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# Critical Land Mapping for Spatial Planning in Yeh Abe Watershed

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***ABSTRACT***

Tabanan Regency, Indonesia, faces rapid development, particularly in tourism and trade, leading to concerns about land degradation. This study focuses on mapping and evaluating critical land within the Yeh Abe Watershed, an area experiencing significant land-use change in Kerambitan District, Tabanan Regency. Utilizing GIS and remote sensing techniques, the research analyzed parameters such as land cover, slope, erosion hazard, land productivity, and land management to identify critical land areas. The results revealed a significant portion of the watershed as non-critical. However, moderate to critical land areas were identified and found to be predominantly located within urban settlement zones. Overlay analysis between the critical land map and the spatial planning map highlighted areas with high criticality that should be avoided for future development to ensure sustainable watershed management. This research emphasizes the importance of integrating critical land information into spatial planning processes to mitigate land degradation and promote sustainable development in Tabanan Regency.

**Keywords:** critical land mapping, GIS, spatial planning, spatial pattern

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## 1. INTRODUCTION

Tabanan Regency is part of Bali Province, Indonesia. Tabanan Regency is one of the regencies with quite rapid development in the tourism and trade sectors (Parwati et al, 2022). Tabanan Regency has diverse topography, ranging from coastal to mountainous areas (Indriyani et al, 2020). This condition can trigger the emergence of critical land if not managed properly. Critical land is one form of land degradation where land experiences a reduction or even loss of productivity in terms of economics and biology (Giuliani et al, 2020; UN Statistics Division, 2018; Indrihastuti et al, 2016).

Critical land management policies require representative critical land data. This can be done by utilizing GIS (Geographic Information System) technology and remote sensing which are capable of analyzing spatial critical land phenomena. This technology is more efficient compared to field investigations (Sihalolo et al, 2020; Suntoro et al, 2019; Gilani et al, 2015). Studies that integrate GIS and remote sensing technology in mapping critical land have been widely conducted in Indonesia, both on Java, Sumatra, and Sulawesi (Sersermudi et al, 2022; Purwadi & Siswanto, 2021; Butar et al, 2021). However, studies that map critical land and evaluate it based on Spatial Planning (Rencana Tata Ruang Wilayah/RTRW) are still rare. In fact, the integration of critical land information in spatial planning is one of the concrete steps in managing land degradation and watershed management (Suntoro et al, 2019; Oliveira et al, 2018).

Based on this, the study will focus on mapping critical lands in part of Tabanan Regency and evaluating them through the lens of Spatial Planning. The key area of interest is the Yeh Abe Watershed, which is located in Kerambitan District, an area that has seen the largest conversion of agricultural land into settlements (Adyaguhyatriko et al, 2024). The outcome of this study is expected to provide guidance for spatial planning in watershed management. The sustainability of a watershed relies on considering the roles of every biotic, abiotic, and human component, along with their interactions within the watershed (Rafidah et al, 2024; Canteiro, 2024). Watersheds play a crucial role in the planning and management of natural resources, emphasizing the importance of integrated approaches to ensure sustainable management of these vital areas (Azarnivand et al, 2017; Fariz et al, 2024). The urgency of this study is further underscored by the increasing pressures of climate change, population growth, and land-use changes, which threaten the ecological balance of watersheds. Without accurate and up-to-date critical land mapping integrated into spatial planning, the risk of irreversible environmental damage, becomes significantly higher.

## 2. METHODS

The location in this study is in Yeh Abe Watershed, Tabanan Regency, Bali Island (Figure 1). Yeh Abe Watershed is located in part of Kerambitan District, Tabanan District and Penebel District. The downstream of Yeh Abe Watershed flows into the Bali Sea which is located in the south of Bali Island.

