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MORALITY BEFORE KNOWLEDGE

Spatial planning: Spatial pattern deviations and recommendations for spatial planning regulation settlement zone (2010–2030) based on current conditions

Luqman Ash-Shiddiqie[1,*]
[1] *Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Salemba, Central Jakarta, Jakarta 10430, Indonesia.*
*Correspondence: luqman.ashshiddiqie@ui.ac.id

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ABSTRACT

Background: Kota Batu, located in East Java Province, has experienced rapid urban growth, which poses challenges in spatial planning, particularly in balancing development with environmental sustainability. Night Time Light (NTL) analysis is often used to measure human activity intensity through nighttime illumination, providing valuable insights for urban development studies. **Methods:** The research employed spatial analysis using NTL data to assess human activity intensity and land use patterns, combined with land cover mapping to identify paddy field distribution. A disaster risk analysis was conducted to map flash flood-prone areas, and agglomeration analysis was applied to determine settlement zone recommendations. The total deviation in spatial patterns was calculated to quantify the extent of inconsistency with the Spatial Planning Regulation/*Rencana Tata Ruang Wilayah* (RTRW). **Findings:** The results revealed a spatial pattern deviation of 2,160.84 hectares, representing 11.58% of Kota Batu's total area. Based on agglomeration analysis, 18 villages/urban wards were identified as recommended settlement zones. Meanwhile, 21 villages/urban wards were categorized as priority areas due to high flash flood risk. These findings highlight the tension between potential residential expansion and disaster risk management in urban planning. **Conclusion:** Spatial planning in Kota Batu requires an integrated approach that addresses urban growth while preserving agricultural land and mitigating disaster risks. The findings provide evidence-based recommendations for refining the RTRW to enhance sustainable and disaster-resilient development. **Novelty/Originality of this article:** This study integrates NTL-based human activity mapping, agricultural land preservation analysis, and flash flood disaster risk assessment to produce a spatial planning recommendation for Kota Batu, a methodological combination that has been rarely applied in Indonesian mid-sized cities.

KEYWORDS: disaster risk; night time light; Kota Batu; spatial planning; urban growth.

1. Introduction

Kota Batu, located in East Java Province, is one of the cities experiencing rapid urban growth. Initially known as a tourism and agricultural area, the city has undergone significant urban expansion and land use changes over time. In this context, the Kota Batu Spatial Planning Regulation/*Rencana Tata Ruang Wilayah* (RTRW) serves as a crucial instrument for regulating and managing regional development, particularly concerning land use, ecosystems, and natural disaster risks. One approach to evaluating this spatial

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planning is through the utilization of data from Night Time Light (NTL), Designated Paddy Field Land/*Lahan Baku Sawah* (LBS), agglomeration analysis, and natural disaster potential.

Night Time Light (NTL) is a commonly used method to measure the intensity of human activity based on nighttime lighting. NTL data in Kota Batu indicates a significant increase in lighting intensity over the past few years, reflecting economic growth, urbanization, and urban expansion. Evaluating Kota Batu's RTRW through NTL analysis can provide insights into the extent to which urban growth aligns with the established plan and its potential impact on the surrounding environment and ecosystem.

On the other hand, the existence of LBS is one of the key elements in maintaining ecosystem balance, especially in regions that rely on the agricultural sector, such as Kota Batu. With the rapid pace of urbanization, many paddy fields have been converted into residential or industrial areas. This issue needs to be addressed in the evaluation of the RTRW, as the loss of productive agricultural land can disrupt local food security and the agrarian ecosystem. Therefore, Kota Batu's RTRW must be able to balance urban development needs with the protection of agricultural land.

Agglomeration is a phenomenon that occurs when economic development and population growth become concentrated in a specific area, attracting more investment and migration. In Kota Batu, agglomeration is centered around tourism areas and the city center, leading to rapid growth in certain regions while others tend to lag behind. Evaluating spatial planning through an agglomeration approach can help determine whether development in Kota Batu is evenly distributed or instead creates regional disparities. Effective spatial planning should address these imbalances by establishing new growth centers outside the core areas.

Natural disasters are another important factor that must be considered in spatial planning evaluation. Kota Batu is located in an area prone to various types of natural disasters, such as landslides and floods. Uncontrolled land-use changes can increase disaster risks, especially if hazard-prone areas are used for residential or infrastructure development. In the RTRW, areas vulnerable to disasters should be designated as restricted development zones or equipped with adequate mitigation infrastructure. The spatial planning evaluation of Kota Batu must also take into account the overall ecosystem aspects. Rapid urban growth can lead to environmental degradation, especially in areas that should be protected, such as forests or wetlands. The importance of forest conservation is closely related to the crucial ecological and economic services that forests provide. Forest areas play a significant role in the global carbon cycle by removing CO_2 from the atmosphere and helping stabilize climate conditions (Miller & Spoolman, 2015).

The RTRW must ensure that development does not disrupt the existing ecosystem balance by prioritizing sustainable environmental management. This can be achieved through appropriate zoning policies and the implementation of protected area conservation policies. Therefore, the evaluation of Kota Batu's RTRW must be conducted holistically, considering various factors such as urban growth (through NTL), agricultural land sustainability (LBS), forest conservation, development distribution (Agglomeration), and natural disaster risk mitigation. The results of this evaluation can serve as a basis for revising or improving spatial planning policies to be more adaptive to urban growth dynamics while maintaining ecosystem balance.

As a rapidly developing region, Kota Batu faces significant challenges in balancing urban agglomeration and ecological preservation. One emerging issue is the expansion of residential areas, both formal and informal, which often do not align with the designated zoning directives in the RTRW. This rapid development also has the potential to damage local ecosystems and reduce the availability of green spaces. Therefore, an evaluation is needed to determine the extent to which the spatial pattern and settlement zoning directives in the RTRW align with ecological conditions and current agglomeration trends. This study seeks to answer key questions, namely: how well does the spatial pattern of Kota Batu's RTRW 2010 - 2030 correspond with the current conditions, and how should the settlement zoning directives be evaluated based on these conditions? The research aims to analyze spatial pattern deviations to assess the compatibility of Kota Batu's RTRW 2010 -

2030 and evaluate the settlement zoning directives based on current conditions and disaster aspects.

By conducting this study, the findings are expected to provide significant contributions to scientific knowledge, particularly in the field of spatial planning evaluation. Practically, this research is also expected to offer insights for formulating more effective and sustainable spatial planning policies, as well as providing recommendations for improving the implementation of Kota Batu's RTRW 2010-2030 in accordance with current development dynamics and emerging challenges.

1.1 Spatial planning plan

Spatial planning involves the division of spatial structures and patterns as outlined in planning documents at both national and regional levels (Pambudi & Sitorus, 2021). Spatial structure helps in understanding regional development and planning better infrastructure and growth strategies (Pambudi & Sitorus, 2021). In an urban context, spatial structure reflects economic, social, and cultural policies (Ma'sum & Fadhilah, 2022). Spatial patterns regulate the distribution or allocation of space within a region based on conservation functions and/or resource utilization (Muh et al., 2024). This spatial planning concept reflects spatial-geographical aspects that are integral to economic, social, and cultural policies.

The Regional Spatial Plan/*Rencana Tata Ruang Wilayah* (RTRW) is a crucial spatial planning document that serves as a guideline for sectoral development, land use, and spatial control in Indonesia (Madaul & Ibal, 2023). Periodic evaluation and revision of the RTRW are necessary to address land-use changes and ensure alignment with current conditions (Ardiansyah et al., 2022). To ensure effective spatial planning, it is important to consider national, regional, and local policies, as well as the implications of regional autonomy in the planning process (Madaul & Ibal, 2023).

1.2 Urban ecology

Urban ecology is the study of all organisms, including humans, and their environment in urban areas affected by city development, expansion, and operation, such as watersheds that provide drinking water for urban populations (Parris, 2016). Urban ecology includes humans due to their presence, population dynamics, behaviors, and environmental changes that occur as they build small and large cities.

The characteristics of urban ecology are particularly interesting to study because they encompass: the vast and continuously expanding urban environment, its intrinsic appeal, its suitability for testing ecological theories, its impact on human health, and its importance in preserving biodiversity. Understanding urban ecology helps protect species, maintain ecosystem functions, and improve human well-being, especially amid rapid population growth and urbanization. Therefore, this study explores urban development in greater detail, particularly human populations and their relationship with the environment.

1.3 Urban development

The shape of a city does not form naturally; rather, it is the result of human actions. With the abilities of creativity, emotions, willpower, and craftsmanship, humans have the capacity to shape the characteristics of a city. This creates a strong relationship between a city's physical conditions and its culture. The characteristics of a city, which stem from its culture, continuously evolve over time, both physically and non-physically. Urban changes and dynamics are phenomena influenced by various factors, such as social, economic, and political developments, technological advancements, and other elements (Murtiono, 2022).

Urban development reflects transformations in its physical form, which are often the focus of urban planning and design. The continuously evolving physical structure of a city represents the dynamic lives of its inhabitants, which also undergo changes (Ayudya &

Ikaputra, 2022). These transformations occur because urban spaces are a reflection of daily human activities, meaning every change affects the city's shape. This is due to the fact that a city is a product of spatial and temporal interactions—a fusion of social, economic, and cultural activities that create urban spaces.

