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Use of geographic information systems to analyze the distribution of water catchment areas in Ambon City, Indonesia

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ABSTRACT
Background: Ambon City, as the capital of Maluku province, faces serious challenges in water resources management due to rapid urbanization and climate change that affects rainfall patterns. This study aims to analyze the distribution of water catchment areas using Geographic Information Systems. **Methods:** This study used variables of rainfall, soil type, land use, and slope which were analyzed using Geographic Information System (GIS) approach with overlay technique. **Findings:** The results showed that the water catchment area in Ambon City with a rather critical condition has an area of 2,350.27 ha, good condition of 13,524.39 ha, starting critical condition of 2,827.62 ha, normal natural condition of 13,636.20 ha and very critical condition of 236.12 ha. This research shows that soil characteristics, land use, slope, and rainfall in Ambon City have a significant influence on the capacity of water catchment areas. Findings from analysis using Geographic Information Systems (GIS) show that soil type, land use, and slope have a significant effect on water infiltration capacity, with alluvial soils having the best infiltration capacity. **Conclusion:** The results of this study emphasize the need for better management and strict implementation of spatial policies to protect water catchment areas, in order to reduce disaster risk and support sustainable development in Ambon City.

KEYWORDS: ambon; GIS; spatial analysis; water catchement.

1. Introduction

Ambon City, as the capital city of Maluku Province, has an abundant diversity of natural resources, including the potential of water catchment areas that are very important for ecosystem sustainability and water resource management. However, with rapid population growth and unplanned urbanization, water catchment areas in Ambon City face various challenges, such as land conversion, pollution, and climate change that can threaten groundwater availability (Salakory & Rakuasa 2022). Therefore, it is important to conduct an in-depth analysis of the distribution of water catchment areas in the city to support sustainable water resources management. Geographic Information System (GIS) is an effective tool for analyzing and visualizing spatial data (Gebru and Tesfahunegn 2020). Using GIS, researchers can integrate various parameters that affect water catchment areas, such as soil type, rainfall, land use, and slope (Simanjuntak et al., 2022). This method allows

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researchers to produce accurate and informative maps of the distribution of water catchment areas, which can be used as a basis for decision-making by the government and stakeholders (Asri 2024).

Previous research has shown that water catchment areas play an important role in regulating the hydrological cycle and maintaining water quality. For example, research by Mwaura et al., (2022), showed that good water catchment areas can reduce the risk of floods and droughts, and improve groundwater quality. Therefore, mapping and analyzing water catchment areas in Ambon City is very important to understand the existing conditions and potential. Ambon City has unique geographical characteristics, with a hilly topography and high rainfall. This creates its own challenges in water resources management. Research by Waluyo & Haq (2017), emphasized the importance of understanding local geographical and climatic conditions in planning water catchment area management. Thus, this study aims to provide a clear picture of the distribution of water catchment areas in Ambon City.

In the context of apparent climate change, the analysis of water catchment areas is becoming increasingly relevant (Mwaura et al. 2022). Changing rainfall patterns and increasing temperatures can affect the ability of soil to absorb water. Research by Liu et al. (2022) showed that climate change can alter water infiltration dynamics and affect slope stability. Therefore, it is important to conduct a comprehensive analysis of the distribution of water catchment areas in Ambon City to anticipate the impacts of climate change. In addition, unplanned land use can reduce the area of water catchment areas. Research by Mahdiyah et al. (2022) showed that the conversion of agricultural land into residential land can reduce the soil's ability to absorb water. Therefore, this study will also analyze land use in Ambon City and its impact on the distribution of water catchment areas. By considering various factors affecting water catchment areas, this research is expected to provide useful recommendations for water resources management in Ambon City. The results of this research are expected to be used by the local government and other stakeholders in formulating policies that support the sustainability of water resources. Overall, this research aims to provide a better understanding of the distribution of water catchment areas in Ambon City using Geographic Information Systems. Thus, it is hoped that this research can contribute to better and more sustainable water resources management efforts in Ambon City, as well as serve as a reference for future research in the same field.

2. Methods

This research was conducted in Ambon City, which is administratively the capital of Maluku province, Indonesia. The variables used to analyze the distribution of groundwater recharge areas include rainfall, soil type, land use and slope adapted from the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P. 32/Menhut-II/2009 concerning Procedures for Preparing Technical Plans for Forest and Land Rehabilitation in Watersheds (Kementerian Lingkungan Hidup dan Kehutanan 2009; Dalimunthe et al., 2019). The slope variable was obtained from the analysis of DEMNAS (Digital Elevation Model National)- Geospatial Information Agency, the rainfall variable was obtained from the BMKG Station of Ambon City, the soil type variable was obtained from the Regional Development Agency of Ambon City and the land use/land cover variable was obtained from the analysis of SPOT 6 satellite images obtained from the Regional Development Agency of Ambon City.

