Environmental Impact Assessment (EIA) on Tourism Destination Area in Seismic Zones

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Abstract: *This study examines the Environmental Impact Assessment (EIA) posed earthquake activity in the Ciletuh tourism destination, Sukabumi Regency, Indonesia. Despite being in a moderately earthquake-prone area, the region has yet to fully implement adequate earthquake risk mitigation standards. The research utilizes remote sensing techniques, including Synthetic Aperture Radar (SAR) imagery, to analyze ground deformation and assess seismic vulnerability. In addition, the band math classification and change detection were applied to Landsat Oli data to evaluate the expansion of built-up areas in tourism regions. These findings are integrated with field surveys on community awareness of disaster risks, providing a holistic spatial analysis through the overlay of demographic, zoning, and infrastructure data. The results reveal a significant lack of community awareness regarding earthquake-resistant infrastructure, despite the area's moderate seismic risk. The study advocates for improved earthquake-resistant design and construction techniques, coupled with effective mitigation strategies, to reduce the risk of damage. The comprehensive application of the EIA is crucial not only for enhancing the safety and development of tourism destinations but also for promoting environmental sustainability and protecting the local community from seismic threats. This research highlights the importance of proactive measures in developing safe and resilient tourism infrastructure in earthquake-prone regions.*

Keywords: Environmental Impact Assessment (EIA), earthquake mitigation, tourism infrastructure, seismic vulnerability, Ciletuh, Sukabumi

Introduction

Indonesia is one of the most seismically active regions in the world, making it prone to frequent earthquakes and volcanic activity (Hall & Morley, 2004). As tourism is a significant contributor to the national economy, it is essential to assess the vulnerability of tourism destinations in seismic zones (Bappenas, 2021). The Environmental Impact Assessment (EIA) is a critical tool for ensuring sustainable and safe tourism development in these regions (Glasson et al., 2012). However, many tourist destinations in Indonesia, including the Ciletuh Geopark in the Sukabumi Regency (Figure 1), have yet to fully adopt adequate earthquake mitigation standards for their infrastructure and facilities (Muslim et al. 2019). Although this area is part of the UNESCO Global Geopark network, renowned for its ancient geological formations dating back over 50 million years, iconic waterfalls, diverse topography ranging from rugged coastal cliffs to mountainous regions, rich biodiversity, rare wildlife, and natural beauty, it also preserves Sundanese cultural heritage, making it an attractive destination for nature tourism. However, for the case study in Ciletuh Geopark, the analysis focuses solely on two districts that serve as tourism centers, namely the Ciemas and Simpenan districts (Figure 1).

The aim of this study was to evaluate the environmental impacts of potential earthquakes on Ciletuh tourism destinations by integrating remote sensing, GIS data, and community awareness surveys. The assessment focuses on identifying seismic vulnerabilities, analyzing built-up area development, and proposing mitigation strategies to enhance safety and resilience against seismic threats (Sutrisno et al., 2024).

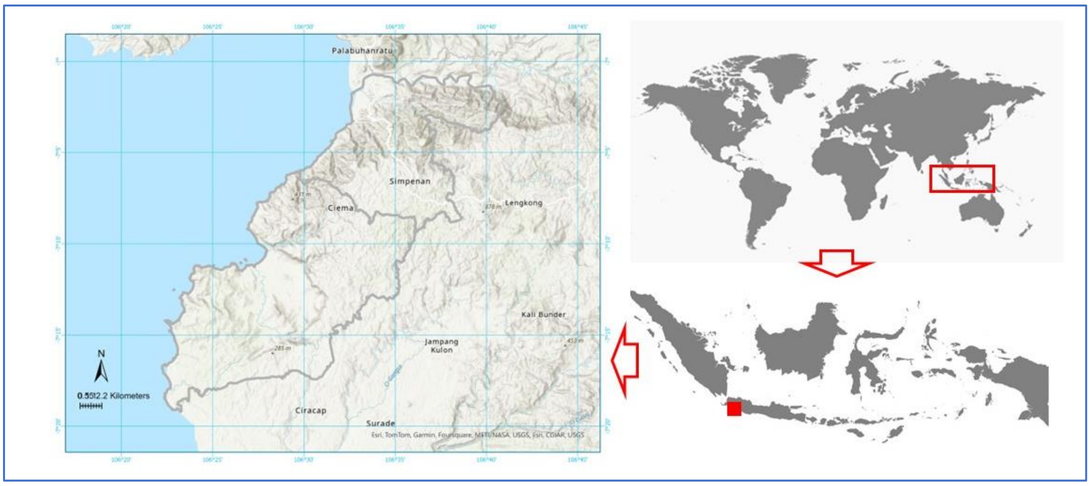

Figure 1: Study area (Source: WRLD-EPS-01-0005, Venmap, topographic map of Indonesia/RBI)

