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Land use allocation analysis for sustainable tourism development in Situ Tunggilis, Bogor Regency

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ABSTRACT

The spatial allocation in the buffer zone of Situ Tunggilis is currently not optimal, necessitating a more in-depth analysis to understand the environmental conditions and ecosystem of the area. This spatial allocation analysis can aid in developing effective and sustainable management strategies for the buffer zone. This study aims to analyze land cover in Situ Tunggilis, calculate the area of land cover around its buffer zone, and identify potential opportunities and threats faced by Situ Tunggilis for strategic management. Using aerial photo data from a Mavic 3 Enterprise drone equipped with RTK (Real-Time Kinematic) tools, land cover classification was conducted in the Situ Tunggilis area. The analysis results identified various types of land cover such as open land, recreational areas, residential areas, water bodies, cemeteries, and roads. The buffer zone area of Situ Tunggilis is approximately 17.678 hectares (Ha), predominantly covered by open land at 57.33%, followed by residential areas at 19.3% and fields at 10.7%. The main threat to Situ Tunggilis lies in potential land conversion for residential and agricultural purposes that could reduce water body size and environmental quality; additionally, invasive plant species covering about 13.322 hectares were found on water bodies within Situ Tunggilis that could disrupt ecosystem balance.

Keywords: *Aerial photography, buffer zone management, GIS, land cover analysis, Situ Tunggilis*

INTRODUCTION

Situ Tunggilis is one of the important lakes located in the Bogor region, West Java. This lake functions as a natural water reservoir that collects rainwater and surface runoff, and it plays a key role in maintaining the balance of the local ecosystem (Hidayat et al., 2021) (Mahfudz & Admawidjadja, 2020). However, with the rapid urban development and increasing human activities, land use changes around Situ Tunggilis have become an urgent issue that needs to be studied and addressed. According to data from the Central Statistics Agency (BPS) of Bogor Regency, of the total area of Situ Tunggilis, approximately 70% is used for agricultural activities and the remaining 30% is used for other purposes BPS 2022. However, this data does not include detailed information regarding land allocation in the buffer zone of Situ Tunggilis, thus a more in-depth analysis is necessary to understand the environmental conditions and ecosystem of the lake.

Land use changes around the lake, such as the conversion of land into settlements, industries, and intensive agriculture, have led to several serious environmental problems (Mahfudz, 2023) (Mulya et al., 2022). Increased sedimentation rates, water pollution, and the reduction of water infiltration areas are among the direct impacts of these changes (Wynants et al., 2019). Land allocation also has the potential to disrupt the ecological function of the lake as a habitat for various species of flora and fauna (Newbold et al., 2020). In addition, Situ Tunggilis faces several environmental issues that need to be addressed, such as water pollution, soil erosion, and habitat degradation. Water pollution in Situ Tunggilis is caused by untreated industrial and domestic waste, which can affect water quality and aquatic life in the lake (Szatten & Habel, 2020). Soil erosion around Situ Tunggilis is driven by uncontrolled agricultural activities, which can impact soil quality and surrounding vegetation(Trigunasih et al., 2025). Habitat degradation is the result of uncontrolled human activities, which may negatively affect both aquatic and terrestrial ecosystems(Chalise & Kumar, 2019).

The negative impacts of land use changes are not limited to ecological aspects but also affect the socio-economic conditions of local communities (Long et al., 2021) (Roy et al., 2022) (Gupta et al., 2022). Many local residents depend on the existence of the lake, either directly through fishing and agriculture or indirectly through the ecosystem services provided by the lake, such as flood control and irrigation water supply (Desta, 2021) (Sdgs & Ho, 2021). Therefore, spatial allocation analysis

around Situ Tunggilis is crucial to ensure that land use remains sustainable and does not harm the environment or community well-being (Xie et al., 2020).

According to Law No. 26 of 2007 on Spatial Planning, spatial allocation is the process of determining and organizing space for various human activities, including economic, social, and environmental purposes. Poor spatial allocation can affect the environmental condition and ecosystem of the lake, hence effective management is required to preserve its sustainability. This study aims to identify the potentials and threats faced by Situ Tunggilis through land cover analysis using aerial photographs taken directly in the field. The study is expected to provide recommendations for local governments, communities, and other stakeholders in formulating sustainable spatial planning policies.

METHODS

The research was conducted at Situ Tunggilis, a lake located in Situsari Village, Cileungsi Sub-district, Bogor Regency, West Java, Indonesia (Figure 1). The lake is situated at an elevation of approximately 263.15 meters above sea level and covers an area of approximately 35.5 hectares.