Urban development brings both positive and negative impacts on various aspects of society. Economically, it can increase regional income and drive local economic growth (Ronia Pulungan et al., 2024). Socially, it can enhance social interactions, provide recreational spaces, and improve overall quality of life (Ayudya & Ikaputra, 2022). Urban modernization also introduces technologies that improve human well-being. However, urban development can also lead to environmental issues such as the Urban Heat Island (UHI) phenomenon, which results from land-use changes and surface material modifications (Larasati et al., 2022). Therefore, maintaining a balance between urban growth and environmental conservation is crucial through sustainable urban planning (Pulungan et al., 2024).

The use of nighttime satellite imagery to monitor economic activity has become an increasingly relevant method in geospatial research. One commonly used approach is nighttime light intensity analysis, which reflects the level of socio-economic activity in a given area. Studies indicate that nighttime light intensity strongly correlates with regional income growth and urbanization, making it a useful indicator for measuring a region's economic dynamics (Imam Machdi et al., 2023). Satellite imagery, such as that from Sentinel-1, also enables the monitoring of land-use changes related to economic activities, providing valuable data for regional planning and development (Fadlin et al., 2022).

Furthermore, satellite imagery can assist in mapping population mobility and commercial activities, which are key factors in urban economic growth. For instance, research in Kota Batu has shown that population distribution and socio-economic activities—such as trade and services—significantly influence mobility patterns and regional development (Jannah et al., 2023). By leveraging satellite data, we can identify these patterns with greater accuracy and detail.

Economic activities in a region can also be influenced by local factors, such as indigenous knowledge and community traditions. In Bustaman Village, diverse economic activities, including culinary businesses and livestock farming, have become an integral part of the community's livelihood and contribute to the village's economy (Sukmawati & Yuliastuti, 2016). Using satellite imagery, we can monitor how these activities interact with land-use changes and their impact on the local economy.

Similar to studies conducted in West Payakumbuh District, economic growth is accompanied by an increasing demand for built-up spaces, necessitating efforts to maintain sustainable environmental balance (Saputra, 2023). For this reason, a legally established spatial plan has been in place since 2018. One of the primary roles of spatial planning is to serve as a regulatory tool for controlling land use amid urban expansion. With the growing demand for space in West Payakumbuh District, land-use management must be adjusted to align with the existing spatial planning regulations.

Economic activities in a region can also be influenced by local factors, such as indigenous knowledge and community traditions. In Bustaman Village, diverse economic activities, including culinary businesses and livestock farming, have become an integral part of the community's livelihood and contribute to the village's economy (Sukmawati & Yuliastuti, 2016). By utilizing satellite imagery, we can monitor how these activities interact with land-use changes and their impact on the local economy.

As seen in research on West Payakumbuh District, economic growth is accompanied by an increasing demand for built-up spaces, necessitating efforts to maintain a sustainable environmental balance (Saputra, 2023). Therefore, a legal framework in the form of a spatial plan has been in place since 2018. One of the primary roles of spatial planning is to serve as a regulatory tool for controlling land use amid urban expansion. With the growing demand for space in West Payakumbuh District, land-use management must be adjusted to align with the existing spatial planning regulations.

1.4 Development of human activities

The development of human activities encompasses various aspects, including social, economic, and environmental interactions. Human activities are not limited to individual actions but also involve broader dynamics that influence society and the environment. In this context, research indicates that the disciplinary structure of human geography in China—which includes economic geography, urban geography, and social-cultural geography—has evolved alongside human activities and policy needs (Fan et al., 2022). This highlights the importance of understanding human activities in formulating effective development strategies.

Furthermore, rapid socio-economic transitions often have significant environmental impacts. Studies show that rapid economic growth can exert substantial pressure on the environment, including excessive resource consumption and harmful emissions (Liang & Zhong, 2023). Therefore, it is crucial to consider environmental impacts in development planning and human activities to achieve sustainability. In the context of urbanization, human activities in urban areas also have profound environmental effects. Research suggests that urbanization contributes to environmental changes at various scales and influences the intensity of human activities, such as energy consumption and infrastructure development (Fan et al., 2022). Effective management of urban growth is essential to ensure that human activities do not degrade existing ecosystems.

On the other hand, human activities can also be measured through welfare indicators. Research has used nighttime satellite imagery to assess human well-being and identify inequalities in human development (Ghosh et al., 2013). The intensity of visible light in night time light (NTL) images reflects population density and human activities in a given area. These images are often used in urbanization analysis, city development, and monitoring various nighttime human activities, including economic activities, transportation, and security aspects (Afrianto & Graha, 2023). Moreover, changes in human activities can also impact ecosystems and biodiversity. Studies indicate that human footprints continue to expand, leading to the loss of intact ecosystems, which in turn affects environmental balance (Williams et al., 2020). Therefore, integrating environmental considerations into human activity planning is essential to protect natural resources.

Overall, the development of human activities is a complex and multidimensional phenomenon. Understanding the interactions between human activities, the environment, and development policies is crucial to achieving sustainability and social well-being. In the context of urbanization, human activities in urban areas also have profound environmental effects. Research suggests that urbanization contributes to environmental changes at various scales and influences the intensity of human activities, such as energy consumption and infrastructure development (Fan et al., 2022). Effective management of urban growth is essential to ensure that human activities do not degrade existing ecosystems.

1.5 Agglomeration

Urban agglomeration refers to the increasing concentration of population and economic activities in urban areas as cities expand. This phenomenon often results from rapid urbanization, where suburban areas become new centers of growth. While agglomeration offers economic advantages—such as resource efficiency and improved accessibility—it also presents challenges, including environmental issues and social inequality (Sugestiadi & Basuki, 2019).

Agglomeration often drives faster economic growth. As population density increases, so does the demand for goods and services, which in turn creates more job opportunities. A study in the Mertoyudan Corridor area found that spatial changes due to agglomeration are closely linked to improvements in the socioeconomic conditions of local communities (Anggraeni & Sunaryo, 2015). This suggests that agglomeration can serve as a key driver of local economic development. Rapid urban expansion frequently leads to significant spatial transformations. In suburban areas, such as Banyumas Regency, large-scale urban growth has resulted in the formation of 26 urban agglomerations (Sari & Mardiansjah, 2022). This illustrates how residential and industrial zones expand to meet the needs of a growing population.

Despite its economic benefits, agglomeration also has negative environmental impacts. Urban sprawl, or unplanned city expansion, can lead to environmental degradation, including the loss of green spaces and increased pollution (Widiawaty et al., 2019). Research in Kota Surakarta indicates that rapid population growth and unregulated development contribute to land-use changes that harm environmental quality (Baroroh & Pangi, 2019).

Agglomeration can also exacerbate social inequality. Residents in suburban areas often have limited access to public services and infrastructure compared to those living in city centers. Studies show that marginalization and social exclusion frequently occur in agglomerated regions, where certain social groups do not fully benefit from economic growth (Surya et al., 2021).

To address the challenges of agglomeration, sustainable urban planning is essential. Governments should implement policies that promote efficient land use while balancing economic growth and environmental conservation (Pratiwi et al., 2022). The impact of urban agglomeration is complex, bringing both positive and negative consequences. While it stimulates economic growth and job creation, it also poses serious challenges, including environmental issues and social disparities. Therefore, a holistic and sustainable approach to managing urban expansion is crucial to ensuring that the benefits of agglomeration are distributed equitably across all societal groups.

1.6 Disaster risk vulnerability

Disaster risk in Indonesia is a highly critical issue, given that the country is located in a disaster-prone region, including earthquakes, tsunamis, and floods. In this context, the InaRISK application, developed by the National Disaster Management Agency (BNPB), has become an essential tool for assessing and mitigating disaster risks. InaRISK integrates digital technology, Geographic Information Systems (GIS), and the Internet of Things (IoT) to provide real-time access to disaster-related data and information (Suharini et al., 2023).

InaRISK is a platform designed to provide information about disaster risks, including threats, vulnerabilities, and existing capacities in a specific area. This application aims to increase public awareness and preparedness in facing disasters. By using InaRISK, users can access disaster risk maps that highlight areas most vulnerable to various types of disasters (Wisudawan, 2021). This feature is crucial in helping communities and governments plan appropriate mitigation actions.

The use of InaRISK can significantly enhance community preparedness for disasters. With accurate and up-to-date information, people can be better prepared for emergency situations. Research has shown that this application helps communities understand the risks they face and the necessary steps to protect themselves (Sari et al., 2020). Despite its many benefits, there are some challenges in implementing InaRISK. One of the main challenges is limited internet access in certain areas, which can hinder the effective use of this application (Fauzan et al., 2023). Additionally, efforts are needed to improve public understanding of how to use the application and integrate it into their daily lives (Suharini et al., 2023).

Disaster risk in Indonesia requires serious attention, and the InaRISK application is a highly valuable tool in improving disaster preparedness and mitigation efforts. By utilizing modern technology, InaRISK can assist both communities and the government in managing disaster risks more effectively. However, to achieve optimal results, collaborative efforts between the government, society, and relevant institutions are necessary to overcome existing challenges and ensure that all parties can make the best use of this application.

