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| Research Article |

Utilizing Google Earth Data to Assess Spatial-Temporal Land Use Changes around Jatibarang Reservoir, Semarang City

Ayu Handayani*, Adi Wibowo

Department of Geography, Faculty of Mathematics and Natural Sciences, University of Indonesia, 16424 Depok, Indonesia

** Correspondence: ayu.handayani21@ui.ac.id*

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Abstract: This study aims to assess the spatial-temporal land use changes around Jatibarang Reservoir in Semarang City, Indonesia City from 2012 to 2022, utilizing Google Earth data. The Jatibarang Reservoir and its surrounding areas have been subject to rapid urbanization and land use transformations in recent years, leading to significant environmental and socio-economic implications. The classification accuracy of seven land use categories was validated, demonstrating a high level of accuracy. The analysis reveals a dominance of agricultural land use, with notable shifts observed in forest cover, settlements, and reservoir areas. Population growth, economic development, and policy interventions are identified as the main drivers behind these land use changes. The spatial analysis using Nearest Neighbor Analysis (NNA) indicates a scattered distribution pattern of land use changes, primarily concentrated in the western part of the reservoir area. These land use changes have significant social, economic, and environmental implications, impacting the sustainability of the reservoir and surrounding areas. The study highlights the need for improved data quality, rigorous validation methods, and spatial modeling approaches in future research. By understanding the dynamics of land use changes and their implications, policymakers and stakeholders can make informed decisions for sustainable land management and environmental conservation in similar contexts.

Keywords: Land Use, Land Use Change, Jatibarang Reservoir, Spatial Analysis

INTRODUCTION

Indonesia, renowned as an agricultural country with a large population, experiences a yearly increase in its population (Hamilton-Hart, 2019). This population growth poses a threat to Indonesia's arable land, as the demand for land escalates. The expansion of cities necessitates land for residential purposes and various activities undertaken by its inhabitants (Kusrini et al., 2011; Monsaputra, 2023). The rise in urban areas is a consequence of infrastructure development and the continuous growth of urban populations (Conolly et al., 2021). Land use change is a fundamental process that reflects the outcome of interactions between human activities and land resources. Social, economic, and environmental factors are influential in triggering changes in land use (Tian et al., 2020). These land use changes significantly impact flood drainage, water quality (Jayadi et al., 2000; Hartanto & Rachmawati, 2017; Pratama & Chamid, 2021), as well as the hydrological characteristics of the watershed (Tarigan, 2016). Alterations in land use can lead to increased flood discharge, and excessive changes in land use can adversely affect air quality, diminish ecological conditions, and impact other pathways, as highlighted in the research conducted by Arifasihati & Kaswanto (2016) on land use changes in the vicinity of the Ciliwung watershed and Cisadane.

Semarang City, the capital of Central Java Province, serves as a vital link between Surabaya City and DKI Jakarta. The city's development has led to an increase in population (Handayani et al., 2023), with 1,559,198 people in 2012 and 1,659,975 people in 2022. This population growth has directly contributed to the growing demand for land, while land availability remains limited. One prominent issue faced by Semarang City is recurrent flooding, which is exacerbated by conflicts arising from land use changes, resulting in high levels of sedimentation.

To mitigate the impact of flooding in Semarang City, the government initiated the construction of the Jatibarang reservoir, which became operational in 2014. This reservoir was constructed in response to major floods that occurred in the city in 1973, 1988, 1990, and 1993. Situated on the Kreo River, a tributary of the Garang River, the reservoir covers a catchment area of 54 km^2, with an inundation area of 189 hectares and a capacity of 20.4 million cubic meters (Dhanisworo, 2022). The construction of the Jatibarang Reservoir holds significant importance in enhancing conservation efforts within the watershed, managing water resources, and controlling flooding (Putrisia et al., 2022). It is expected to serve as a preventive measure against flooding in Semarang City for the next 100 years.

The region's growth and development have led to an increasing population and the growing demand for settlement facilities. However, this trend has resulted in significant challenges such as deforestation, limited land availability, and adverse impacts on water quality and flood discharge in the Jatibarang Reservoir and its surrounding drainage area system. To address these issues, monitoring land use changes on a temporal basis is crucial. Findings from Leta et al. (2021), Wübbelmann et al. (2023), and Hasan et al. (2023) support the notion that land use and land cover changes have both short-term and long-term temporal and spatial effects, contributing to increased hydrological hazards. Additionally, research by Setiawan & Nandini (2022) indicates that land use and land cover changes impact the peak discharge of the Sari Watershed, where decreased forest cover and increased dry agriculture and settlements lead to higher peak discharge.