The use of soil type, land use, and slope in the analysis of water catchment areas in Ambon City is very important for several reasons related to physical and environmental characteristics that affect the ability of an area to absorb and store water. Soil type has a major influence on permeability and water infiltration capacity. Soils with certain textures, such as clay or sand, will have different characteristics in terms of how quickly water can infiltrate into the soil. According to the Minister of Forestry Regulation, an understanding of soil type helps in determining water infiltration potential and effective management of groundwater resources. Land use includes various human activities that can affect the soil's ability to absorb water. For example, land used for settlements or industry tends to have a

harder surface and does not absorb water well compared to land planted with vegetation. By analyzing land use, we can identify potential water catchment areas and plan appropriate conservation.

Slope affects surface water flow and erosion potential. Steeper slopes can cause water to flow faster, reducing the time available for infiltration. Conversely, gentler slopes tend to allow more water to infiltrate into the soil. Slope analysis is therefore important for understanding water flow dynamics and planning effective management of water catchment areas. By adapting these parameters from the Minister of Forestry Regulation, a comprehensive analysis of water catchment areas in Ambon City can be conducted, resulting in better recommendations for water resources management and mitigation of disaster risks such as floods and droughts. Spatial data processing was done entirely in ArcGIS Pro software. All variables were then given scores and weights based on their level of influence and then the overlay process was carried out. To produce a classification of the water catchment area, the sum of the product of the scores and weights of each variable was done. The classification, score, weight of each variable and infiltration rate in this study can be seen in Table 1.

Table 1. Variables

Variables	Classification	Infiltration	Score	Weight
Soil Type	Aluvial	Very High	5	5
	Kambiso	High	4	
	Litosol	Medium	2	
	Renzina	High	4	
Land Cover	Forest	Very High	5	3
	Farmland	High	4	
	Open Land	Medium	2	
	Settlement	Low	1	
	River	Very High	5	
Slope	>8 %	Very High	5	2
	8-15%	High	4	
	15-25%	Fair	3	
	25-40%	Medium	2	
	>40%	Low	1	
Rainfall	2.500 -3000	High	4	4

(Simanjuntak et al., 2022; Asri, 2024)

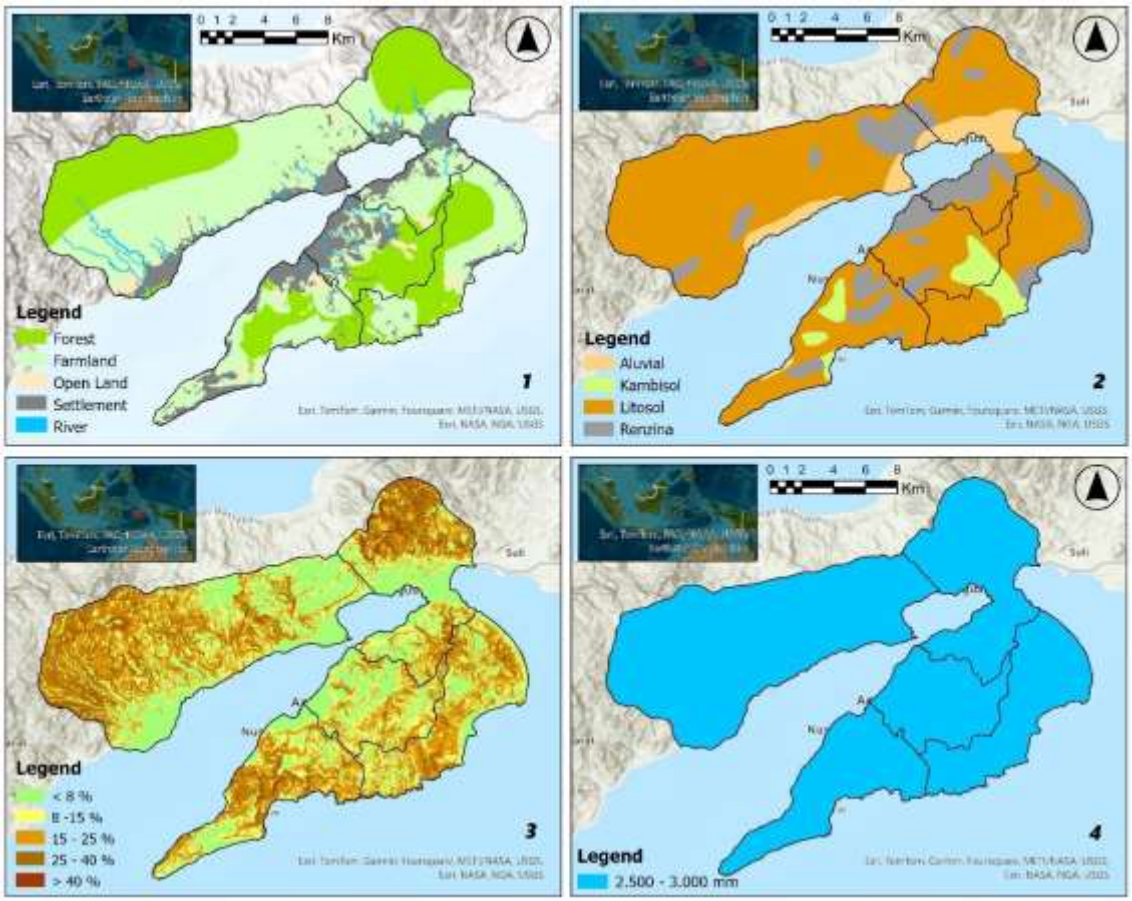
The weighting of the water catchment area is calculated using a modified formula from (Hastono et al., 2012; Asri 2024), namely Water catchment area = soil type score * soil type weight + slope score + slope weight + land use score * land use weight + rainfall score * rainfall weight. Classification of the condition of the water catchment area can be based on the criteria for water catchment conditions, namely scores >48 are good, 44-47 are normal natural conditions, 40-43 are starting to be critical, 37-39 are somewhat critical conditions, and scores <37 are very critical conditions (Asri 2024).