1.7 Spatial planning evaluation

Spatial planning regulation/*Rencana Tata Ruang Wilayah* (RTRW) is a crucial instrument in spatial management, aiming to regulate land use sustainably. Smart growth policies in spatial planning can help prevent urban sprawl, reduce traffic congestion, and protect land ecologically (Miller & Spoolman, 2017). However, despite its benefits, several issues and weaknesses exist in practice. One of the main problems is that developers can influence or alter zoning decisions, potentially threatening or degrading agricultural land, forest areas, and open spaces. Therefore, it is necessary to evaluate the RTRW of Kota Batu to ensure that policies align with agricultural land preservation and forest conservation efforts.

Evaluating RTRW is crucial in the context of rapid urban growth, where land use changes often do not align with the established spatial plans. The rapid physical expansion of urban areas can lead to discrepancies between actual land use and spatial planning, potentially causing social, economic, and environmental problems (Sari, 2021). In practice, land use does not always align with the designated spatial planning policies. Violations or inconsistencies in land use are driven by market-driven development pressures, unclear control mechanisms, and weak law enforcement. As a result, land use continues to change at a fast pace, in line with the city's economic growth dynamics (Rizkhi et al., 2024). Urban expansion often results in unplanned land use changes. Research in Jakarta indicates that many new buildings are constructed outside the existing RTRW regulations, disrupting the predetermined development plans (Sari, 2021). These inconsistencies can lead to issues such as traffic congestion, environmental degradation, and the loss of green open spaces.

Land-use conversion from agriculture to residential or industrial zones is a common phenomenon due to urban expansion. A study in Toba Regency found that infrastructure development, such as bypass roads, has led to significant land-use conversion, which does not always comply with RTRW policies (Tampubolon et al., 2022). This poses challenges in maintaining food security and environmental sustainability. Rapid population growth in urban areas is often not matched by adequate infrastructure development. An RTRW evaluation in Semarang City highlighted that accessibility to public health centers and other essential facilities must be reassessed to accommodate the growing population's needs (Suryani & Adharina, 2024). Limited infrastructure can lead to a decline in the quality of life and accessibility to essential services.

Additionally, spatial planning evaluations should include disaster risk assessments. Research in Kota Ambon emphasized the importance of evaluating RTRW policies concerning flood risk, as floods frequently occur in the city, causing severe damage to communities and the environment (Muin & Rakuasa, 2023). Evaluating RTRW with flood risk considerations helps governments and communities prevent floods and mitigate their impact on residents and the environment. This evaluation also assists in identifying flood-prone areas, enabling more effective prevention and mitigation measures. Furthermore, an RTRW based on flood vulnerability contributes to maintaining environmental quality by preventing uncontrolled land-use changes, preserving natural water absorption areas, and reducing the risk of ecological degradation caused by urban expansion and infrastructure development. Evaluating spatial planning is essential for reviewing land-use changes in response to the increasing demand for residential land. Understanding the long-term impacts of urban expansion is crucial, particularly regarding uncontrolled urban sprawl, which is driven by population growth and increased urban development (Aldiansyah & Wibowo, 2022).

2. Methods

2.1 Research location and ata collection methods

The research location is Kota Batu, a city in East Java Province, Indonesia. Kota Batu is divided into three districts: Bumiaji District, Batu District, and Junrejo District. It is located

90 km southwest of Surabaya or 15 km northwest of Malang. Data collection was conducted by reviewing sectoral policy data and spatial data processed from various sources. The details of the data collection are as follows.

Table 1. Stages of data collection

Data	Source
Spatial Pattern	Regional Regulation of Kota Batu Number 7 of 2011 on the Spatial Planning of Kota Batu for 2010-2030.
Designation of Forest Areas	Ministry of Environment and Forestry
Designated Paddy Field Land (LBS)	Ministry of Agriculture
Disaster	InaRISK BNPB
Spatial Building	Open Street Map
Night Time Light (Aktifitas Malam Hari)	Visible Infrared Imaging Radiometer Suite (VIIRS)

2.2 Data analysis method

2.2.1 Spatial pattern suitability analysis

In this study, a spatial pattern suitability analysis was conducted with a focus on protected zones and cultivation zones. This analysis aims to evaluate whether existing land use aligns with the designated spatial plan, particularly in distinguishing areas that must be preserved from human activities and those that can be utilized for cultivation. One of the approaches used in this analysis is overlaying policy regulations with key spatial elements such as forest areas, irrigated rice fields, and existing settlements. This overlay process allows for mapping and understanding the level of conformity between spatial planning (RTRW) allocations and real-world conditions, including considerations for protected forest areas, essential agricultural lands for food security, and the expansion of existing settlements.

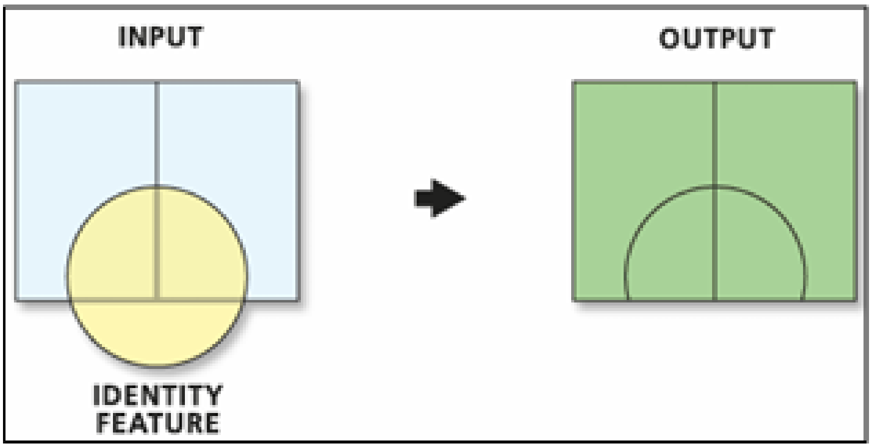

Fig. 1. Overlay illustration (ArcGIS 10.8)

The analysis of protected zone suitability is conducted by comparing forest area designation data from the Ministry of Environment and Forestry with the spatial pattern of protected zones in the RTRW of Kota Batu. Meanwhile, the analysis of cultivation zone suitability is carried out by comparing existing agricultural and residential activities with the planned cultivation zones outlined in the RTRW document of Kota Batu. Through this approach, it is possible to identify conflicts or overlaps in land use that may potentially disrupt the function of protected areas and to assess potential conflicts between cultivation activities and residential areas. These findings can serve as a basis for adjusting RTRW policies to ensure better land-use management.

2.2.2 Agglomeration analysis

Agglomeration analysis is an effective method for understanding the distribution patterns and concentration of human activities in a given region. In this study, agglomeration analysis is conducted using nighttime light (NTL) data and urban clusters identified through the DBSCAN (Density-Based Spatial Clustering of Applications with Noise) method.

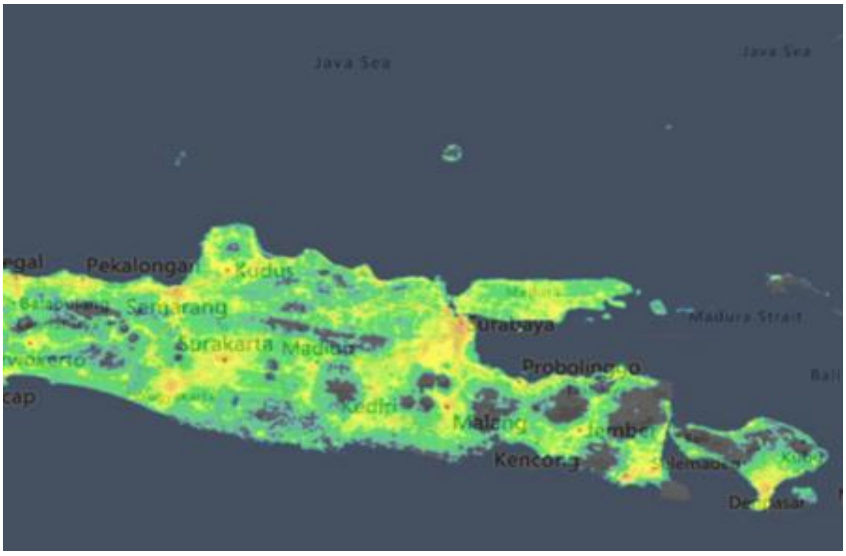

Fig. 2. Illustration of NTL in East Java
(lightpollutionmap, 2023)

NTL provides an overview of the intensity of artificial light generated by human activities at night. This data is typically obtained through remote sensing, primarily using satellites equipped with sensors to detect light emitted from the Earth's surface. NTL data is highly useful for identifying areas with high activity levels, particularly in urban regions.