The analysis of land use change using temporal spatial data is highly valuable, particularly for identifying areas experiencing land use changes (Nuraeni et al., 2017; Zou et al., 2023). Nearest Neighbor Analysis (NNA) is a method employed to examine the distance to the nearest neighbor within a random pattern of points (Riadhi et al., 2020; Ofem & Ufot-Akpabio, 2023). This analysis is instrumental in determining the distribution pattern and directional development of residential land use (Monsaputra, 2023). Consequently, the present study aims to analyze land use changes and spatial patterns around the Jatibarang Reservoir in Semarang City using a descriptive method coupled with Nearest Neighbor Analysis (NNA).

The objective of this study is to analyze the land use changes around the Jatibarang Reservoir over a ten-year period (2012-2022) and assess their implications. The study aims to address the following specific goals. Firstly, the study seeks to identify and quantify the extent and magnitude of land use changes. This objective involves determining the changes in various land cover categories, including forest, farm, bare land, settlement, and paddy fields, in the vicinity of the Jatibarang Reservoir. By quantifying the extent of these changes, the study will provide a comprehensive understanding of the transformation of land use patterns. Secondly, the research aims to examine the spatial distribution and patterns of land use changes. To achieve this objective, the study will employ the Nearest Neighbor Analysis (NNA) technique. By analyzing the proximity and clustering of different land cover types, the study will identify spatial relationships and patterns. This analysis will enhance our understanding of the dynamics of land use transformations in the area surrounding the Jatibarang Reservoir. Lastly, the study aims to evaluate the implications of land use changes on the reservoir's longevity. This objective focuses on assessing the potential impacts of land use changes on erosion, sedimentation, and flood control around the Jatibarang Reservoir. By examining these factors, the study will provide insights into the impact of land use transformations on the reservoir's functionality and effectiveness. The findings will help inform appropriate land management strategies to ensure the reservoir's sustainable operation.

The novelty of this study lies in several aspects. One significant aspect is the specific study area. The research targets the Jatibarang Reservoir area, providing a localized analysis of land use changes. This localized approach allows for a more detailed understanding of the dynamics and patterns of land use transformation in this specific geographical context. By focusing on this particular area, the study can capture the unique characteristics and challenges associated with land use changes around the Jatibarang Reservoir. Another notable aspect is the comprehensive analysis of multiple land cover categories. The study considers various land cover types, including forest, farm, bare land, settlement, and paddy fields. By examining different land cover types, the research offers a holistic perspective on land use changes. This comprehensive assessment provides insights into the extent and magnitude of land use transformations in the study area, contributing to a more thorough understanding of the overall land use dynamics. The study also utilizes the Nearest Neighbor Analysis (NNA) as a spatial analysis technique. By employing NNA, the study examines the distribution pattern of land use changes. This method allows for the identification of spatial relationships and patterns in land use transformations. By analyzing the proximity and clustering of different land cover types, the research provides valuable insights into the spatial dynamics of land use change around the reservoir. This spatial analysis technique adds a new dimension to the understanding of land use changes in the study area. Furthermore, the study emphasizes the implications of land use changes for the longevity of the Jatibarang Reservoir. By highlighting the potential threats posed by ongoing land use changes, such as erosion, sedimentation, and flood control issues, the research underscores the importance of proper land management. Understanding the implications of land use transformations on the reservoir's functionality and effectiveness is crucial for developing appropriate strategies to ensure its long-term sustainability.

In comparison to previous research, this study contributes by offering a localized analysis of land use changes around the Jatibarang Reservoir, employing NNA as a spatial analysis technique, and emphasizing the implications for the reservoir's longevity. These aspects provide a unique and comprehensive perspective on the dynamics, patterns, and potential consequences of land use changes in the specific study area, differentiating it from previous research efforts.

METHOD

The study area encompasses the vicinity of the Jatibarang Reservoir, which is situated in Semarang City. Specifically, it covers two sub-districts known as Mijen, including the Gunungpati, Jatirejo Village, Kandri Village, Ponangan Village, Sadeng Village, Jatibarang Village, Kedungpane Village, Mijen Village, and Islamic Boarding School Village. The geographical details are visually represented in Figure 1. The selection of this location for the research is based on the fact that the Jatibarang Reservoir is a relatively new dam that was constructed from 2009 onwards and is currently in operation. Thus, the study aims to monitor and examine the land use changes occurring in the surrounding areas of the Jatibarang Reservoir.