The research began with the acquisition of aerial imagery using a Mavic 3 drone equipped with a Real-Time Kinematic (RTK) system (Kalacska et al., 2020). Accuracy testing was conducted using the Root Mean Square Error (RMSE) method, which is calculated using the following formula:

$$RMSE = \sqrt{\Sigma[(xdata-xcek)^2 + (ydata- ycek)^2]} \quad (1)$$

Aerial photographs were then analyzed to identify land use through digitization, following the land cover classification for the Situ Tunggilis area. The classification was based on the Indonesian National Standard (SNI) 7645:2010 – "*Land Cover Classification*".

Figure 1. Research location of Situ Tunggilis, in Cileungsi Sub-district, Bogor Regency, West Java, Indonesia.

RESULTS AND DISCUSSION

Aerial Imagery Accuracy Test

The aerial imagery accuracy test was conducted to determine the level of precision of the data obtained from mapping using aerial photographs. The results of the accuracy test serve as the foundation for detailed-scale mapping. The data processing results from the aerial imagery are presented in Table 1. According to Table 2, the accuracy test using Independent Check Points (ICP) indicates that the aerial imagery achieved an RMS value of 1.2. Based on a mapping scale of 1:3000, this corresponds to accuracy class 3, with a positional error tolerance of 1.2 meters. The relatively large RMS value was due to the limited number of ICPs—only three points were used to evaluate the accuracy of the aerial map. This limitation was a result of the challenging terrain, which restricted the placement of more ICPs.

Table 1. Horizontal accuracy test of aerial photos.

Point Number	Point Name	X (Coordinates ICP)	X (Orthophoto Mosaic Coordinates)	(D X)	(D X)^2	Y (Coordinates ICP)	Y (Orthophoto Mosaic Coordinates)	(D Y)	(D Y)^2	(D X)^2 + (D Y)^2
A	B	C	D	E	F	G	H	I	J	K
1	ICP 1	724,657.783	724,657.065	-0.718	0.515	9,289,967	9289968.07	1.018	1.036	1.551
2	ICP 2	724,577.035	724,576.134	-0.901	0.811	9,290,028	9290028.77	0.901	0.812	1.623
3	ICP 3	724,496.775	724,496.013	-0.762	0.580	9,290,088	9290089.18	0.784	0.615	1.195

Table 2. Geometric accuracy of RBI Map.

		Map Accuracy 1:3000 scale		
Accuracy	**Test Result CE 90**	**Class 1**	**Class 2**	**Class 3**
Horizontal	1.83	0.5	1.0	2.0

Source: BIG Perka, 2016.

Land Cover Analysis of Situ Tunggilis

Following the processing of aerial photographs into an Aerial Photo Map, a Land Cover Map of Situ Tunggilis was created based on the results of the previous aerial photo mapping, as shown in Figure 2. The Land cover map of the Situ Tunggilis area was produced through a digitization process. The land cover area around Situ

Tunggilis is presented in Table 3. Based on the digitized analysis, the water body area of Situ Tunggilis was calculated to be 34.827 hectares (Table 4). This result closely aligns with the water body area stated on the official website of Bogor Regency Exploration, which is 35.5 hectares. A land cover object in the form of a road was identified crossing the eastern part of the water body of Situ Tunggilis. The lake is surrounded by land cover in the form of residential areas, with the northern part of Situ Tunggilis directly adjacent to settlement areas.

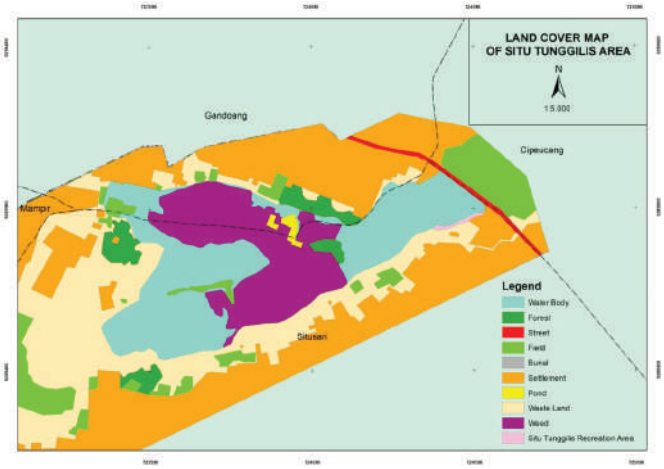

Figure 2. Land cover maps of Situ Tunggilis.

Table 3. Land cover area of Situ Tunggilis.