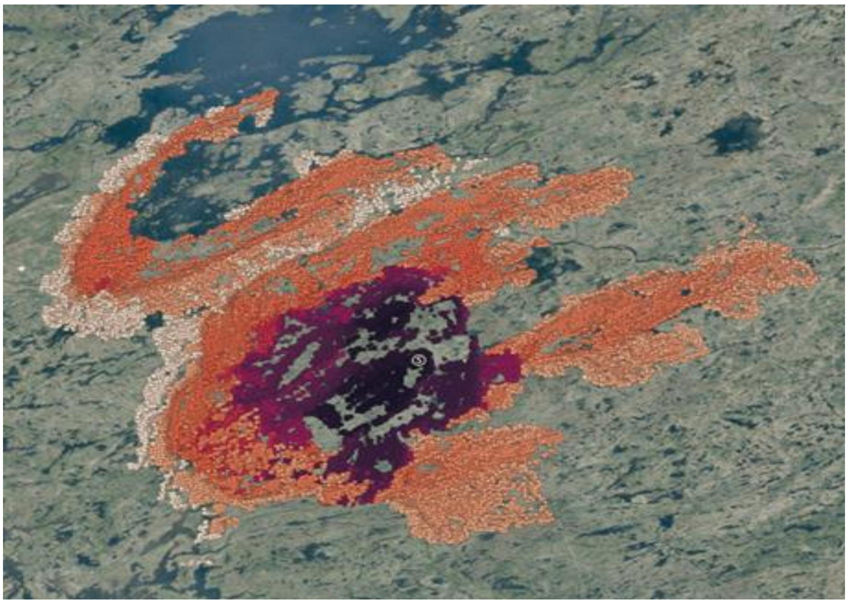

Fig. 3. Illustration of DBSCAN Clusters
(OPENGIS, 2024)

In agglomeration analysis, it is essential to identify the urban form based on settlement clusters. The clustering method used in this study is DBSCAN (Density-Based Spatial Clustering of Applications with Noise). This method effectively identifies agglomeration clusters based on building density. With DBSCAN, it is possible to detect clearer agglomeration patterns, both in terms of location and distribution, which might not be as apparent when using other analytical methods.

The results of this agglomeration analysis provide valuable insights into the economic and social dynamics of the studied region and can be utilized for spatial planning and policy development. By understanding agglomeration patterns through NTL data and DBSCAN clustering results, decision-makers can develop better strategies for improving infrastructure, public services, and land use while optimizing economic growth in identified activity centers.

2.2.3 Disaster analysis

Disaster Analysis of the spatial pattern in the Spatial Planning Regulation/*Rencana Tata Ruang Wilayah* (RTRW) is a systematic effort to understand the interaction between a region's physical conditions and its disaster potential. A thorough evaluation of disaster threats, such as flash floods, can help identify disaster-prone zones that require attention. By comparing disaster-prone area maps with the spatial pattern maps in the RTRW, a clear understanding can be obtained regarding the alignment between land allocation and disaster risk levels. Once the disaster-prone zone maps are obtained, the next step is to compare them with the spatial pattern maps outlined in the RTRW. This comparison aims to identify inconsistencies between land use allocation and disaster risk levels. For example, if a high-density residential area is located within a flood-prone zone, it indicates a high potential risk for the communities residing in that area.

3. Results and Discussion

3.1 General overview of Kota Batu

3.1.1 Geography

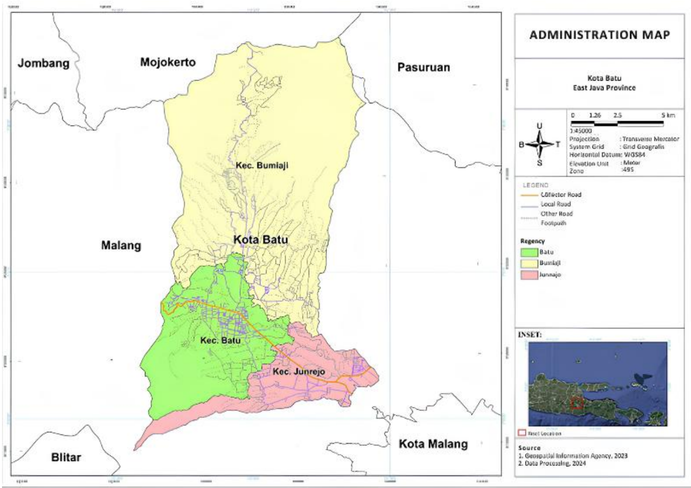

Fig. 4. Kota Batu administration map

The general overview is used to understand the characteristics of the Kota Batu region. It also serves as a basis for identifying data characteristics as input for analysis. The general overview of Kota Batu includes geographical conditions, topography, geology, hydrology, climatology, forest areas, designated paddy field land, residential areas, and disaster risk vulnerability. The general overview is used to understand the characteristics of the Kota Batu region. It also serves as a basis for identifying data characteristics as input for analysis. The general overview of Kota Batu includes geographical conditions, topography, geology, hydrology, climatology, forest areas, designated paddy field land, residential areas, and disaster risk vulnerability.

Kota Batu is a city covering an area of 18,662.13 hectares, located in East Java Province, Indonesia. The city is divided into three Urban Development Zones (BWK) across three districts: Bumiaji District, Batu District, and Junrejo District. Kota Batu is situated 90 km southwest of Surabaya and 15 km northwest of Malang, positioned along the Malang-Kediri and Malang-Jombang routes. Kota Batu shares its borders with Mojokerto Regency and Pasuruan Regency to the north, and with Malang Regency to the east, south, and west. Geographically, the city is located at 122.17° - 122.57° East longitude and 7.44° - 8.26° South latitude.

3.1.2 Topography

Kota Batu has an elevation ranging from 600 meters to 3,000 meters above sea level (masl). Based on elevation, the city is classified into six categories. The first category, with an elevation of 600-1,000 masl, includes Batu District, primarily Sidomulyo Village, as well as Junrejo District, which consists of Junrejo, Torongrejo, Pendem, Beji, Mojorejo, and Dadaprejo Villages, along with part of Tlekung Village and a small portion of villages in Bumiaji District. The second category, with an elevation of 1,000-1,500 masl, consists of most villages in Bumiaji and Batu Districts, as well as part of Tlekung Village in Junrejo District. The third category, with an elevation of 1,500-2,000 masl, includes a small portion of Tlekung Village in Junrejo District and all villages in Bumiaji District. The fourth category, ranging from 2,000-2,500 masl, covers some villages in Batu District, Wagir District, and Bumiaji District. The fifth category, with an elevation of 2,500-3,000 masl, consists of some villages in Bumiaji District, especially those bordering Prigen District. The final category, at 3,000 masl, includes several villages in Bumiaji District, particularly those located around Mount Arjuno, Mount Kembar, and Mount Welirang. Kota Batu is well known for its cool climate due to its mountainous topography. In 2019, the average air temperature in Kota Batu was 22°C, with the lowest recorded temperature of 16°C in July (BPS, 2020).

3.1.3 Geology

According to the Regional Medium-Term Development Plan (RPJMD) of Kota Batu 2017-2022, the geological conditions of Kota Batu are closely related to soil structure and characteristics, as well as its potential, which is significantly influenced by the type of underlying rock formations. Most of the soil in Kota Batu is formed from fertile rock types. Approximately 6,231.12 hectares are composed of andosol rock, which is the most fertile type, while 3,026.37 hectares consist of cambisol rock, which is considered moderately fertile. The remaining areas are formed from alluvial and latosol rocks, which are less fertile and contain limestone deposits. This indicates that 84.4% of the total land area in Kota Batu has fertile soil characteristics, making it highly suitable for agriculture and plantation development.

The hydrological conditions of Kota Batu are significantly influenced by the rivers that flow through the city's central areas, which also impact its development. Hydrological conditions in Kota Batu are classified into three types: surface water, groundwater, and spring water sources. The Brantas River and its tributaries serve as an alternative surface water source for the city. The following is a detailed classification of rock types in Kota Batu:

Table 2. Rock types in Kota Batu

Districts	Rock Types (ha)			
	Andosol	Cambisol	Alluvial	Latosol
Batu	1,832.04	889.31	239.86	260.34
Junrejo	1,526.19	741.25	199.93	217.00
Bumiaji	2,873.89	1,395.81	376.48	408.61
Total Area	6,231.12	3,026.37	816.27	886.95

3.1.4 Hydrolog

In terms of groundwater, Kota Batu has abundant groundwater reserves, particularly in Junrejo District, which is classified as a high-to-moderate productive groundwater zone. Additionally, the city's water availability fluctuates in response to seasonal changes, as Kota Batu experiences a two-season climate cycle, consisting of the rainy season and the dry season. In 2007, the rainy season began in September and ended in June, with drier weather conditions compared to the previous year. This was due to a decrease in both rainfall intensity and the number of rainy days. According to the Kota Batu Water Resources and Energy Department, the average rainfall reached 97.5 mm per month, with 128 rainy days recorded annually (RPIJM Kota Batu).