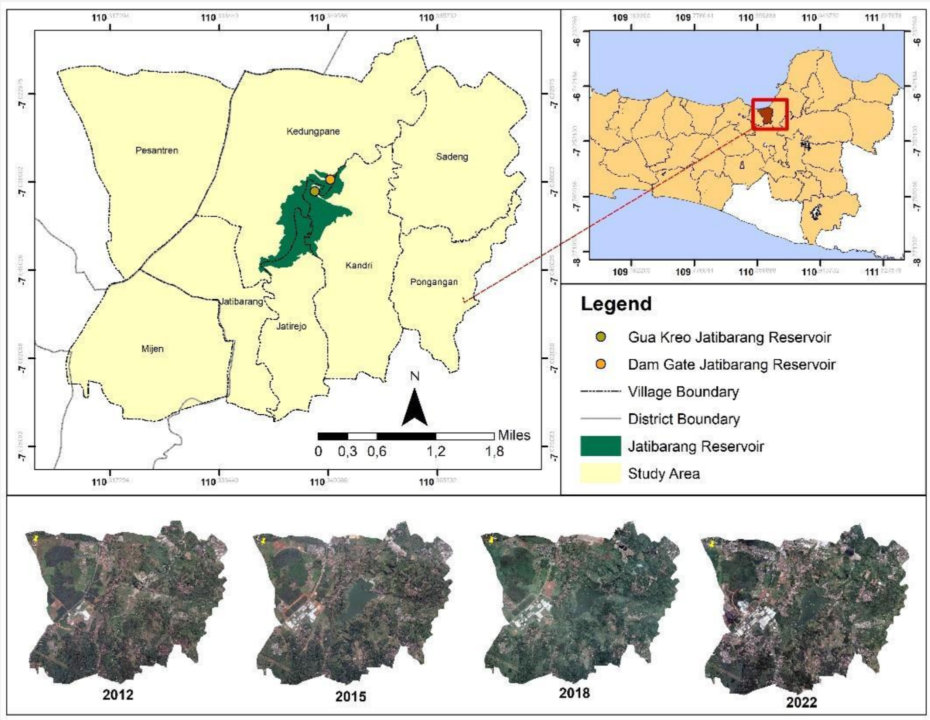

Figure 1. Study area

The data utilized in this study were obtained exclusively from Google Earth due to its wide availability, exceptional resolution, and ease of data retrieval (Wibowo et al., 2016). The data primarily consisted of satellite imagery and administrative data sourced from Indonesian Geospatial Information Agency (BIG). The satellite images displayed on Google Earth were sourced from the Geoeye satellite, which offers a remarkable resolution of 0.41 meters in panchromatic mode and 1.65 meters in spectral mode. The digitization process was conducted over a span of several years, specifically focusing on the years 2012, 2015, 2018, and 2022 for this particular study.

The research methodology employed in this study is descriptive in nature, employing the Nearest Neighbor Analysis (ANN) technique. The research process encompassed several stages, commencing with data collection, followed by data management and subsequent data analysis. The primary emphasis of this research lies in examining the spatial-temporal changes in land use, utilizing the extensive data available through Google Earth. For a visual representation of the research findings, refer to Figure 2.

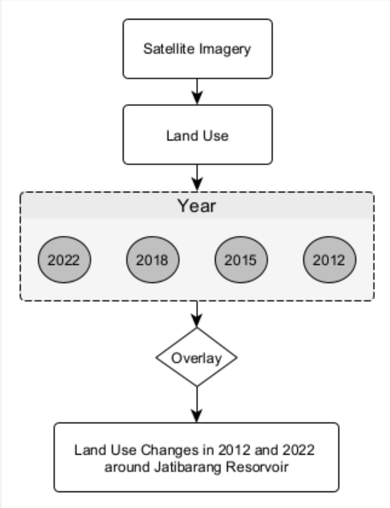

Figure 2. Research workflow

Image interpretation is a crucial process in which image objects are grouped, typically by identifying their colors as observed in the image (Dhahlan et al., 2022). The utilization of Google Earth imagery in conjunction with Geospatial Information System (GIS) facilitates the production of up-to-date data on existing land use. The initial stage of data management involves creating a mosaic of the satellite imagery data obtained from Google Earth using ArcGIS software. It should be noted that the satellite imagery data from Google Earth does not inherently possess a coordinate system. Hence, a georeferencing process is necessary to assign system coordinates based on the Universal Transverse Mercator (UTM) projections (Triantafyllou et al., 2017).

Following the georeferencing process, the manual interpretation of the imagery is carried out using the on-screen digitization method. This approach is feasible due to the availability of high-resolution imagery from Google Earth, enabling the manual classification of land to generate land use maps. To validate the results of the land classification, a validation survey is conducted, involving an accuracy test comparing the classification results against the 2022 image. The accuracy of the classification results is assessed using various percentages, including producer accuracy, user accuracy, overall accuracy, and the kappa coefficient. These values are typically presented in the form of a confusion matrix, allowing for a comprehensive evaluation of the accuracy test (Sun et al., 2022).