Methodology

a. Data

The data used for this study were vertical displacement data (Stevany and Manessa, 2024), classified the associated risks of earthquakes, seismic hazards (Inarisk), Landsat 8 Oli acquired on September 24th 2018, Landsat 9 Oli acquired on August 15th 2024, geological maps, topographic maps, and social survey data.

c. Remote Sensing and GIS Analysis

The steps undertaken in this remote sensing and GIS data analysis are as follows:

- The analysis begins with an examination of earth deformation, which, together with geological and seismic data analysis, is used to generate the level of activity of an earthquake in the form of land capability to endure the impacts of seismic activity. This assessment is essential to determine the safety and stability of both natural landscapes and human settlements.
- Prior to this, geological data were accessed to classify rock formations in withstanding earthquake tremors. Different rock types respond differently to seismic forces, and this classification allows for more accurate prediction of potential damage during an earthquake. It also aids in identifying areas of higher risk and those that are more resilient.
- Subsequently, trends and changes in settlements were assessed using band math and change detection analysis of Landsat imagery for 2018 and 2024 (Figure 1). To project residential area changes over the next six years, Land Use Change Models (LUCC) were employed, utilizing the trends and patterns of residential development derived from the analysis of remote sensing imagery from 2018 to 2024. This assessment provides valuable insights into how human development patterns intersect with seismic risk. Changes in land use, particularly residential expansion, can increase vulnerability to earthquakes if new developments occur in high-risk areas.

This comprehensive, multi-layered approach not only identifies high-risk zones, but also informs strategies for sustainable built-up area (BUA) development and disaster risk reduction, ensuring that the land's capability to endure earthquakes is thoroughly incorporated into future planning.

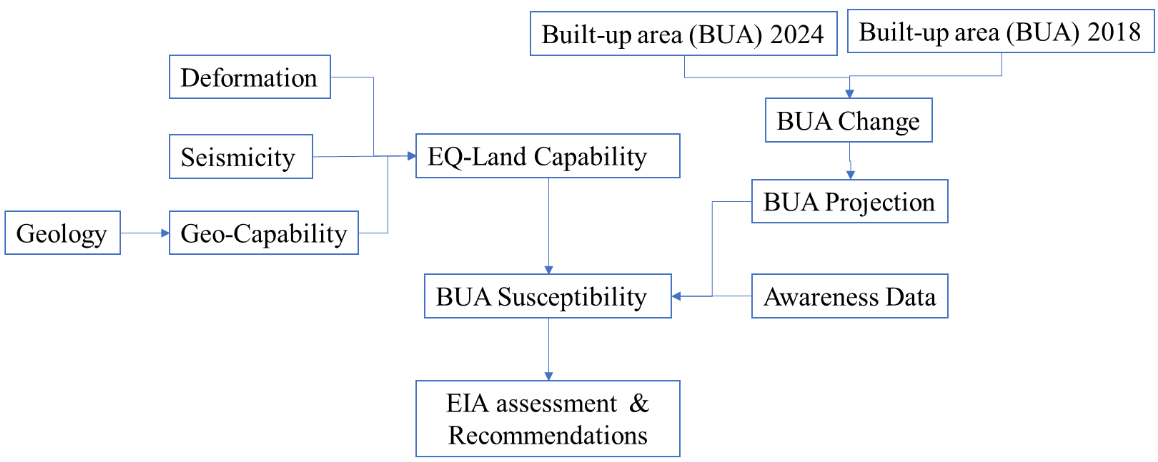

Figure 1. Flowchart of Analysis Stages

c. Field Survey on Community Awareness

A field survey was conducted to assess the level of community awareness and preparedness for earthquakes in Ciletuh. We employed a normal distribution algorithm to calculate the appropriate number of respondents, based on their respective proportions within the total population. We used a 95% confidence level and margin of error of 0.10. The questionnaire was designed based on a literature study and expert discussions and consisted of three main sections: individual awareness, building construction awareness, and disaster facilities and infrastructure. These data were integrated with remote sensing and GIS findings to form a holistic view of the region's preparedness for seismic events.

Results and Discussion

a. Earthquake Land Capability

Ground deformation, together with geological and seismic data, was revealed to be the key to determining the land capability to endure earthquake within the Ciletuh Geopark. These areas showed signs of land instability, which could exacerbate the effects of the earthquakes (Figure 2).