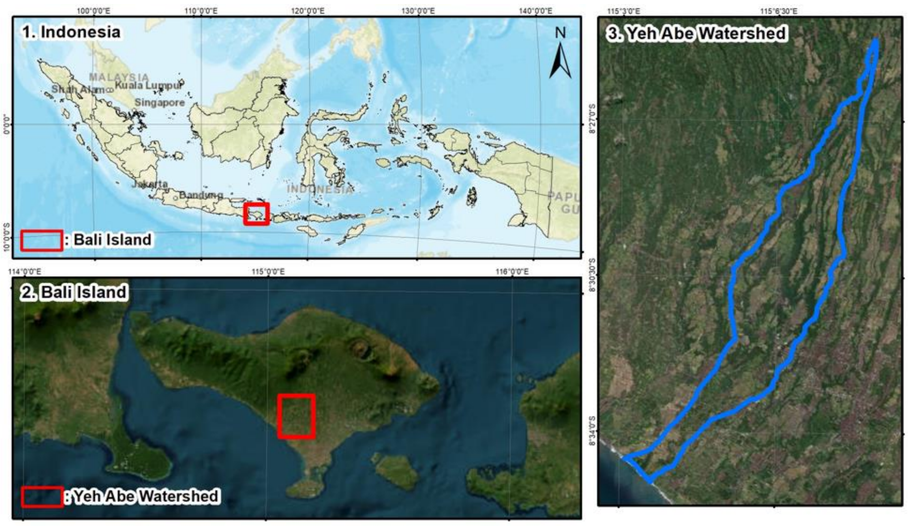


**Figure 1.** Research location

In this research, the parameters used as determinants of critical land refer to Regulation of the Indonesian Ministry of Forestry (Permenhut) Number P.32 / Menhut-II / 2009, including land cover, slope, erosion hazard level, land productivity and land management (Norsaidah et al, 2021; Putra et al, 2024). Data collection and analysis techniques in this research are as follows:

## 1. Land cover

Land cover is one of the parameters used in determining critical land. The determination of land cover was carried out using interpretation of remote sensing data, namely Sentinel-2 satellite imagery acquired in 2022 and Pleiades satellite imagery acquired in 2018. The data analysis technique used is a hybrid image interpretation of manual interpretation with automatic interpretation using supervised classification. The combination of these two methods is because manual interpretation produces quality land cover maps but long processing times, while automatic interpretation produces less accurate land cover maps but very short processing times (Fariz & Nurhidayati, 2020; Wijaya et al, 2019).

The weight for land cover is 50%, so the score for this paremeter is (score x weight). This land cover data uses interpretation results from remote sensing, so that the determination of land cover classification is seen from the percentage of vegetation in Table 1.

**Table 1.** Parameter Classification of Vegetation Percentage for Land Cover

| Class | Vegetation Percentage |
|---|---|
| Very good | >80 % |
| Good | 61 - 80% |
| Medium | 41 - 60% |
| Bad | 21 - 40% |
| Very Bad | <20% |

(Widyatmanti et al, 2018; Indonesia Ministry of Forestry, 2013)

## 2. Slope

Slope is the ratio between the height difference and the vertical distance of a land to its horizontal distance (Dewi et al, 2021). The amount of slope can be expressed in several units, which for this research uses units of percent (%). The slope in this research uses DEMNAS data with a pixel size of 8.33m. DEMNAS is an elevation model from BIG (Geospatial Information Agency) built from the assimilation of IFSAR, RADARSAT, ALOS and mass point data, so that DEMNAS can take the form of a DSM (Digital Surface Model) or DTM (Digital Terrain Model) depending on the data from the builder (Amalia et al, 2024; Zylshal et al, 2021). Slope is built using slope analysis which is part of 3-dimensional analysis, the slope classification used is presented in Table 2.