Mathematically, the accuracy test can be expressed using the following equation:

$$P_{PA} = \frac{K_{jj}}{K_{+j}}, \tag{1}$$

$$P_{UA} = \frac{K_{ii}}{K_{i+}}, \tag{2}$$

$$P_{OA} = \frac{\sum_{i=1}^{n} K_{ii}}{T}, \tag{3}$$

$$K = \frac{T\sum_{i=1}^{n} K_{ii} - \sum_{i,j=1}^{n}(K_{i+}K_{+j})}{T^2 - \sum_{i,j=1}^{n}(K_{i+}K_{+j})} \tag{4}$$

Where, P_{PA} is producer's accuracy, P_{UA} is user accuracy, P_{OA} is overall accuracy, K is the efficient Kappa, n is the number of columns in the confusion matrix (number of classifications), K_{ii} is the number of pixels in the matrix at the intersection of the ith row and the th column -i -i (number of correct classifications), K_{i+} and K_{+j} are the total number of pixels in the i-th row and i-column, and T is the number of pixels used to evaluate accuracy.

These equations allow for the quantitative assessment of the accuracy of the land classification results, taking into account both the producer accuracy, which measures the correctness of positive predictions, and the user accuracy, which measures the correctness of true positive identifications. The overall accuracy provides a measure of the overall correctness of the classification results. Finally, the kappa coefficient provides a statistical measure of the agreement between the classification results and the reference data, considering the possibility of agreement occurring by chance.

In this research, the changes in land use were examined through the implementation of the overlay technique, utilizing the 2012 and 2022 land use maps. The primary objective was to analyze the spatial distribution of built-up land in the vicinity of the Jatibarang Reservoir in Semarang City. To achieve this, the Nearest Neighbor Analysis (ANN) was employed as a spatial analytical method. ANN allows for the exploration of the distribution pattern of location points by considering factors such as distance, the number of location points, and land area. The analysis produces an index ranging from 0 to 2.15, which quantifies the spatial clustering or dispersion of the points (Figure 3).

The Nearest Neighbor parameter, referred to as the Nearest Neighbor Statistic T, provides a measure that can be visualized as a continuum. This parameter facilitates the comparison of dot patterns, enabling a more comprehensive understanding of the spatial relationships. The calculation of T incorporates the principles outlined by Monsaputra (2023), taking into account the proximity and arrangement of the location points. By examining the Nearest Neighbor Statistic T, researchers can discern the degree of clustering or dispersion exhibited by the land use patterns, aiding in the interpretation of the spatial distribution of built-up land around the Jatibarang Reservoir.

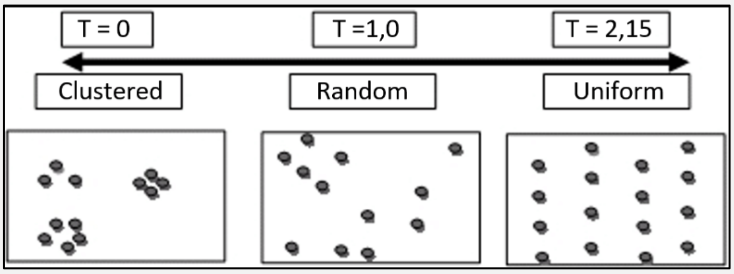

Figure 3. Nearest Neighbor Analysis

RESULTS

Land Use

The interpretation of land use in this study resulted in the classification of land into seven categories: lakes, forests, farms, open land, settlements, paddy fields, and reservoirs. To validate the accuracy of the land use classification, an accuracy test was conducted, and the results are presented in Table 1, which includes a confusion matrix.

Table 1. Land Use Classification Validation and Accuracy

Classification Validation	Farm	Forest	Settlement	Reservoir	Paddy Field	Open Land	Lake	Total	User's Accuracy
Farm	21	1	0	0	0	1	0	23	0,913
Forest	0	9	0	0	1	0	0	10	0,9
Settlement	0	0	13	0	1	1	0	15	0,866
Lake	0	0	1	9	0	0	0	10	0,9
Paddy Field	0	0	0	0	10	0	0	10	1
Open Land	0	0	0	0	0	10	0	10	1
Lake	0	0	0	0	0	0	10	10	1
Total	21	10	14	9	12	12	10	88	0
Producer's Accuracy	1	0,9	0,928	1	0,833	0,833	1	0	0,931
Overall Accuracy = 0,93% Kappa Coefficient 0,92									

The classification validation table shows the number of instances where each land use category was correctly identified (producer's accuracy) and the percentage of correct classifications for each category (user's accuracy). The overall accuracy of the land use classification is approximately 0.93%, indicating a high level of accuracy. The Kappa Coefficient, which measures the agreement between the observed and predicted classifications, is 0.92, further confirming the reliability of the image interpretation process in classifying land use.

Figure 4 displays the spatial distribution of land use around the Jatibarang Reservoir in Semarang City for the period of 2012-2022. The land use map illustrates the different categories, including lakes, forests, farms, open land, settlements, paddy fields, and reservoirs. This analysis enables the examination of land use changes before and after the construction of the Jatibarang Reservoir, providing valuable insights into the dynamics of land use in the area.