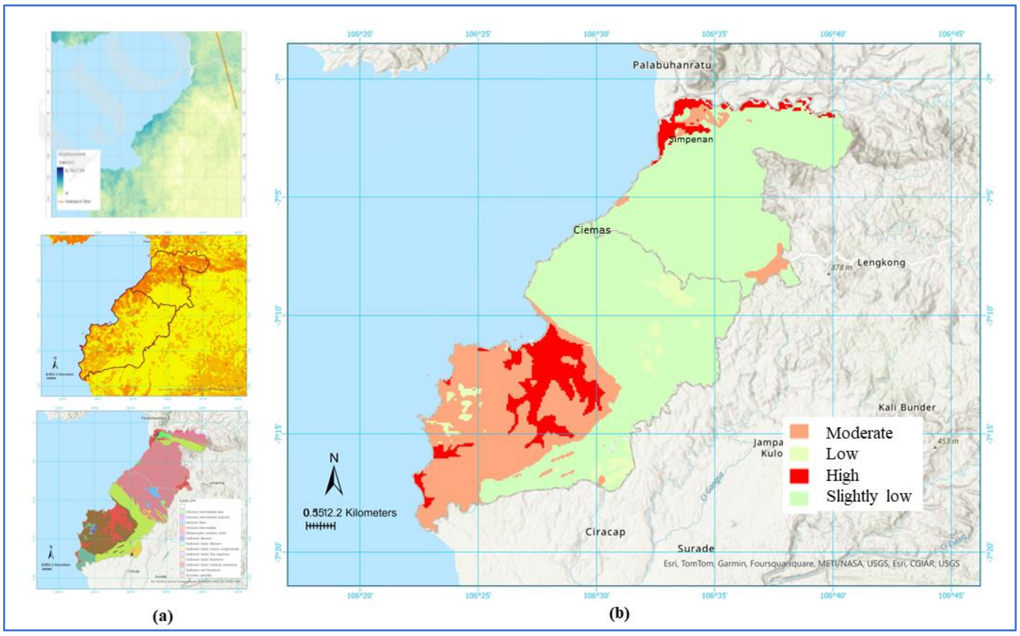

Figure 2. (a) input data for assessment vertical displacement data (Stevany and Manessa, 2024), risk of seismicity, geological capability; (b) earthquake land capability map

The analysis results indicate that areas with lowest land capability to endure earthquake are found in the central region of the Ciletuh Geopark, particularly in the villages of Ciwaru, Mekarsakti, and Tamanjaya in the Ciemas District, which directly faces Ciletuh Bay. The villages of Cidadap and Cibuntu in the Simpenan District, also part of the Ciletuh-Pelabuhan Ratu Geopark, exhibit similar characteristics. Both areas are key tourist destinations that attract domestic and international visitors.

The land in these regions is characterized by soft alluvial formations, primarily composed of quaternary deposits, such as alluvium, coastal sediments, and young volcanic lava. These unconsolidated rock types exhibit low resistance to earthquakes, corresponding to a Modified Mercalli Intensity (MMI) of VII-VIII, which suggests the potential for moderate-to-strong shaking and light-to-moderate damage. The terrain ranges from flat coastal areas to hilly regions (Sutrisno et al., 2024).

b. Expansion of Built-up Areas

Change detection using band math analysis of Landsat Oli 8 and 9 data showed slightly rapid development of built-up areas in certain parts of the tourism destination (Figure 3). Unfortunately, this change detection analysis did not exclude marine areas during the analytical process, resulting in change detection being applied to both marine and coastal zones, which led to misanalysis in certain regions. However, this issue should be addressed in future studies.