No	Type of Land Cover Area	Area (Ha)
1	Open land	29.515227
2	Situ Tunggilis recreation area	0.174135
3	Settlement	51.989247
4	Situ Tunggilis	34.827118
5	Cemetery	0.947049
6	Forest	3.32818
7	Road	0.950748
8	Pond	0.408214
9	Road	0.950748
10	Field	13.526473
11	Pest plant area	13.324767

Land Cover Analysis Within the Water Body of Situ Tunggilis

The overlay analysis between the land cover and the water body area of Situ Tunggilis revealed sections of land cover located within the lake's water body, as shown in Figure 3. Based on the findings, the most dominant land cover type in Situ Tunggilis is the water body itself, covering an area of 19.939 hectares. This represents 57.25% of the total study area, which is 34.83 hectares. The significant presence of water indicates that Situ Tunggilis serves as an important water resource, both for the local ecosystem and the needs of surrounding communities. Furthermore, pond areas cover 0.408 hectares, contributing 1.17% to the total area. Although this percentage is small, the presence of ponds reflects aquaculture activities that can serve as a source of income for the local population.

Forest areas in this region cover 0.440 hectares, accounting for 1.27% of the total area. Despite its relatively small extent, the forest plays a role as a carbon sink and provides habitat for various species of flora and fauna (C et al., 2020) (Nunes et al., 2020). Protection of this forested area is crucial for maintaining ecological balance and preventing environmental degradation, which could negatively impact water quality and surrounding ecosystems. The final land cover type identified is invasive vegetation, which occupies 13.322 hectares or 38.25% of the total area. The presence of invasive plants highlights a challenge in land management, where unwanted vegetation can hinder the growth of productive crops.

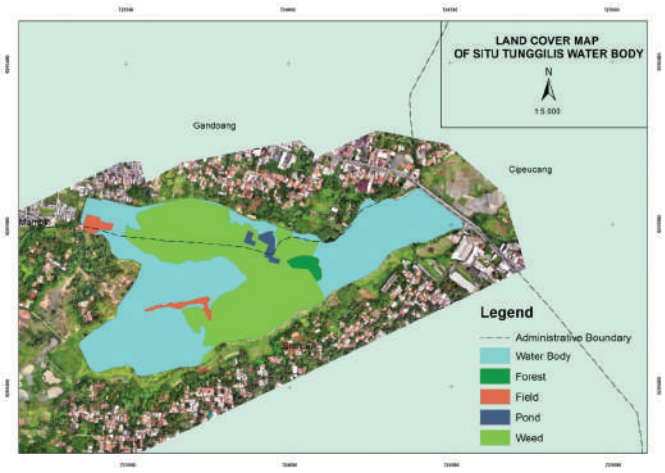

Figure 3. Land cover maps of Situ Tunggilis water body.

Table 4. Land cover area of Situ Tunggilis.

No	Type Land Cover Water Body	Area	Percentage
1	Water body	19.939182	57.25
2	Ponds	0.408214	1.17
3	Settlement	0.716705	2.08
4	Forest	0.440686	1.27
5	Pest Plant	13.322331	38.25
Total Area of Situ Tunggilis			**34.827118**

Border of Situ Tunggilis

The determination of the border boundary for lakes is based on the Regulation of the Minister of Public Works and Public Housing Number 28/PRT/M/2015. In Chapter II, Article 12, it is stated that the buffer zone line for lakes must be established at a minimum distance of 50 (fifty) meters from the highest recorded water level. This regulation serves as the basis for the creation of the buffer zone map for Situ Tunggilis. The buffer zone map of Situ Tunggilis is shown in Figure 4.

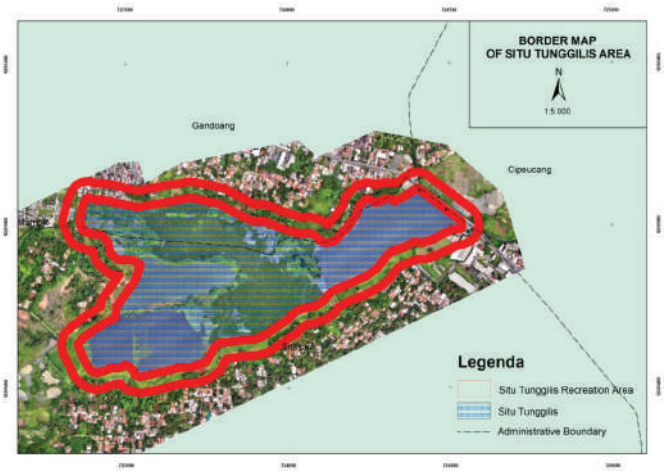

Figure 4. Border maps of Situ Tunggilis.