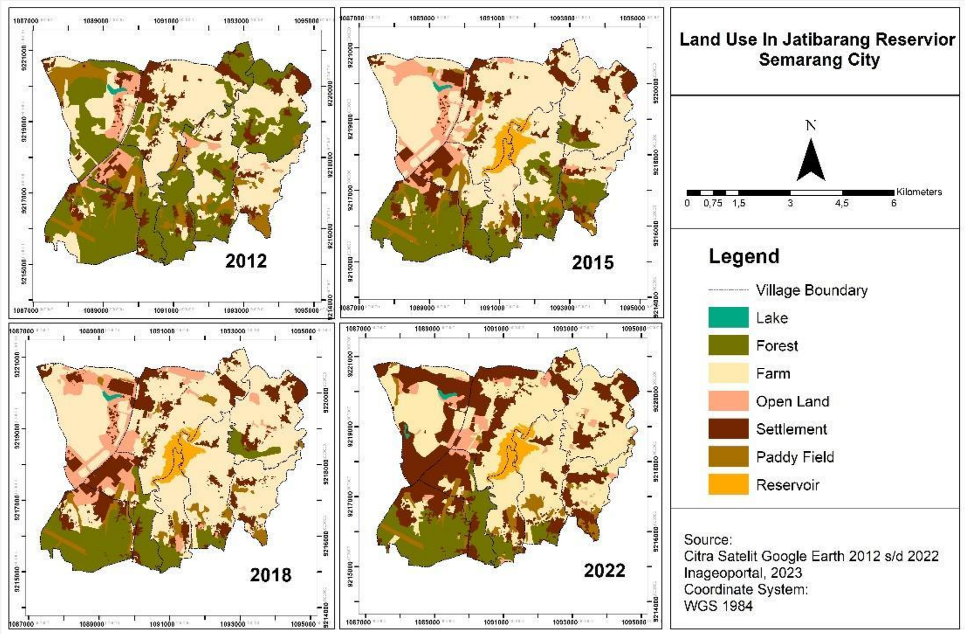

Figure 4. Land Use in 2012-2022 around in Jatibarang Reservoir

Based on the land use classification, agricultural land use dominates the area around the Jatibarang Reservoir. This study primarily focuses on analyzing the land use changes that occurred in the vicinity of the Jatibarang Reservoir in Semarang City, as shown in Table 2.

Table 2. Area of Land Use around Jatibarang Reservoir

Land Classes	Year (ha)			
	2012	2015	2018	2022
Lake	7,16	6,50	6,80	9,47
Forest	1363,71	703,94	445,28	385,05
Farm	1265,69	1759,93	1866,24	1373,49
Open Land	149,53	259,81	327,01	136,61
Settlement	363,55	437,25	513,66	1215,49
Paddy field	323,76	199,03	158,64	146,44
Reservoir	0	109,71	158,75	210,28
Total	3473,43	3476,20	3476,40	3476,87

Throughout the years, the land use areas based on the land use class have shown fluctuations. The increase in land use between 2012 and 2022 was predominantly seen in settlements (851.45 ha) and reservoirs (210.28 ha). This finding aligns with the research conducted by Mubarok et al. (2022), which indicates that population growth leads to a shift in land use from agriculture to settlements. On the other hand, there was a decrease in forest land use by 978.66 ha, consistent with the findings of Dhanisworo (2022), who reported a 6.0% reduction in forest land/vegetation within the Jatibarang Reservoir water catchment area from 2015 to 2020.

In 2015 and 2018, the largest land use category was plantations, accounting for approximately 50.62% and 53.68% respectively. The smallest land use category in those years was lakes, comprising around 0.18% and 0.19% respectively. Among the villages, Kedungpane Village had the highest residential land use in 2012 with an area of 106.55 ha, followed by Mijen Village with an area of 45.92

ha. In 2022, the Islamic Boarding School Village had the highest residential land use with an area of 260.37 ha, followed by Kedungpane Village with an area of 228.65 ha. Kedungpane Village also exhibited the highest use of garden land in both 2012 and 2022, attributed to its larger area compared to the surrounding villages. This pattern of land use changes in Semarang City aligns with the findings of Kelly-Fair et al. (2022), who observed a decrease in agricultural and forest land along with an increase in urban and commercial/industrial land. These changes are influenced by economic growth and improvements in infrastructure within the city.

Land Use Changes

The distribution of land use changes in the vicinity of the Jatibarang Reservoir over a span of ten years, specifically from 2012 to 2022, is highly significant, as illustrated in Figure 5. This figure depicts the alterations in land use during the aforementioned period around the Jatibarang Reservoir.