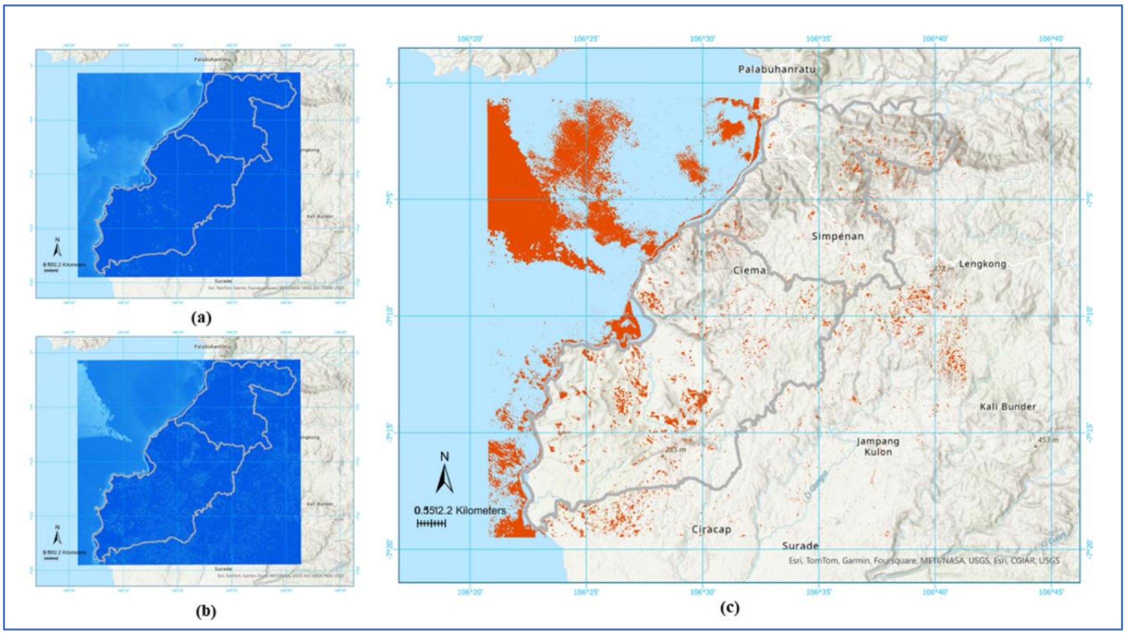

Figure 3. BUA 2018 (a), BUA 2024 (b) and change of BUA (c)

A projection analysis of the built-area expansion trend is shown in Figure 4. The results of this projection analysis demonstrate the significant potential for development in areas with the lowest land capability levels to endure earthquake tremors.

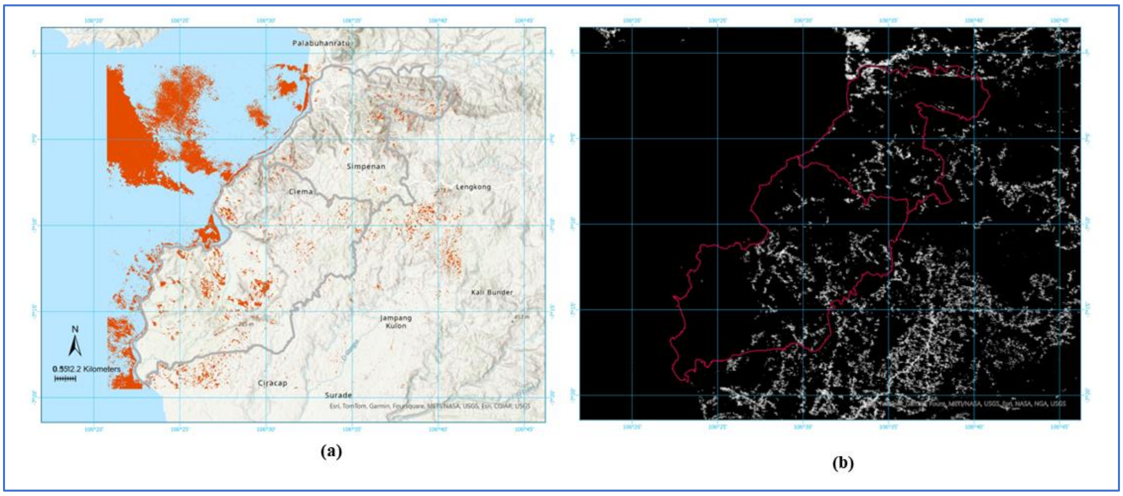

Figure 4. Change and trend of BUA (a), Projection of BUA in 2030 (b)

c. Community Awareness

The finding of community awareness reveals a notable lack of awareness regarding earthquake mitigation and infrastructure safety. Despite the area's high earthquake risk, most residents and stakeholders were unaware of the necessary precautions to reduce damage from seismic events, such as the standards for earthquake-resistant houses. However, the local population has a clear understanding of how to protect themselves during secondary disasters such as tsunamis, thanks to the numerous evacuation signs and safety guidelines installed by the government. The absence of proper disaster education and preparedness programs poses a serious risk to local communities and tourists (Lindell & Perry, 2000; Paton, 2003).

d. Comprehensive EIA on Ciletuh Geopark.