Using overlay techniques and the **clip** feature in the ArcGIS toolbox, a Land Cover Map of the Situ Tunggilis buffer zone—extending 50 meters from the lake's edge—was generated. The result of this analysis can be seen in Figure 5.

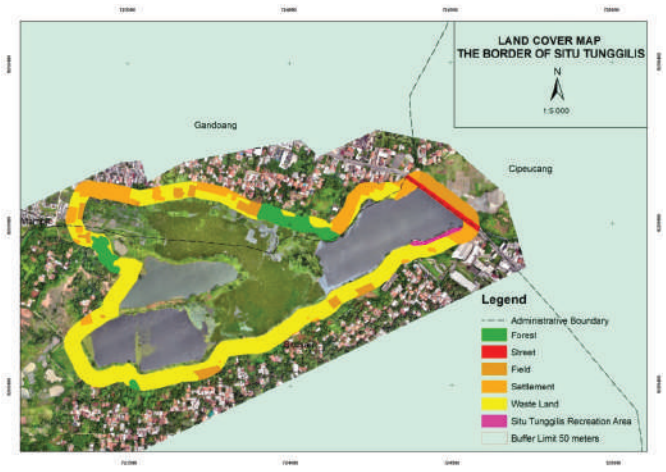

Figure 5. Border maps of Situ Tunggilis.

Table 5. Land cover border of Situ Tunggilis.

Land cover border of Situ Tunggilis	Area	Percentage
Open land	10.136561	57.33983352
Recreation	0.174134	0.985029792
Road	0.408107	2.308552915
Settlement	3.409101	19.28437897
Fields	1.89875	10.74072448
Forest	1.651391	9.341480313
Total Border Area	17.678044	

Based on Table 5, it can be seen that the total area of the buffer zone of Situ Tunggilis is approximately 17.678 hectares. Of this total area, around 3.4 hectares or about 19.2% is used for residential purposes. Meanwhile, the area designated for recreational use at Situ Tunggilis is only about 0.174134 hectares or approximately 0.9% of the total area. This indicates that the tourism potential in the Situ Tunggilis area has not been fully optimized.

In terms of environmental conservation, approximately 10.1 hectares or around 57% of the total area is classified as open land. This shows that the Situ Tunggilis area still has significant potential in terms of environmental conservation.

CONCLUSION

The buffer zone of Situ Tunggilis has substantial potential for residential and recreational development due to its strategic location and accessibility to supporting facilities and infrastructure. However, to optimize this potential, a comprehensive analysis of spatial allocation and land use is required. Accordingly, this study aimed to analyze the spatial allocation within the buffer zone of Situ Tunggilis and to identify its potential for future development. Based on the results of the analysis, several key conclusions can be drawn.

First, the land cover of Situ Tunggilis is dominated by the water body, covering 19.939 hectares or 57.25% of the total area of 34.83 hectares. In addition, invasive vegetation occupies 13.322 hectares (38.25%), while the remaining area consists of ponds, fields, and forest. These conditions indicate that Situ Tunggilis functions as an important aquatic ecosystem but also faces serious challenges from the expansion of invasive vegetation that requires proper management.

Second, the main potential of Situ Tunggilis lies in its extensive water body, which can be utilized for aquaculture, recreation, and other economic activities. Nevertheless, several threats must be addressed, particularly the rapid growth of invasive vegetation that can disrupt ecosystem balance, as well as land conversion for residential and agricultural purposes that may reduce the size of the water body and degrade environmental quality. Therefore, sustainable and integrated management is essential to minimize these risks.

Third, land cover analysis of the buffer zone shows that open land dominates an area of 10.137 hectares (57.34%) out of a total buffer zone area of 17.678 hectares, followed by residential areas, fields, forest, and recreational facilities. To maintain the sustainability of Situ Tunggilis, it is crucial to preserve open land and forest areas and to strictly regulate land use for settlements and other activities to prevent ecological degradation. The establishment of an optimal protection zone within the buffer area is also strongly recommended to safeguard water quality and biodiversity.

In conclusion, the dominance of open land in the buffer zone indicates that Situ Tunggilis has strong potential for sustainable development that can enhance environmental quality and community welfare. However, further planning is required to maintain a balance between residential development, agricultural activities, and green open spaces. Efforts to optimize land use,

increase agricultural productivity, and improve the quality of life of surrounding communities must be supported by clear regulations and effective management strategies. With proper spatial planning and sustainable management, Situ Tunggilis has strong potential to serve as a model for sustainable natural resource management that benefits both the environment and the local population.

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