3.1.5 Climatology

Kota Batu is predominantly a mountainous and hilly region, resulting in a cool climate with air temperatures ranging between 17°C and 25.6°C. The city's humidity level is 86%, with wind speeds reaching 10.73 km/h (RPIJM Kota Batu, 2007). According to the Karangploso Climatology Station, the average temperature in Kota Batu in 2020 was 22°C, with the lowest recorded temperature at 10°C. The highest average temperatures were recorded between January and May, while the lowest average temperature occurred in November (Kota Batu in Figures, 2021). Based on CHRS portal data, the average annual rainfall in Kota Batu ranges from 2,350 mm – 2,800 mm, 2,800 mm – 3,200 mm, and 3,200 mm – 3,650 mm, depending on the specific area within the city.

3.1.6 Forest area designation

Table 3. Forest areas in Kota Batu

Districts	Village/Subdistrict	Forest Area Size (ha)		
		Protected Forest	Permanent Production Forest	Grand Forest Park
Batu	Ngaglik	175.45	92.98	-
	Oro-oro Ombo	514.19	220.57	-
	Pesanggrahan	205.10	95.95	
	Sidomulyo	-	-	-
	Sisir	23.48	41.59	-
	Songgokerto	135.03	175.08	-
	Sumberejo	35.63	53.04	-
	Temas	-	-	-
Bumiaji	Bulukerto	139.41	303.83	227.20
	Bumiaji	28.15	189.16	97.71
	Giripurno	45.49	132.20	73.48
	Gunungsari	85.86	230.42	-
	Pandanrejo	0.08	1.29	-
	Punten	3.28	92.75	-
	Sumberbrantas	16.91	55.47	2,206.86
	Sumbergondo	250.73	361.43	494.61
	Tulungrejo	850.82	725.22	1,121.10
Junrejo	Beji	-	-	-
	Dadaprejo	-	-	-
	Junrejo	-	5.77	-
	Mojorejo	-	-	-
	Pendem	-	-	-
	Tlekung	331.68	182.03	-
	Torongrejo	-	-	-
Total		2,841.29	2,958.79	4,220.96

Forest areas in each region are designated by the Ministry of Environment and Forestry. In Kota Batu, forest areas are designated under BA Number 20.5/PBW/IGD.04.04/6/2023. There are three types of forest areas in Kota Batu: protected forest, permanent production forest, and grand forest park. Based on the data above, almost all villages or districts in Kota Batu have forest areas, except for Sidomulyo Village, Beji Village, and Dadaprejo Subdistrict. The largest forest area type is the Grand Forest Park, covering 4,220.96 hectares, though it is not as widely distributed across all villages as protected forests and permanent production forests. All designated forest areas must be incorporated into spatial planning policies, including the RTRW at the city or regency level.

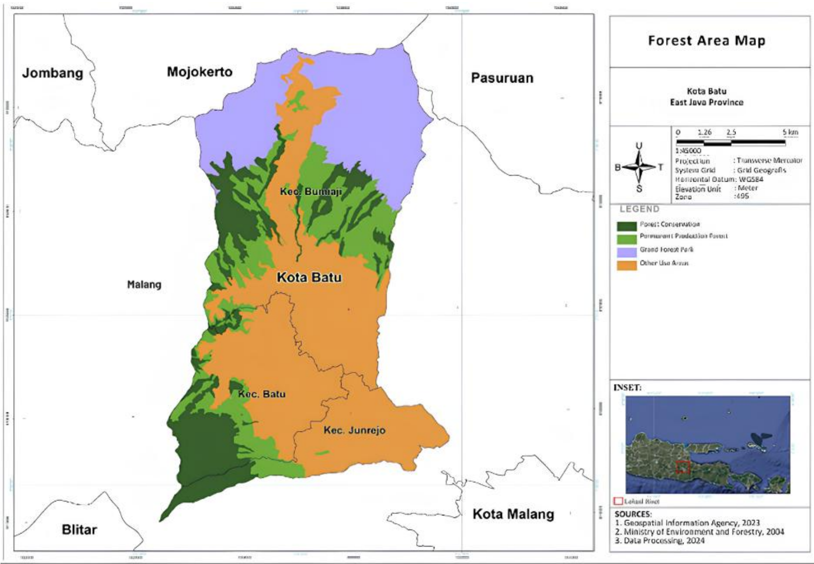

Fig. 5. Forest area map of Kota Batu

3.1.7 Designated paddy field land (Lahan Baku Sawah, LBS)

Designated Paddy Field Land (LBS) is designated by the Ministry of Agriculture to ensure that a region can maintain its food security. The establishment of LBS also supports sustainable spatial planning, both in terms of environmental conservation and food availability. Similarly, in Kota Batu, certain areas have been designated as LBS by the Ministry of Agriculture. The following is the distribution of LBS across villages and subdistricts in Kota Batu:

Table 4. LBS area size in Kota Batu in 2024

District	Village/Subdisctrict	LBS Area (ha)
Batu	Ngaglik	0.72
	Oro-oro Ombo	27.49
	Pesanggrahan	53.99
	Sidomulyo	87.38
	Sisir	67.30
	Songgokerto	73.74
	Sumberejo	80.98
	Temas	106.13
Bumiaji	Bulukerto	23.29
	Bumiaji	71.76
	Giripurno	129.40
	Gunungsari	54.91
	Pandanrejo	152.13
	Punten	19.12
	Sumberbrantas	-
	Sumbergondo	-
	Tulungrejo	-

District	Village/Subdisctrict	LBS Area (ha)
Junrejo	Beji	63.62
	Dadaprejo	73.33
	Junrejo	93.94
	Mojorejo	56.81
	Pendem	175.89
	Tlekung	18.14
	Torongrejo	186.68
Total		1,616.76

Based on the data in the table above, LBS is designated in every village and subdistrict except Sumberbrantas Village, Sumbergondo Village, and Tulungrejo Village. The total area of LBS in Kota Batu is 1,616.76 hectares, with the largest LBS area located in Pendem Village, Junrejo District. The importance of accommodating LBS in spatial planning patterns cannot be overlooked. Rice fields are a strategic asset for regional food security, including in Kota Batu. With a clear spatial allocation for rice fields, local food production can be ensured, reducing dependence on imports and stabilizing food prices.

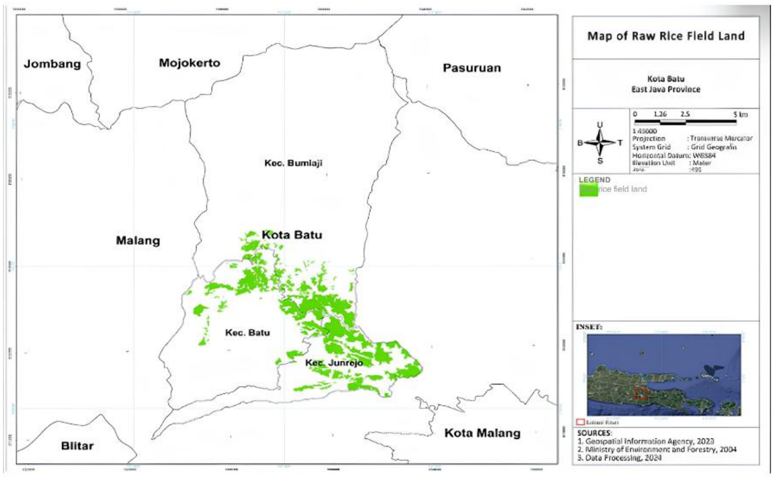

Fig. 6. LBS map of Kota Batu

3.1.8 Residential areas

Settlements continue to expand each year in response to rapid population growth and increasing socio-economic activities, which consequently intensify the demand for land, particularly for residential development. Urban expansion is often characterized by the conversion of agricultural and open spaces into built-up areas, reflecting the growing pressure on land resources in developing urban regions.

This phenomenon not only alters the physical landscape but also influences environmental sustainability, spatial planning, and the balance between urban and rural functions. Similarly, Kota Batu has experienced significant residential growth over recent years. As one of the developing urban and tourism centers in East Java, Kota Batu attracts continuous population movement and economic development, which further stimulates the expansion of housing areas. The increasing need for residential infrastructure has encouraged the spread of settlements from the urban core toward peripheral areas, leading to notable land-use changes across the region.

To identify the distribution and extent of residential areas, existing settlements in Kota Batu were mapped through a digitization process using 2024 satellite imagery. This approach enables a more accurate representation of current built-up areas and provides spatial information regarding the pattern of residential expansion within the city. The following figure presents the existing residential areas in Kota Batu in 2024:

Table 5. Total residential area in Kota Batu in 2024

District	Village/Subdisctrict	Existing Residential Area Size (Ha)
Batu	Ngaglik	200.49
	Oro-oro Ombo	316.55
	Pesanggrahan	252.73
	Sidomulyo	224.77
	Sisir	358.02
	Songgokerto	179.16
	Sumberejo	123.31
	Temas	194.99
Bumiaji	Bulukerto	160.06
	Bumiaji	167.87
	Giripurno	137.77
	Gunungsari	81.27
	Pandanrejo	97.51
	Punten	77.24
	Sumberbrantas	45.20
	Sumbergondo	60.24
	Tulungrejo	181.04
Junrejo	Beji	234.79
	Dadaprejo	178.96
	Junrejo	309.75
	Mojorejo	152.62
	Pendem	190.61
	Tlekung	70.97
	Torongrejo	46.04
Total		1.616,76

(Digitation from Citra Satelit, 2024)

The data above represents the existing residential land in Kota Batu in 2024. The total area of existing residential land in Kota Batu in 2024 is 14,620.18 hectares. The district with the largest residential land area is Batu District, covering 1,850.02 hectares. The village with the largest residential land area is Oro-Oro Ombo Village, with a total of 316.55 hectares.