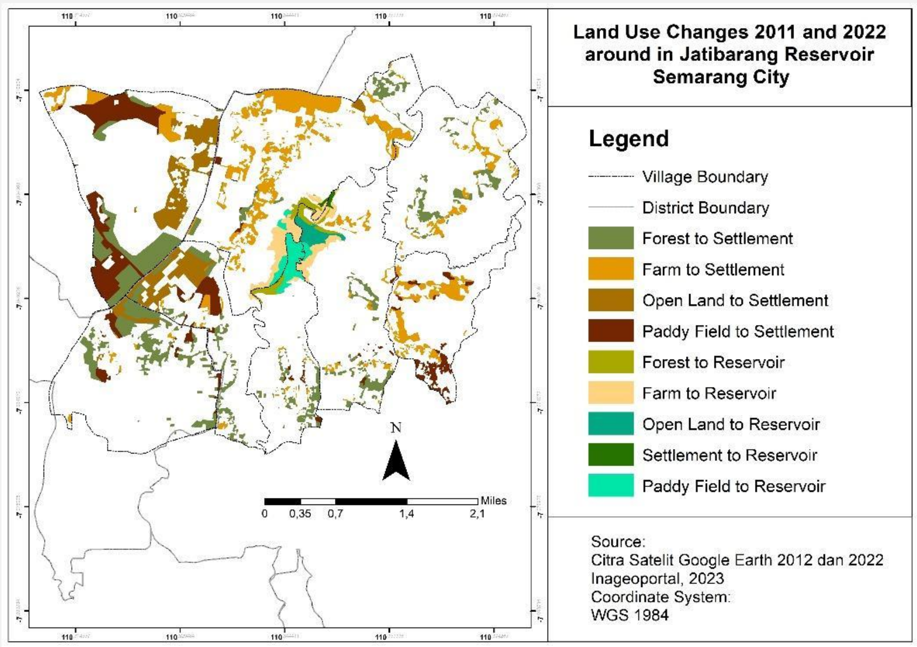

Figure 5. Land Use Changes 2012 and 2022 around Jatibarang Reservoir

Furthermore, Table 3 provides detailed information regarding the extent and proportion of land use changes surrounding the reservoir between 2011 and 2022.

Table 3. Area of Land Use Changes around Jatibarang Reservoir

Land Use Changes	ha	%
Forest to Settlement	236,97	28,67
Farm to Settlement	228,44	27,64
Open Land to Settlement	112,05	13,56
Paddy field to Settlement	138,98	16,81
Forest to Reservoir	19,18	2,32
Farm to Reservoir	46,52	5,63
Bare Land to Reservoir	13,65	1,65
Settlement to Reservoir	2,63	0,32
Paddy field to Reservoir	28,12	3,40
Total	826,58	100,00

Land cover and use changes occur due to various driving factors and actors that contribute to specific rates of change (Bürgi et al., 2007; Juniyanti et al., 2020). According to the table above, the total area of land use changes is 826.58 ha, with the most significant change being forest land transformed into settlements, accounting for approximately 28.67% of the total changes. This is followed by garden land converted into settlements, accounting for 27.64%. The driving factor behind these land use changes in the Jatibarang Reservoir area is primarily the fulfillment of basic needs, such as housing and infrastructure provision (Mubarok et al., 2022).

The smallest land use change observed is settlements transformed into reservoirs, accounting for approximately 0.32%. This is due to the Jatibarang Reservoir area being a center of economic activity, leading to the conversion of agricultural land, especially for housing purposes. The highest land use change occurred in Kedungpane Village, with an area of 116.02 ha, in the category of garden land transformed into settlements. This was followed by the Islamic Boarding School Village, with an area of 82.32 ha, in the category of rice field conversion to settlements. On the other hand, the lowest changes in land use were observed in Ponngan Village and Kedungpane Village. If these land use changes continue without proper land management, there is a concern that the longevity of the Jatibarang Reservoir may be threatened (Dhanisworo, 2022). Moreover, the changes in land use in 2012 and 2022 within the Jatibarang Reservoir can lead to increased erosion rates, sedimentation, and increased air discharge, which can disrupt the effectiveness of flood control infrastructure (reservoirs, dams, drainage channels, etc.). This is consistent with the findings of Swardana et al. (2021) research, which suggests that changes in land use contribute to flooding due to reduced forest and plantation areas.