**Table 2.** Classification of Slope Parameters

| Class | Slope (%) |
|---|---|
| Flat | <8 |
| Sloping | 8 - 15 |
| Rather Steep | 16 - 25 |
| Steep | 26 - 40 |

| | |
|---|---|
| Very steep | > 40 |

Indonesian Ministry of Forestry, 2013

### 3. Erosion hazard level

The erosion hazard level can be calculated by comparing the erosion rate in a land unit and the effective soil depth in a land. The weight of this parameter is 10%. In this research, the method to calculate the Erosion Hazard Level uses the USLE (*Universal Soil Lost Equation*) method. The USLE method uses four factors that affect erosion including climate, soil type, topography and land cover vegetation (Alawell et al, 2019).

**A= R x K x LS x C x P**

Where,

**A** = Amount of soil eroded (*tons ha-1 yr-1*)

**R** = Rainfall and surface flow factor (Erosivity) (*MJ mm ha-1 hr-1 yr-1*)

**K** = Soil erodibility factor (*tons ha hr MJ-1 mm-1 ha-1*)

**LS** = Slope length and slope factor (*dimensionless*)

**C** = Ground cover vegetation and crop management factor (*dimensionless*)

**P** = Soil conservation special measures factor (*dimensionless*)

**Table 3.** Classification of Erosion Hazard Level Parameters

| Class | Soil Erosion (tons/ha/year) |
|---|---|
| Very low | <15 |
| Low | 15 - 60 |
| Medium | 60 - 180 |
| High | 180 - 480 |
| Very High | >480 |

(Simanungkalit et, 2015; Indonesian Ministry of Forestry, 2013; Morgan et al, 1984)

### 4. Land Productivity

Land productivity data is one that is used to assess the level of land criticality in agricultural cultivation areas (Ambarwulan et al, 2021). Land productivity is assessed based on soil erosion from the sum of agricultural productivity of fruits with woody stems in the same year in each sub-district (Table 4). The weight for this parameter is 30%.

**Table 4.** Classification of Productivity Parameters

| Class | Soil Erosion (tons/ha/year) |
|---|---|
| Very Low | <10 |
| Low | 11 - 40 |
| Medium | 41 - 60 |
| High | 61 -80 |
| Very High | >80 |

Indonesian Ministry of Forestry, 2013

### 5. Land Management

Land management is one of the criteria used to assess critical land in protected forest areas which is assessed based on management aspects which include management aspects, the presence of springs and others (Ambarwati et al, 2021). This parameter has a weight of 10%. Management criteria in determining critical land are divided into 3 classes, namely poor, moderate and good (Table 5).

**Table 5.** Classification of Management Parameters

| Class | Description |
|---|---|
| Bad | None |
| Medium | Incomplete |
| Good | Complete* |

Widyatmanti et al, 2018; Indonesian Ministry of Forestry, 2013

## 6. Critical Land Analysis

The method used in critical land analysis is scoring. Each parameter determining critical land is given a score, from each scoring each parameter is summed to get the results of critical land. Overlay analysis is an important analysis in GIS, which combines more than one input data to obtain new information (Wang et al, 2023; Putra et al, 2024). Classification of critical land levels based on the number of critical land parameter scores in Table 6.

**Table 6.** Classification of Critical Land Analysis Score Values

| Score Value | Critical Land Criteria |
|---|---|
| 426 - 500 | Not Critical |
| 351 - 425 | Critical Potential |
| 276 - 350 | Somewhat Critical |
| 201 - 275 | Critical |
| 115 - 200 | Very Critical |