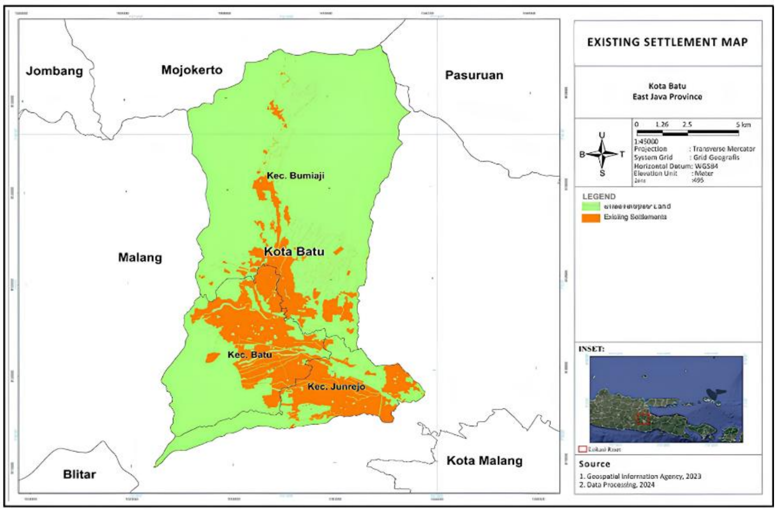

Fig. 7. Residential area map of Kota Batu in 2024

3.1.9 Disaster-prone risk

One of the disasters that frequently occur in Kota Batu is flash floods. According to data from inaRISK, Kota Batu has a high vulnerability to flash flood disasters. Factors such as steep topography, high rainfall intensity, and land-use changes are the main triggers for this disaster. The situation is exacerbated by the lack of adequate flood control infrastructure, which further increases the risk of flash floods in Kota Batu.

Table 6. Flash flood risk in Kota Batu

District	Village/Subdistrict	Risk Index Area (Ha)			
		Low	Mid	High	Total
Batu	Ngaglik	23.59	9.75	72.48	105.82
	Oro-oro Ombo	79.68	11.48	8.74	99.90
	Pesanggrahan	4.52	5.94	22.70	33.16
	Sidomulyo	60.13	36.54	58.80	155.47
	Sisir	54.84	35.94	30.61	121.39
	Sumberejo	20.00	22.41	31.50	73.91
	Temas	48.53	55.65	75.63	179.80
Bumiaji	Bulukerto	50.18	33.42	39.45	123.05
	Bumiaji	6.00	5.47	4.71	16.18
	Giripurno	37.19	46.24	47.97	131.40
	Gunungsari	26.05	14.11	29.83	69.98
	Pandanrejo	3.92	14.04	20.00	37.96
	Punten	12.80	18.94	31.70	63.45
	Sumberbrantas	112.65	11.19	10.61	134.45
	Sumbergondo	58.06	79.69	66.18	203.93
	Tulungrejo	105.13	104.98	96.35	306.47
Junrejo	Beji	38.75	29.25	20.79	88.79
	Dadaprejo	15.23	31.62	110.37	157.22
	Junrejo	13.78	35.71	80.09	129.58
	Mojorejo	41.89	23.35	42.30	107.53
	Pendem	-	13.88	20.57	34.44
	Tlekung	15.52	11.10	47.70	74.32
	Torongrejo	8.86	32.59	31.87	73.32
Total		837.30	683.28	1,000.93	2,521.51

(inaRISK, 2024, Has been reprocessed)

Based on the data in the table above, the highest flash flood risk index in Kota Batu is the high-risk index with an area of 1,000.93 hectares. Meanwhile, the village or subdistrict with the largest high-risk area in Kota Batu is Dadaprejo Subdistrict, with an area of 110.37 hectares. The village or subdistrict most vulnerable to flash flood disasters across all risk indices is Tulungrejo Village, with an area of 306.47 hectares. This is an important point of attention, particularly for the local government, to consider areas with disaster-prone risks.

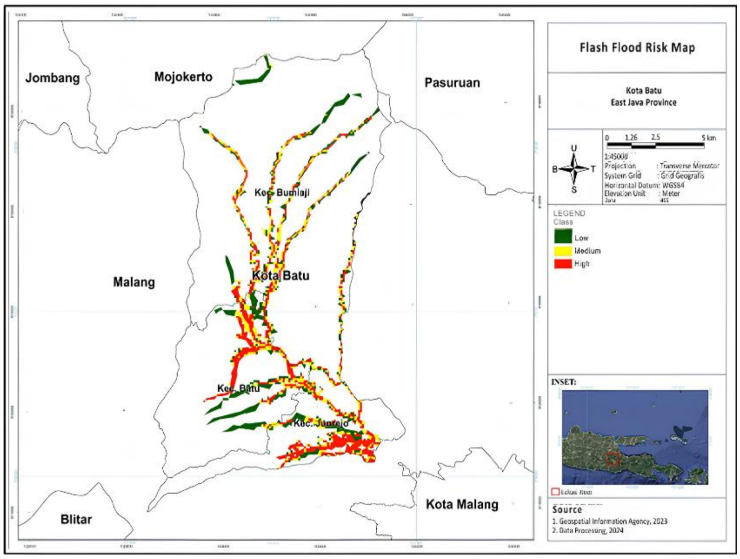

Fig. 8. Flash flood risk map of Kota Batu

InaRISK data has predicted that Kota Batu has the potential for flash floods. Unfortunately, this prediction has proven to be true, with several flash flood events occurring in recent years. This highlights the importance of utilizing inaRISK data as a reference in decision-making related to disaster management. Below is the distribution of risk indices for low, medium, and high flash flood disasters in Kota Batu:

3.2 Spatial planning regulation of Kota Batu 2010–2030

The spatial planning regulation/*Rencana Tata Ruang Wilayah* (RTRW) of Kota Batu is a crucial planning document for managing the growth and development of the city. The RTRW of Kota Batu covers various aspects of planning, ranging from land use, spatial patterns, to infrastructure. This document regulates the zoning of areas, such as residential zones, industrial zones, tourism zones, and protected areas. Below are the spatial pattern directions for the RTRW of Kota Batu from 2010 to 2030:

Table 7. Spatial pattern of the spatial planning regulation of Kota Batu 2010-2030

Area		Size (Ha)	Percentage
Protected	Protected Forest	2,695.66	14.44%
	River Buffer Zone	402.36	2.16%
	SUTT (High Voltage Transmission Line) Buffer Zone	37.71	0.20%
	Great Forest Park	4,325.20	23.18%
	Green Open Space	309.34	1.66%
Cultivation	Roadway	283.15	1.52%
	Public Facilities	162.91	0.87%
	Production Forest	3,285.34	17.60%
	Industry and Warehousing	25.91	0.14%
	Tourism Area	188.78	1.01%
	Defense and Security Area	45.92	0.25%
	Trade and Services Area	204.65	1.10%
	Residential	78.56	0.42%
	Agriculture	3,967.09	21.26%
	Housing	2,649.57	14.20%
Total		18,662.13	100.00%

(Regional Regulation of Kota Batu Number 7 of 2011)

The directive for protected areas in Kota Batu, based on the RTRW document, is 7,770.26 hectares, while the directive for cultivation areas is 10,891.87 hectares. The largest protected area directive is the Great Forest Park, covering 4,325.20 hectares, or 23.18% of the entire Kota Batu area. Meanwhile, the largest cultivation area directive is the agricultural area, covering 3,967.09 hectares, or 21.26% of the entire Kota Batu area.

3.3 Analysis of the spatial pattern suitability of the RTRW of Kota Batu 2010 – 2030

The spatial pattern suitability analysis is conducted using the overlay technique. The analysis is carried out for both protected areas and cultivation areas. The spatial pattern suitability is assessed by comparing the spatial pattern of the RTRW of Kota Batu with the designation of forest areas, paddy fields, and existing residential areas. Below are the results of the spatial pattern deviation in relation to the designation of forest areas:

Table 8. Spatial pattern deviation with forest areas

Area		Forest Area (Ha)				Percentage
		Protected Forest	Production Forest	Great Forest Park	Total	
Protected Area	Protected Forest	-	191.43	15.02	206.45	1.11%

 https://doi.org/10.61511/spms.v2i2.2025.2198

Area		Forest Area (Ha)				Percentage
		Protected Forest	Production Forest	Great Forest Park	Total	
	Open Green Space	-	5.31	-	5.31	0.03%
	River Buffer Zone	6.99	17.65	-	24.64	0.13%
	SUTT (High Voltage Transmission Line) Buffer Zone	3.07	2.45	-	5.52	0.03%
	Great Forest Park	63.74	39.87	-	103.62	0.56%
Cultivation Area	Roadway	0.08	3.91	0.03	4.02	0.02%
	Public Facilities	-	0.02	-	0.02	0.00%
	Production Forest	316.34	-	24.86	341.20	1.83%
	Industry and Warehousing	-	5.31	-	5.31	0.03%
	Tourism Area	6.99	17.65	-	24.64	0.13%
	Defense and Security Area	3.07	2.45	-	5.52	0.03%
	Trade and Services Area	63.74	39.87	-	103.62	0.56%
	Cultivation	72.45	136.72	31.54	240.71	1.29%
	Residential	0.04	1.78	0.07	1.89	0.01%
Total		463.54	400.42	71.51	589.94	3.16%

Overall, the spatial pattern deviation with forest areas in Kota Batu is 589.94 hectares, or about 3.16% of the entire area of Kota Batu. The largest deviation occurs in the production forest area, where the area is designated as a protected forest according to the Ministry of Environment and Forestry's regulation. While a 3.16% deviation is relatively small, all forest areas must still be accommodated in the spatial planning. Next, we will discuss the spatial pattern deviation with paddy field areas in Kota Batu.