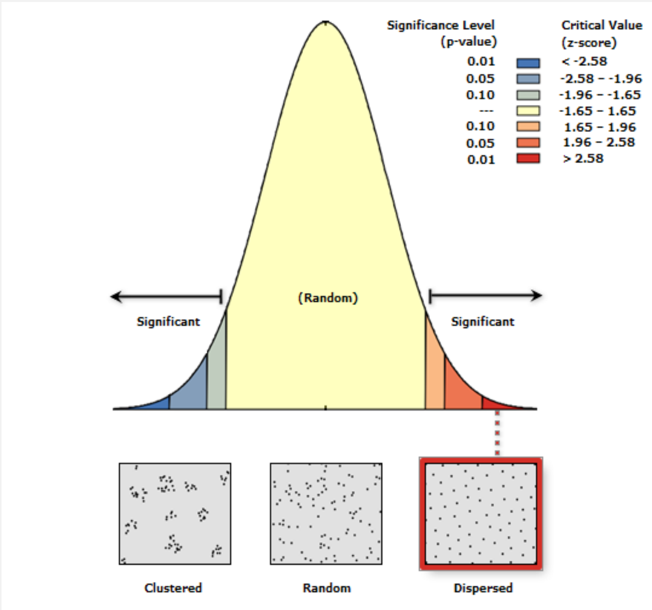

Figure 6. Area of Land Use Changes around Jatibarang Reservoir

To understand the spatial pattern of land use changes in the built-up areas from 2012 to 2022, the Nearest Neighbor Analysis (NNA) was conducted. The results of the NNA analysis, displayed in Figure 6, indicate that the nearest neighbor ratio value is 83.47. The average observed distance is 119.8 m, while the average predicted distance is 1.43 m. The distribution pattern of changes in built-up land around the Jatibarang Reservoir in 2012 and 2022 falls within the scattered category, as determined by the T value. According to the theory of nearest neighbor analysis (Bintarto & Hadisumarno, 1979; Sepriadi & Agustini, 2020), a uniform distribution pattern occurs when the distance between locations is relatively equal, and the exponential value is close to 2.15. When T is equal to or exceeds 2.5, the distribution pattern is considered uniform or spread. The changes in land use primarily spread throughout the western part of the area surrounding the Jatibarang Reservoir, often situated near or along the road network.

DISCUSSION

The validation results presented in Table 1 provide a comprehensive assessment of the accuracy of the land use classification in this study. The user's accuracy and producer's accuracy values for each land use class offer valuable insights into the reliability of the classification results and the model's ability to differentiate between different land use categories. A detailed analysis of these accuracy measures is crucial for a rigorous interpretation of the findings.

The user's accuracy represents the percentage of correctly classified instances within each land use class, reflecting the precision of the classification in accurately identifying specific land use categories. Upon examination of Table 1, it is evident that the majority of land use classes exhibit high user's accuracy values, ranging from 0.866 to 1. These values indicate a high level of precision in classifying these land use categories. For instance, the user's accuracy for settlements is 0.866, suggesting that 86.6% of instances classified as settlements were accurately identified. Similarly, the user's accuracy for farms, forests, and lakes demonstrates a considerable level of accuracy.

However, it is noteworthy that both paddy fields and open land exhibit a user's accuracy value of 1, indicating a perfect classification performance for these categories. While this high accuracy is indicative of successful classification, it raises questions regarding the sensitivity of the model in detecting these specific land use categories. Further investigation into the model's performance and its capability to discern these categories is recommended to ensure a comprehensive understanding of the classification outcomes.

On the other hand, the producer's accuracy represents the percentage of instances correctly classified within each land use class, serving as a measure of the model's ability to accurately assign instances to the appropriate land use categories. Upon analyzing Table 1, it becomes evident that most land use classes demonstrate high producer's accuracy values, ranging from 0.9 to 1. These values indicate a high degree of accuracy in assigning instances to their respective land use categories. For instance, the producer's accuracy for farms is 0.913, suggesting that 91.3% of instances classified as farms were correctly assigned. Similarly, the producer's accuracy for forests, settlements, and lakes is notably high.

It is important to note that the producer's accuracy for both paddy fields and open land is 1, indicating a perfect assignment of instances to these land use classes. While this indicates a robust capability of the model in identifying these categories, it is crucial to investigate potential concerns such as overfitting or possible misinterpretation of distinctive visual features.

The analysis of land use changes around the Jatibarang Reservoir presented in Table 2 and Figure 5 reveals significant transformations in the study area over a ten-year period. To gain a deeper understanding of these changes, it is crucial to explore the driving factors behind them and examine their social, economic, and environmental implications. This discussion will draw upon relevant literature and previous studies conducted in similar contexts to support the analysis.

The observed land use changes can be attributed to various driving factors, including population growth, economic development, and policy interventions. Population growth often leads to increased demand for housing and infrastructure, resulting in the conversion of agricultural land into settlements, as evidenced by the substantial increase in the area of settlements around the reservoir. This finding aligns with research conducted by Mubarok et al. (2022), which highlights the influence of population growth on land use shifts from agriculture to settlements. The conversion of forest and garden land into settlements suggests the pressing need to accommodate the expanding population in the study area.

Economic development is another significant driving factor contributing to land use changes. As the economy grows and infrastructure improves, there is often a shift from agricultural and forest land to urban and commercial/industrial areas. This transformation is evident in the decrease in agricultural and forest land and the corresponding increase in settlements observed around the Jatibarang Reservoir. This finding is consistent with the findings of Hassan et al. (2016) and Kelly-Fair et al. (2022), who noted similar land use changes in response to economic growth and infrastructure improvements in their study.

