one of the main objectives of this study by using nine indicators based on Minister of Public Works Regulation No. 20/2007: morphology, workability, slope stability, foundation stability, drainage, water availability, erosion, waste, and natural disasters (Table 9). The analysis is conducted using GIS-based overlay of spatial data.

**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

Based on the Minister of Public Works Regulation No. 20 of 2007, Batu City's land capability analysis uses nine indicators, including morphology, slope stability, drainage, and disaster risk. The city is classified as Class D, indicating moderately high development potential across 7,189 hectares (37%), mainly in Bumiaji District. This land is suitable for medium-density housing, commercial services, agriculture, and light industry, provided sustainable practices like wastewater treatment and irrigation are in place. An overlay of land capability and tourist sites reveals that 37% of tourism areas fall under very low development capability due to steep slopes and high disaster risk, requiring strict mitigation measures. Meanwhile, 27% are moderately capable and 19% are low, both needing careful planning. Only 17% of tourist areas have moderately high capability, offering safer conditions, though development should still consider environmental impact.

Batu City, spanning 19,418 hectares, presents both opportunities and challenges for sustainable tourism development. Land analysis based on disaster risk, land capability, erosion, and drainage indicates that 86% of the area has low natural disaster potential, making it well-suited for eco-tourism and adventure tourism. The remaining 14% poses moderate risks and requires mitigation measures such as resilient infrastructure and evacuation planning. Land capability assessments show that 37% of the area has moderately high development potential, suitable for tourism and residential use with proper infrastructure. Meanwhile, erosion-prone and poorly drained areas are better suited for low-impact, nature-based tourism and need careful environmental planning. Land cover changes from 2014 to 2024 reveal growing urbanization, which could pressure eco-tourism zones but also provide opportunities for infrastructure expansion.

GIS proves essential in guiding sustainable tourism, helping visualize spatial patterns and relationships between land use, disaster risk, and tourism potential (Karnatak et al., 2007; Bhermana & Susilawati, 2023; Torres-Román et al., 2018; Ihsan et al., 2021). GIS analysis confirms that most of Batu City is safe for tourism, while areas with moderate risks require proactive planning (Jossi et al., 2022; Erwindy et al., 2021). Additionally, carrying capacity analysis supports informed planning by assessing how much tourism activity can occur without degrading the environment (Han et al., 2021; Yang et al., 2019). This study confirms that, with sustainable infrastructure, Batu City can accommodate a diverse range of tourism activities.

However, increasing urban sprawl, as shown in land use data from 2014 to 2024, may threaten areas valuable for eco-tourism. This underscores the need to integrate land use planning with environmental protection (Liu, 2012). Sustainable urban development must balance growth with conservation and disaster risk reduction. In conclusion, this study reinforces prior research on the importance of GIS and carrying capacity in supporting sustainable tourism. By combining these tools, policymakers can guide tourism growth that respects environmental limits and enhances resilience to natural hazards. Continuous monitoring and adaptive planning are essential to ensure the long-term sustainability of Batu City's tourism sector. The Batu City Government supports culturally and ecologically focused tourism by integrating sustainable practices into its development plans (Prayitno et al., 2023; Augusty et al., 2022).

## CONCLUSION

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.

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.

## ACKNOWLEDGMENT

The researchers would like to extend our gratitude to the Ministry of Education and Culture, Directorate General of Vocational Education Indonesia for the financial support that enabled this research to be carried out well and to Universitas Merdeka Malang for the opportunities and facilities provided during this research.