Table 9. Spatial pattern deviation with paddy field areas in Kota Batu

Area		LBS (Ha)	Percentage
	Protected Forest	10.21	0.05%
	Green Open Space	29.43	0.16%
	River Buffer Zone	92.11	0.49%
Protected	SUTT (High Voltage Transmission Line) Buffer Zone	10.47	0.06%
	Great Forest Park	-	-
	Roadway	-	-
	Public Facilities	10.96	0.06%
	Production Forest	7.75	0.04%
	Industry and Warehousing	1.23	0.01%
	Tourism Area	5.72	0,03%
	Defense and Security Area	6.87	0.04%
Cultivation	Trade and Services Area	1.55	001%
	Residential	1.46	001%
	Agriculture	-	-
	Housing	490.71	2.63%
Total		18,662.13	668.45

The overall deviation of spatial patterns from Designated Paddy Field Land (LBS) amounts to 668.4 hectares or 3.58% of the total area of Kota Batu. The largest deviation occurs in residential areas, where the land has been designated as LBS according to the

Ministry of Agriculture's regulations. This indicates that settlement expansion has become the primary factor contributing to the conversion and mismatch of agricultural land allocation within the spatial planning framework. The increasing demand for housing and urban development places considerable pressure on productive agricultural land, particularly in rapidly developing urban areas such as Kota Batu.

No LBS has been converted into roadways or grand forest parks in the Kota Batu Spatial Plan for 2010–2030. This finding suggests that major infrastructure and conservation planning remain relatively consistent with the designated agricultural land policy. Although the 3.58% deviation is relatively small compared to the total area of Kota Batu, the existence of any spatial inconsistency still requires serious attention. All designated LBS areas should be fully accommodated and protected within spatial planning policies to maintain agricultural sustainability, support food security, and prevent uncontrolled land conversion in the future.

The overall deviation of spatial patterns from existing residential areas amounts to 902.45 hectares or 4.84% of the total area of Kota Batu. The largest deviation occurs in residential areas within agricultural zones, as designated in the Kota Batu Spatial Plan for 2010–2030. There are no existing residential areas within green open spaces, riverbanks, high-voltage transmission line easements, or grand forest parks. Although the 4.78% deviation is relatively small, controlling residential development in areas designated for such purposes in the Kota Batu Spatial Plan for 2010–2030 remains necessary. Next is the deviation of spatial patterns from existing residential areas in Kota Batu:

Table 10. Deviation of spatial patterns from existing areas in Kota Batu

Area		Existing Residential Areas (Ha)	Percentage
Protected	Protected Forest	10.48	0.06%
	Green Open Space	-	-
	River Buffer Zone	-	-
	SUTT (High Voltage Transmission Line) Buffer Zone	-	-
	Great Forest Park	-	-
Cultivation	Roadway	279.13	1.50%
	Public Facilities	-	-
	Production Forest	16.75	0.09%
	Industry and Warehousing	25.66	0.14%
	Tourism Area	188.13	1.00%
	Defense and Security Area	-	-
	Trade and Services Area	-	-
	Residential	-	-
	Agriculture	383.31	2.05%
	Housing	-	-
Total		902.45	4.84%

Next, the deviations in spatial patterns described above are calculated. A recap of each deviation (forest areas, Designated Paddy Field Land (LBS), and residential areas) is conducted. The total deviation in spatial patterns within the Kota Batu Spatial Plan for 2010–2030 amounts to 2,160.84 hectares or 11.58% of the total area of Kota Batu. Below is a detailed recap of spatial pattern compatibility in the Kota Batu Spatial Plan for 2010–2030.

Table 11. Recapitulation of spatial pattern deviations in the Kota Batu spatial plan (RTRW) 2010–2030

Spatial Pattern Deviation	Size (Ha)	Percentage
Forest Areas	589.94	3.16%
Designated Paddy Field Land (LBS)	668.45	3.58%
Residential Areas	902.45	4.84%
Total	2,160.84	1.58%

3.4 Agglomeration analysis

Agglomeration analysis is an effective method for understanding the distribution patterns and concentration of human activities in a region. In this study, agglomeration analysis is conducted using nighttime activity data known as Night Time Light (NTL) and urban clusters identified through the DBSCAN (Density-Based Spatial Clustering of Applications with Noise) method. Below is the progression of light intensity based on NTL data in Kota Batu.

Night Time Light Map of Kota Batu in 2017 | Night Time Light Map of Kota Batu in 2020 | Night Time Light Map of Kota Batu in 2023

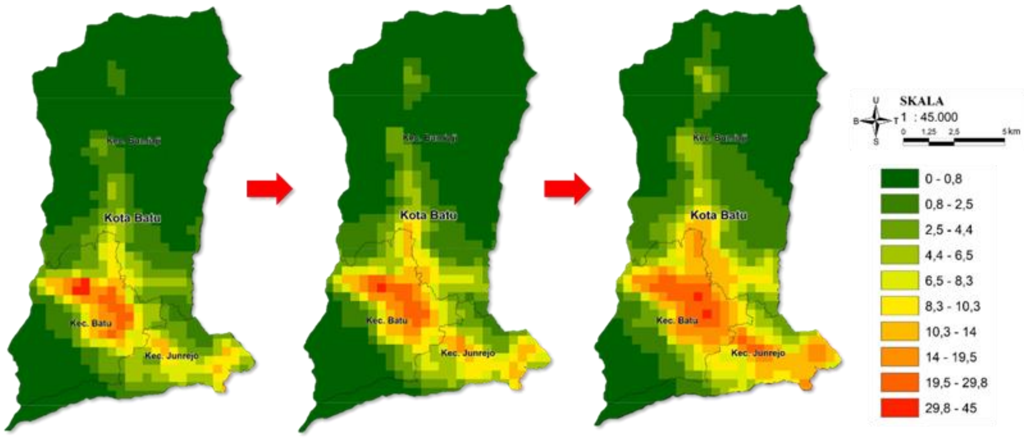

Fig. 9. NTL development in Kota Batu (2017–2023)

The images illustrate changes in nighttime light intensity in Kota Batu over time. Nighttime light intensity is generally associated with the level of human activity in a given area. The brighter an area appears, the higher the human activity is likely to be. Overall, the data shows that nighttime light intensity in Kota Batu has tended to increase from 2017 to 2023. This indicates a rise in human activity within the region. Not only has the intensity increased, but the illuminated areas have also expanded, suggesting that human activity is spreading across more areas of Kota Batu.

The data belopw represents the distribution of NTL values for each village and subdistrict in Kota Batu from 2017 to 2023. The eight villages or subdistricts with the highest NTL values are Ngaglik Subdistrict, Sidomulyo Village, Sisir Subdistrict, Temas Subdistrict, Beji Village, Dadaprejo Subdistrict, Mojorejo Village, and Pendem Village. These eight areas can be identified as having the highest levels of human activity. Given their significantly higher activity levels compared to other villages or subdistricts, these areas can be recommended for residential development.