The vulnerability analysis of built-up areas in the environments most affected by earthquake hazards is shown in Figure 5. These areas are characterized as being located on highly unstable land adjacent to the subduction zone or within an active fault zone, with moderately dense settlements, often in towns or tourist areas such as Ciwaru village. However, the buildings are mostly permanent non-concrete houses in Ciemas and some permanent concrete houses, especially those close to Pelabuhan, exposed to very strong earthquake shaking, with the potential for moderate damage.

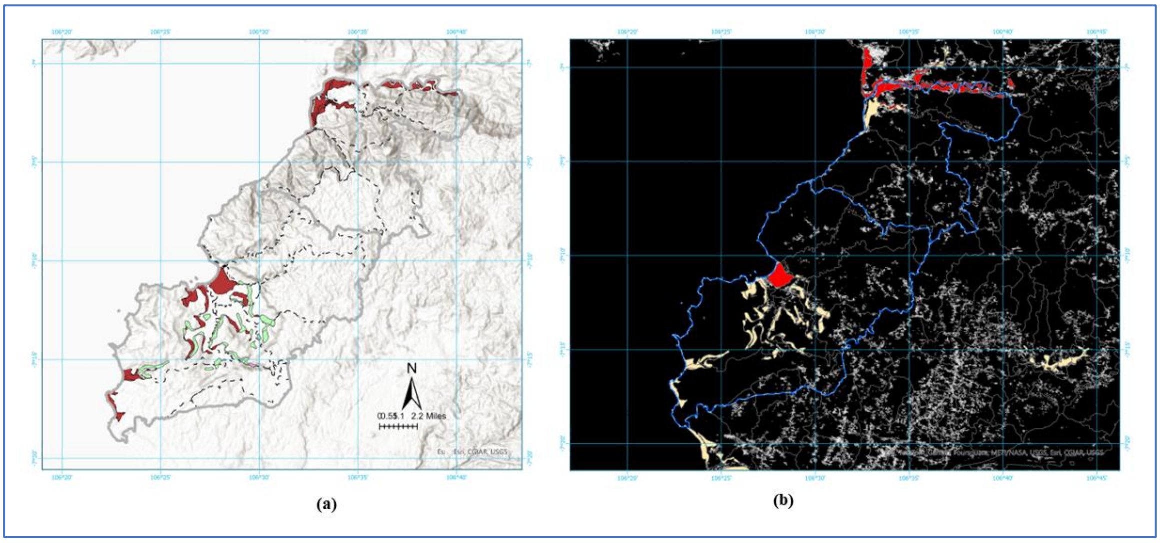

Figure 5. Existing EIA on BUA (a) and Projection of EIA on BUA (b)

By integrating remote sensing data, field survey results, and GIS mapping, this study provides a comprehensive spatial analysis of the environmental impact of earthquake hazards on the local community within the Ciletuh Geopark, as well as prospects for tourism development. The overlay of demographic data, infrastructure maps, and zoning information revealed that several high-risk areas lacked sufficient earthquake-resistant infrastructure or effective mitigation strategies. This finding underscores the need for stricter Environmental Impact Assessment (EIA) protocols in the planning and development of tourism destinations in seismic zones (Campbell, 2012; Glasson et al., 2012). It also highlights the importance of improving building standards and land use planning to mitigate the effects of seismic activity (Hooper et al., 2012; Mora et al., 2014). Rapid urbanization in these regions demands urgent attention to infrastructure standards, especially in earthquake-prone areas (Sonker et al., 2022; Wahyuningtyas et al., 2020).

Conclusion and Recommendation

The findings of this study underline the urgent need for comprehensive seismic risk-mitigation strategies in tourism destinations located in earthquake-prone regions. The Ciletuh Geopark, a popular tourist site, is highly vulnerable to seismic activity owing to the lack of proper earthquake-resistant infrastructure and low community awareness of disaster preparedness.

This study recommends several actions to improve the resilience of tourism areas in seismic zones.

1. Adoption of Earthquake-Resistant Design Standards: Tourism infrastructure, particularly in seismic zones, must adhere to earthquake-resistant construction standards to reduce the damage and loss of life during earthquakes.
2. Community Disaster Education: Local communities and tourism stakeholders must be educated on earthquake mitigation strategies, infrastructure safety, and disaster response.
3. Improved Spatial Planning: Land-use and infrastructure planning should incorporate seismic vulnerability data to ensure that high-risk areas are equipped with adequate mitigation measures.
4. Enhanced EIA Implementation: Environmental Impact Assessments must include a more detailed analysis of seismic risks, particularly in areas of rapid urbanization and tourism development.

By addressing these recommendations, tourism destinations such as Ciletuh can enhance their resilience to seismic threats, while promoting sustainable development and community safety.

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