## REFERENCES

Abbas, M. H. I., Sumarsono, H., Rahmawati, F., & Dwiputri, I. N. (2021). The green economy perspective of batu city: calculating depletion in the tourism sector. KnE Social Sciences. https://doi.org/10.18502/kss.v5i8.9368

Al-Ghorayeb, A., Al-Shaar, W., Elkordi, A., Faour, G., Al-Shaar, M., & Attalah, Y. (2023). Land suitability analysis for sustainable urban development: a case of nabatiyeh region in lebanon. J, 6(2), 267-285. https://doi.org/10.3390/j6020020

Augusty, W. R., Subagiyo, A., Wijayanti, W. P., & Prayitno, G. (2022). Mapping of tourism potential and assessment of development stages in sidomulyo tourism village, batu city. Civil and Environmental Science, 005(01), 096-106. https://doi.org/10.21776/ub.civense.2022.00501.10

Bhermana, A. and Susilawati, S. (2023). Spatial planning concept for genetic resource of local paddy development to support sustainable agriculture in central kalimantan. Jurnal Lahan Suboptimal Journal of Suboptimal Lands, 12(1), 34-41. https://doi.org/10.36706/jlso.12.1.2023.593

Binh, T. T., Ly, N. H., Hieu, L. V., & Son, N. T. (2020). A WebGIS solution for estimation of land use affected by salinity intrusion: Case study in Ben Tre Province, Vietnam. Journal of Geographic Information System, 12(3), 161–172. https://doi.org/10.4236/jgis.2020.123012

Budiarti, S., Azis, R., & Hidayati, S. (2022). "Impact of Tourism Development on Natural Resources: A Case Study in East Java." Journal of Environmental Management, 305, 114413. doi:10.1016/j.jenvman.2021.114413

Candra, P. H., Hamim, M., & Khabir, G. M. (2024). Water conservation through local wisdom as a manifestation of social justice and ecological justice. BIO Web of Conferences, 96, 04007. https://doi.org/10.1051/bioconf/20249604007

Cheng, J., Zhou, K., Dong, C., & Fan, J. (2015). Evaluation and analysis of provincial differences in resources and environment carrying capacity in china. Chinese Geographical Science, 26(4), 539-549. https://doi.org/10.1007/s11769-015-0794-6

Christianawati, A., Prima, F., Aryati, S., Salsabila, G., & Thilfatantil, M. (2020). Analysis of the relationship of land carrying capacity and building area towards the development of kualanamu international airport in 2010 and 2017. Journal of Degraded and Mining Lands Management, 7(2), 2095-2103. https://doi.org/10.15243/jdmlm.2020.072.2095

Erwindy, J., Asdak, C., Suganda, B., & Hadian, M. (2021). Integrated assessment of urban land carrying capacity (ulcc) for reducing earthquake risk risaster in palu city.. https://doi.org/10.21203/rs.3.rs-764274/v1

Han, C., Lu, B., & Zheng, J. (2021). Analysis and prediction of land resources' carrying capacity in 31 provinces of china from 2008 to 2016. Sustainability, 13(23), 13383. https://doi.org/10.3390/su132313383

Ihsan, F., Azis, H., & Amran, A. (2021). Fitness analysis of water suitability for seaeed cultivation kappahycus alvarezii in south buton regency, southeast sulawesi. International Journal of Science Technology & Management, 2(3), 634-641. https://doi.org/10.46729/ijstm.v2i3.127

Irawan, S. (2022). Geographical information system for telkomsel grapari locations for mkios in medan city. Jurnal Ict Information and Communication Technologies, 13(2), 85-91. https://doi.org/10.35335/jict.v13i2.82

Jiang, Q., Fu, Q., Meng, J., Wang, Z., & Zhao, K. (2015). Comprehensive evaluation of land resources carrying capacity under different scales based on raga-ppc., 200-209. https://doi.org/10.1007/978-3-319-19620-6_25

Jossi, E., Bombom, R., Asdak, C., & Mohamad, S. (2022). Integrated assessment of urban land carrying capacity (ulcc) for reducing earthquake risk disaster in palu city. Przegląd Naukowy Inżynieria I Kształtowanie Środowiska, 30(4), 525-536. https://doi.org/10.22630/pniks.2021.30.4.44

Karnatak, H., Saran, S., Bhatia, K., & Roy, P. (2007). Multicriteria spatial decision analysis in web gis environment. Geoinformatica, 11(4), 407-429. https://doi.org/10.1007/s10707-006-0014-8

Li, M. (2014). The developing of query and analysis system for 3d digital city. Advanced Materials Research, 926-930, 673-676. https://doi.org/10.4028/www.scientific.net/amr.926-930.673