Renyut et al, 2018; Ministry of Forestry, 2013

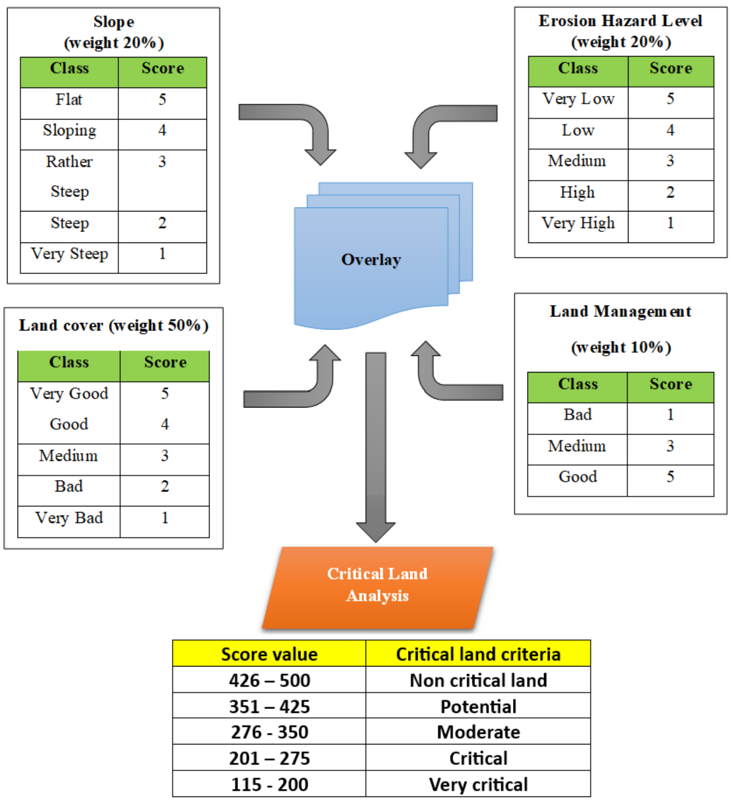


**Figure 3.** Flowchart of data processing and analysis

## 3. RESULTS AND DISCUSSION

Yeh Abe Watershed located in Tabanan Regency is part of the Sarbagita Urban Area which is the largest metropolitan area in the Nusa Tenggara Islands. The Sarbagita Urban Area is also the second largest metropolitan area in the Eastern Indonesia Region, although its land cover is dominated by agricultural land (Putra et al, 2024). The results of land cover mapping using hybrid interpretation show that agricultural land also dominates the land cover in Yeh Abe Watershed. Agricultural land in Yeh Abe Watershed covers an area of 1709.41 Ha or 24.7% of the total land cover in Yeh Abe Watershed. This is in line with the nickname of Tabanan Regency as a granary (*lumbung padi*) on the island of Bali (Kartika et al, 2021; Putra et al, 2024). The results of the majority of scoring analysis for land cover in Yeh Abe Watershed are very poor scores with the appearance of objects in the form of rivers and settlements. This analysis is taken from the low percentage of vegetation. For a very high score, namely mixed garden land cover with a vegetation density of 61-80%, it is very rare in Yah Abe Watershed (Figure 3).

The slope of the slope in Yeh Abe Watershed is predominantly flat, namely with a slope of 0-8%. This area is 1893.69 Ha or 48.5% of the Yeh Abe Watershed area. The dominant score in Yeh Abe Watershed is a score of 5, namely a steep slope score. Slope is related to erosion hazards, because in the USLE method it is built by slope parameters. The level of erosion hazard in Yeh Abe Watershed, the results of the analysis using the USLE (Universal Soil Lost Equation) method, are dominated by a very low level of erosion with an area of 3821.54 Ha or around 97% of the Yeh Abe Watershed area (Figure 3).