Policy interventions also play a crucial role in shaping land use patterns. Government policies related to land management, urban planning, and agricultural practices can influence land use decisions and change the landscape. The studies by Tian et al. (2015) and Long et al. (2021) highlight the significant influence of government actions on household land-use decisions and the dominant morphology of land, respectively. These findings emphasize the importance of considering policy interventions alongside biophysical factors when studying and understanding land use dynamics.

The social implications of these land use changes are multifaceted. The conversion of agricultural land into settlements reflects the growing need for housing and urban infrastructure to accommodate the expanding population. However, this transformation may have implications for food security and agricultural productivity, particularly if prime agricultural land is being converted. Balancing the need for urban development with preserving agricultural land is a critical challenge that requires comprehensive planning and land management strategies. The findings of Ren et al. (2008) underscore the importance of addressing the social implications of such changes through comprehensive planning efforts. Balancing economic development with the preservation of agricultural land is a critical challenge that requires trade-offs and careful management strategies, as exemplified by the Shanghai Municipal Land Use Plan. By considering these findings alongside the land use classification results, it becomes evident that managing land use changes in a socially sustainable manner necessitates a holistic approach that considers environmental preservation, economic development, food security, and agricultural productivity.

From an economic perspective, the increase in urban and commercial/industrial land suggests potential opportunities for economic growth and job creation. However, it is important to consider the sustainability of such development and its long-term impact on the local economy. Sustainable land use practices, efficient resource management, and the promotion of environmentally friendly industries should be prioritized to ensure the long-term economic viability of the region.

The environmental implications of land use changes in the vicinity of the reservoir should not be overlooked. The conversion of forested areas and agricultural land can result in biodiversity loss, habitat fragmentation, and increased vulnerability to erosion and sedimentation. The reduction in forested areas, in particular, may impact water quality, local climate regulation, and ecosystem services. These environmental changes can have cascading effects on the reservoir's sustainability and the surrounding ecosystem. Previous studies, such as the research conducted by DhaniswQro (2022) and Swardana et al. (2021), have reported similar environmental implications of land use changes, including increased erosion rates, sedimentation, and disruption of flood control infrastructure.

Interpreting the NNA results in the context of specific land use transitions can provide insights into potential drivers and spatial correlations. For example, if there is a significant clustering of land use changes from agricultural to settlement areas, it may indicate factors such as population growth, urbanization, or economic development driving the conversion of agricultural land into urban areas. Supporting studies by Wu et al. (2016) and Gaur & Singh (2023) have shown similar patterns of clustering in land use changes associated with urban expansion and population growth.

Moreover, the identification of spatial correlations between specific land use transitions and their potential drivers can help understand the underlying processes shaping the observed patterns. For instance, if there is a noticeable clustering of land use changes from forest to agricultural areas, it might suggest policies promoting afforestation or reforestation efforts. Studies by Xie et al. (2023) and Wu et al. (2023) have reported spatial correlations between forest transitions and environmental policies or reforestation initiatives.

CONCLUSION

In conclusion, this study has provided valuable insights into land use changes around the Jatibarang Reservoir in Semarang City from 2012 to 2022. The results demonstrate significant shifts in land use categories, highlighting the dominance of agricultural land use in the area. The analysis revealed a decrease in forest land and an increase in settlements and reservoirs, indicating the influence of population growth and economic development on land use dynamics.

The accuracy assessment of the land use classification indicated a high level of accuracy, with user's accuracy and producer's accuracy values ranging from 0.9 to 1 for most land use categories. This suggests that the classification results are reliable and able to distinguish between different land use categories effectively. However, it is important to acknowledge the limitations and uncertainties inherent in the study, including potential errors in land use classification, validation process, and data analysis.

The spatial analysis using the Nearest Neighbor Analysis (NNA) provided insights into the clustering or dispersion of land use changes. The observed nearest neighbor ratio, observed distance, and predicted distance values revealed a scattered distribution pattern of land use changes, primarily concentrated in the western part of the Jatibarang Reservoir area, along the road network. This pattern suggests the influence of infrastructure development and economic activities on land use transformations.

The driving factors behind the observed land use changes include population growth, economic development, and policy interventions. The conversion of agricultural land to settlements reflects the fulfillment of basic needs, such as housing and infrastructure provision. The decrease in forest land highlights the impact of economic growth on deforestation. These land use changes have social, economic, and environmental implications, affecting the sustainability of the reservoir and surrounding areas.

To further enhance the understanding of land use changes and their implications, future research should focus on improving data quality, employing rigorous validation methods, integrating ancillary data, and incorporating spatial modeling approaches. These advancements will contribute to more accurate assessments, better identification of driving factors, and the development of sustainable land management strategies.

Overall, this study provides a foundation for further research and supports informed decision-making regarding land use planning, resource management, and environmental conservation in the

Jatibarang Reservoir area and similar contexts. By considering the complexities of land use dynamics and their multifaceted impacts, policymakers and stakeholders can work towards sustainable development and the preservation of valuable ecosystems.

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