Li, B., Wang, H., Zhang, X., & Liu, C. (2023). Development of geographic information system architecture: Feature analysis and evolution trend research. Sustainability, 16(1), 137. https://doi.org/10.3390/su16010137

Liu, H. (2012). Comprehensive carrying capacity of the urban agglomeration in the yangtze river delta, china. Habitat International, 36(4), 462-470. https://doi.org/10.1016/j.habitatint.2012.05.003

Prayitno, G., Augusty, W. R., Wijayanti, W. P., Dinanti, D., Subagiyo, A., & Adrianto, D. W. (2023). The priority of sidomulyo village development strategy as a tourism village for sustainable agriculture batu city. Jurnal Penelitian Pertanian Terapan, 23(1), 141-150. https://doi.org/10.25181/jppt.v23i1.2838

Rahmawati, D. C., Hasibuan, H. S., & Setiawati, S. (2023). Settlement land management based on land capability in batu city. Journal of Degraded and Mining Lands Management, 11(1), 4935. https://doi.org/10.15243/jdmlm.2023.111.4935

Risfandini, A. (2024). Sustainable tourism implementation in Indonesia: Emphasizing greentourism, community-based tourism and local empowerment. BARISTA: Jurnal Kajian Bahasa danPariwisata, 11(1), 58-67. https://doi.org/10.34013/barista.v11i01.1506

Risfandini, A. and Adinda Putri Mustika (2023). The use of case study and grounded theory research strategy in interpretive research in tourism. Barista : Jurnal Kajian Bahasa Dan Pariwisata, 10(01), 94-105. https://doi.org/10.34013/barista.v10i01.1117

Rosyida, N., Dinira, L., Rusydi, A. N., Saputra, A., & Setiabudi, G. (2022). Development of web-based geographic information system for water quality monitoring of watershed in malang. INTENSIF: Jurnal

Ilmiah Penelitian Dan Penerapan Teknologi Sistem Informasi, 6(2), 184-197. https://doi.org/10.29407/intensif.v6i2.17514

Sari, K. (2021). Energy greenhouse gas emission inventory in batu city. IOP Conference Series: Earth and Environmental Science, 916(1), 012003. https://doi.org/10.1088/1755-1315/916/1/0120033

Setyawati, T. (2023). Spatial study of population pressure on the carrying capacity of rice field agricultural land in bantul regency. Iop Conference Series Earth and Environmental Science, 1233(1), 012073. https://doi.org/10.1088/1755-1315/1233/1/012073

Sumarmi, S., Akmalani, M. I., Putri, N. R. C., Cholidah, N. N. Z., & Tanjung, A. (2022). Spatial analysis of temperature changes in batu city due to land conversion in 2015-2020. KnE Social Sciences. https://doi.org/10.18502/kss.v7i16.12189

Torres-Román, J., Urrunaga-Pastor, D., Avilez, J., Helguero-Santin, L., & Málaga, G. (2018). Geographic differences in overweight and obesity prevalence in peruvian children, 2010–2015. BMC Public Health, 18(1). https://doi.org/10.1186/s12889-018-5259-2

UNWTO (United Nations World Tourism Organization). (2020). "Measuring the Economic Impact of COVID-19 on Tourism: A Research Agenda." Retrieved from https://www.unwto.org(https://www.unwto.org)

Yang, N., Li, J., Lu, B., Luo, M., & Li, L. (2019). Exploring the spatial pattern and influencing factors of land carrying capacity in wuhan. Sustainability, 11(10), 2786. https://doi.org/10.3390/su11102786

Yongfu, Q., Tang, L., Qiu, Q., Xu, T., & Liao, J. (2015). A comparative analysis on assessment of land carrying capacity with ecological footprint analysis and index system method. Plos One, 10(6), e0130315. https://doi.org/10.1371/journal.pone.0130315

Zhou, W., Elshkaki, A., Zhong, S., & Shen, L. (2021). Study on relative carrying capacity of land resources and its zoning in 31 provinces of china. Sustainability, 13(3), 1459. https://doi.org/10.3390/su13031459