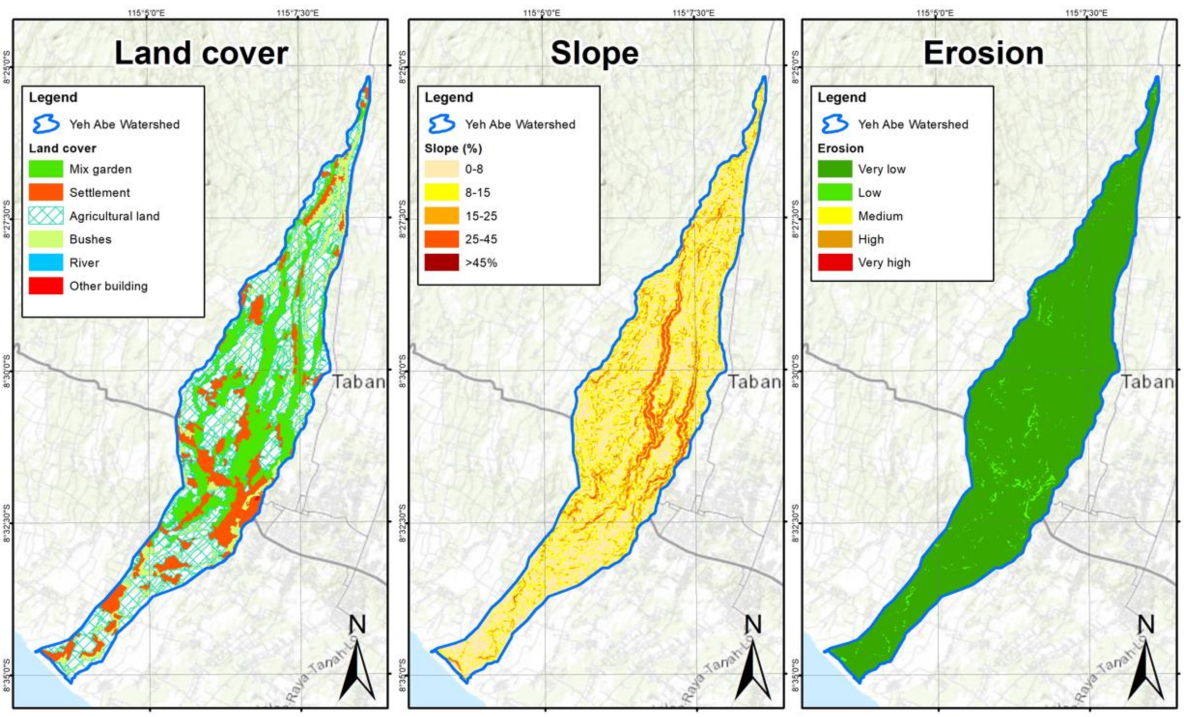


**Figure 3.** Map of land cover, slope and erosion at Yeh Abe Watershed

Land management parameters for critical land analysis in Yeh Abe Watershed have a dominant score for the agricultural land area. For productivity parameters in Yeh Abe Watershed, it is also high in the agricultural sector so that the production results are high. The results of the analysis of the overlay of several parameters that have been produced will produce a total weight value, the total weight is generated from the sum of the scoring value x weight, which can be seen in table 6. The results of the critical land analysis obtained for Yeh Abe Watershed are dominated by non-critical land with an area of 2673.08 Ha or 68% of the area of Yeh Abe Watershed (Figure 4). However, there are areas with moderate critical land and critical land that are evenly distributed in Kerambitan District, Tabanan District and Penebel District.

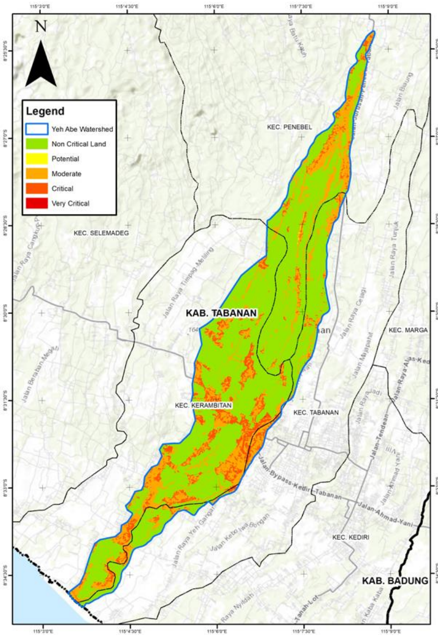


**Figure 4.** Critical land map in Yeh Abe Watershed

The overlay results between the spatial pattern plan map and the critical map are presented in Figure 5. The critical land class that is overlaid is the very critical and critical class. The overlay results show that the majority of critical land in Yeh Abe Watershed is an urban settlement area, with an area of around 258.36 Ha. In the preparation of Spatial Planning in Tabanan Regency, areas that have a high to very critical level of critical land should be avoided for developing settlement areas (Putra et al, 2024). This is because it increases the risk of erosion which will have a negative impact on the community and the environment. So one of the efforts is to plan an urban green space footprint in the area.