A density-based clustering analysis (DBSCAN) is used to visualize spatial proximity and density, as well as the expansion pattern of urban and rural areas at key road intersections. This approach helps in understanding the agglomeration patterns in Kota Batu. The results of the DBSCAN analysis indicate that at its peak, urban agglomeration in Kota Batu is expected to form a pattern similar to Fig. 15. Based on the DBSCAN analysis, the initial agglomeration in Kota Batu is centered in Batu Subdistrict, with potential expansion toward Junrejo Subdistrict and the southern part of Bumiaji Subdistrict. The southern part of Bumiaji remains active due to its proximity to Batu Subdistrict. These areas are considered key locations where the majority of the population gathers for various social and economic activities. The main residential hubs may include the city center, major commercial areas, and government centers. Below is the zonal NTL data for each village to analyze:

Table 12. NTL value per village or subdistrict in Kota Batu

Districts	Village/Subdistrict	Average Light Intensity (watt/cm^2·sr)		
		2017	2020	2023
Batu	Ngaglik	6.67	7.40	9.53
	Oro-oro Ombo	2.33	2.56	4.13
	Pesanggrahan	7.19	6.61	7.83
	Sidomulyo	8.63	9.73	13.40
	Sisir	12.11	12.87	17.02
	Songgokerto	5.05	5.07	6.82
	Sumberejo	3.57	4.72	7.59
	Temas	9.64	11.14	15.89
Bumiaji	Bulukerto	0.89	1.22	2.42
	Bumiaji	1.78	2.41	3.93
	Giripurno	1.51	2.03	3.54
	Gunungsari	1.44	1.83	348
	Pandanrejo	3.79	5.06	7.64
	Punten	2.64	3.48	5.24
	Sumberbrantas	0.09	0.15	0.61
	Sumbergondo	0.49	0.62	1.37
	Tulungrejo	0.45	0.60	1.08
Junrejo	Beji	7.39	9.39	13.53
	Dadaprejo	7.83	9.38	12.23
	Junrejo	6.03	7.35	9.91
	Mojorejo	6.29	7.87	12.17
	Pendem	6.58	7.56	11.67
	Tlekung	1.95	1.50	3.47
	Torongrejo	3.89	4.89	8.54

The analysis indicates that urban concentration in Kota Batu initially focuses on Temas Subdistrict, Sisir Subdistrict, Ngaglik Subdistrict, and Pesanggrahan Village. Over time, urban agglomeration is expected to expand toward Junrejo Village, Beji Village, Batu Village, and Songgokerto Subdistrict. Furthermore, there is potential for continued agglomeration toward Mojorejo Village, Oro-Oro Ombo Village, Pesanggrahan Village, Sidomulyo Village, Pandanrejo Village, Bumiaji Village, Sumberejo Village, Bulukerto Village, Tulungrejo Village, and Gunungsari Village.

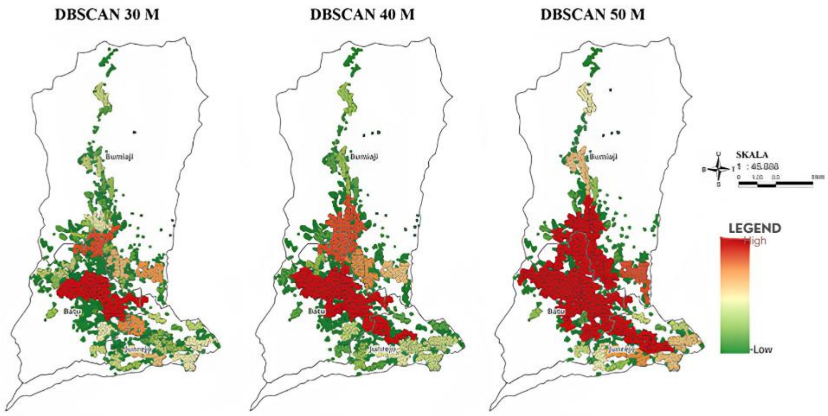

Fig. 10. Agglomeration potential of Kota Batu

3.5 Disaster analysis

Based on the disaster-prone characteristics of Kota Batu, an overlay analysis was conducted with the spatial planning map (RTRW) of Kota Batu for 2010–2030. This process is essential to identify which zones fall within disaster-prone areas, allowing for appropriate mitigation measures or special regulations. Below is the overlay result comparing the Kota Batu RTRW 2010–2030 with flash flood hazard areas:

Table 13. NTL value per village or subdistrict in Kota Batu

Area		Risk Index Area (ha)		
		Low	Mid	High
Protected Area	Protected Forest	52.81	59.90	68.27
	Green Open Space	19.77	23.19	71.43
	River Buffer Zone	40.95	63.96	78.69
	SUTT (High Voltage Transmission Line) Buffer Zone	1.90	3.35	5.40
	Great Forest Park	206.03	44.73	45.45
Cultivation Area	Roadway	17.49	15.34	23.83
	Public Facilities	13.18	10.85	16.19
	Production Forest	113.21	64.10	72.41
	Industry and Warehousing	2.10	0.58	2.26
	Tourism Area	21.38	10.23	7.47
	Defense and Security Area	-	-	-
	Trade and Services Area	20.98	13.35	15.61
	Residential	10.97	5.86	14.88
	Agriculture	115.02	202.78	282.27
	Housing	210.71	17.,23	321.34
Total		846.51	692.45	1,025.51

The data above represents the overlay results of flash flood hazard areas with the Kota Batu Spatial Plan (RTRW) 2010–2030. The residential zone has the largest area classified as high and low-risk flood-prone zones compared to other zones. Meanwhile, the agricultural zone has the most extensive area classified as moderate-risk for flash floods. Additionally, special attention should be given to cultivation areas, particularly the public facilities zone, defense and security zone, trade and services zone, settlement zone, and residential zone. These zones require careful consideration regarding disaster-prone conditions, especially those classified under the high-risk index.

Based on the table above, 21 out of 24 villages and subdistricts require special attention as they are located in high-risk flash flood hazard areas. The analysis reveals a misalignment between spatial planning and disaster risk levels, highlighting the need for a revision of the Kota Batu RTRW to align spatial allocation with actual conditions. It is crucial to educate the community about the disaster risks they face and the importance of implementing mitigation measures. An effective early warning system should be established to alert residents when disasters occur. Additionally, mitigation infrastructure, such as dams, levees, and proper drainage systems, must be developed to minimize disaster impacts.

By identifying disaster-prone zones and adjusting spatial planning accordingly, the risk of loss of life and property can be significantly reduced. Well-prepared areas will be more resilient to disasters and their negative consequences. This analysis serves as a foundation for sustainable spatial planning that incorporates disaster risk considerations. Below is the data on villages and subdistricts that fall into the high-risk index and are located within public facilities zones, defense and security zones, trade and services zones, settlement zones, and residential zones:

Table 14. Public facilities zones, defense and security zones, trade and services zones, settlement zones, and residential zones

District	Village/Subdistrict	Planned Spatial Allocation (ha)				Total
		Public Facilities	Trade and Services	Settlement	Residential	
Bumiaji	Bulukerto	0.01	0.03	-	22.19	22.22
	Bumiaji	0.09	0.03	-	4.32	4.45
	Gunungsari	0.22	0.12	-	5.72	6.06
	Pandanrejo	0.38	0.01	-	0.46	0.85
	Sumbergondo	0.14	0.29	-	6.51	6.94
	Tulungrejo	0.16	-	-	1.08	1.25

District	Village/Subdistrict	Planned Spatial Allocation (ha)				Total
		Public Facilities	Trade and Services	Settlement	Residential	
Junrejo	Beji	-	-	-	0.53	0.53
	Dadaprejo	-	0.02	1.70	12.03	13.74
	Junrejo	3.98	3.26	-	91.20	98.45
	Mojorejo	3.67	4.33	1.98	43.30	53.29
	Pendem	0.86	0.76	-	26.62	28.24
	Tlekung	0.11	-	-	-	0.11
	Torongrejo	0.77	0.06	0.29	4.91	6.03
	Total	-	-	-	0.28	0.28
Total		16,19	15.61	14.88	321.34	368.03

4. Conclusions

Based on the spatial conformity analysis of the Kota Batu RTRW 2010–2030, a total discrepancy of 2,160.84 hectares or 11.58% of the city's total area was identified. This discrepancy includes spatial deviations concerning forest areas, designated paddy fields, and existing settlements. Forest areas and designated paddy fields must be accommodated within the spatial plan to ensure sustainable planning and environmental considerations. The discrepancies in forest areas and designated paddy fields resulted from regulatory updates introduced after the RTRW was established. Meanwhile, the discrepancy in existing settlements stems from a lack of control by the local government. Therefore, local authorities must strengthen policies and enforcement to better regulate settlement development and prevent further spatial misalignment.

Based on the agglomeration analysis using nighttime satellite imagery, the villages and subdistricts with the highest NTL values are Kelurahan Ngaglik, Desa Sidomulyo, Kelurahan Sisir, Kelurahan Temas, Desa Beji, Kelurahan Dadaprejo, Desa Mojorejo, and Desa Pendem. These areas exhibit the highest levels of human activity. Meanwhile, the DBSCAN analysis predicts urban expansion towards Desa Beji, Desa Oro-Oro Ombo, Kelurahan Temas, Kelurahan Sisir, Kelurahan Ngaglik, Desa Pesanggrahan, Desa Sidomulyo, Desa Pandanrejo, Desa Bumiaji, Desa Sumberejo, Kelurahan Songgokerto, Desa Bulukerto, Desa Tulungrejo, and Desa Gunungsari. Based on this agglomeration analysis, these villages and subdistricts are suitable for residential development in Kota Batu. Additionally, the disaster risk analysis identifies 21 out of 24 villages and subdistricts as high-risk areas for flash floods. These areas should be prioritized in the RTRW by establishing special zoning regulations, community resilience strategies, and adequate disaster mitigation infrastructure to reduce potential disaster impacts.

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Author Contribution

The author solely conducted all aspects of this research, including conceptualization, methodology, data collection, analysis, and manuscript preparation. Every stage of this work was independently completed without external contributions.

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Biography of Author

Luqman Ash-Shiddiqie, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Salemba, Central Jakarta, Jakarta 10430, Indonesia.

- Email: luqman.ashshiddiqie@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A