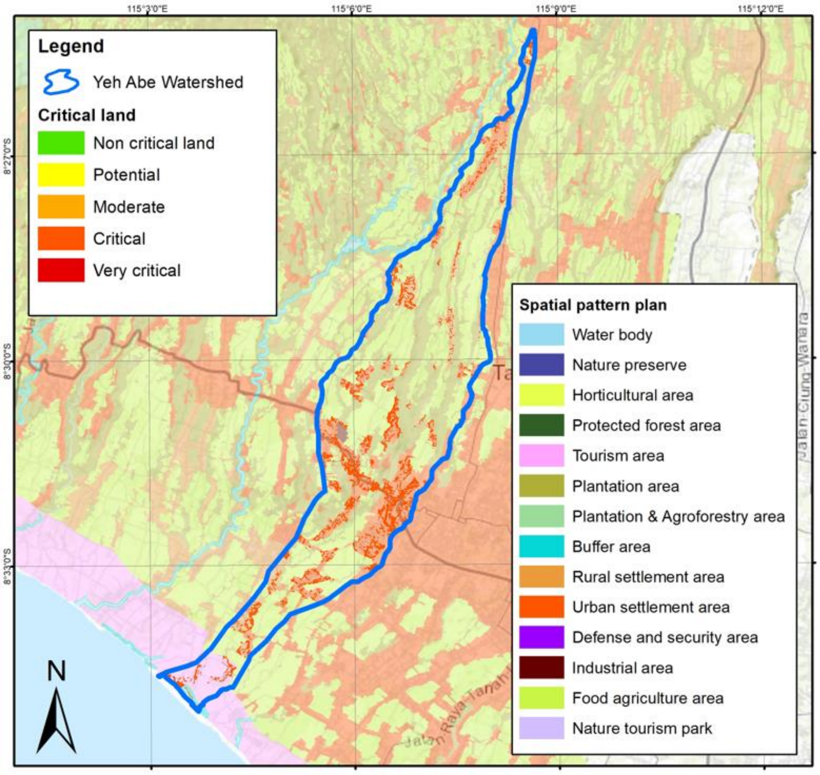


**Figure 5.** Overlay between spatial pattern plan map and critical land in very critical and critical classes

This study still has limitations such as the data analysis process still using conventional overlay analysis or vector-based. Future work that can be applied based on the limitations of this study is to use raster overlay based on fuzzy logic. This approach is more representative than the vector approach that does not maintain the continuous nature of the input data (Oktaviani et al, 2017; Kirschbaum et al, 2016). A more representative approach will produce better critical land management policies as well.

## 4. CONCLUSIONS

The results of the critical land analysis obtained for Yeh Abe Watershed are dominated by non-critical land with an area of 2673.08 Ha or 68% of the area of Yeh Abe Watershed. However, there are areas with moderate critical land and critical land that are evenly distributed in Kerambitan District, Tabanan District and Penebel District. The overlay results between the spatial pattern plan map and the critical map are presented in figure 5. The critical land class that is overlaid is the very critical and critical class. The overlay results show that the majority of critical land in Yeh Abe Watershed is an urban settlement area, with an area of around 258.36 Ha. In the preparation of Spatial Planning in Tabanan Regency, areas that have a high level of critical land to very critical should be avoided for the development of settlement areas. This study still has limitations such as the data analysis process still using conventional or vector-based overlay analysis. Future work that can be applied based on the limitations of this study is to use a raster overlay based on fuzzy logic. This approach is more representative than the vector approach that does not maintain the continuous nature of the input data.

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