3. Result and Discussion

3.1 Water Catchment Area Variables

Land use in Ambon City has a significant impact on water catchment areas, especially with the presence of large agricultural land reaching 15,570.63 ha. Agricultural land serves as an important water catchment area, as it can absorb rainwater and reduce surface runoff. However, the conversion of agricultural land into settlements, which currently covers 4,439.25 ha, can reduce water infiltration capacity. Dense settlements are often equipped with impervious infrastructure, such as roads and buildings, which hinder water infiltration

into the soil. Therefore, it is important to develop policies that protect agricultural land and encourage environmentally friendly agricultural practices to maintain the water catchment function of the area (Latue et al., 2023). In addition, the presence of 924.71 ha of open land and 11,462.28 ha of forest also contributes to the water catchment area in Ambon City. Open land and forests serve as rainwater reservoirs, which help reduce the risk of flooding and improve groundwater quality. Forests, with their deep roots, are able to absorb water more effectively and keep the soil moist. The river that runs along 176.53 ha also plays an important role in the hydrological system, serving as a natural channel for water flow and assisting in groundwater recharge. The research variables can be seen in Figure 1.



(Figure 1. Research variables, 1) land use, 2) soil type, 3) slope, 4) rainfall)

The variable soil type in Ambon City plays an important role in determining the capacity of water catchment areas. The 1,908.99 ha of alluvial soils, formed from river deposits, have good physical properties for water infiltration. These soils generally have a finer texture and high porosity, allowing them to absorb rainwater efficiently. On the other hand, cambisol soil types covering 1,512.00 ha, although having good fertility, tend to have lower infiltration ability compared to alluvial soils (Hastono et al. 2012). This can result in greater water runoff and potentially increase the risk of flooding in the area. Therefore, an understanding of the characteristics of soil types is essential for planning effective management of water catchment areas. In addition, lithosols covering 24,076.04 ha in Ambon City, while having erosion resistance, often have thin soil layers and are less able to store water. This type of soil can reduce water infiltration capacity, especially in areas that experience high rainfall. Rendzina, which covers 5,076.45 ha, also has unique characteristics, in that these soils are usually rich in organic matter but can have problems with water infiltration if not managed properly.

Slope is an important factor affecting water infiltration capacity in Ambon City. Areas with slopes of less than 8% covering 9,754.27 ha have excellent water infiltration potential. Soils in these areas tend to be more stable and able to absorb rainwater efficiently, reducing the risk of runoff and flooding (Mwaura et al. 2022). In contrast, areas with slopes between 8% and 15% covering an area of 6,404.21 ha, while still having good infiltration capabilities, are beginning to show higher runoff potential. This is due to an increase in surface water flow velocity which can reduce the time available for water to infiltrate into the soil. On the other hand, steeper slopes, such as in areas with 15% to 25% slope covering 10,440.07 ha and 25% to 40% covering 5,650.73 ha, tend to have lower water infiltration capacity. At these slopes, rainwater flows more quickly to the surface, reducing infiltration time and increasing the risk of soil erosion. Areas with slopes greater than 40% covering 313.29 ha are highly susceptible to erosion and have very limited infiltration capacity. Therefore, proper management of areas with varying slopes is essential to maintain the water catchment function and prevent natural disasters such as landslides and floods (Sugandhi et al., 2023).

Rainfall is one of the key factors affecting water infiltration capacity in Ambon City. With a total area of 32,573.68 ha that receives rainfall between 2,500 and 3,000 mm per year, this area has good water infiltration potential. High rainfall within this range can increase water infiltration into the soil, especially if supported by suitable soil conditions (Lucyana and Azwar 2022). However, if rainfall exceeds the infiltration capacity of the soil, runoff will occur which can cause flooding (Rakuasa et al., 2022). Therefore, it is important to understand the relationship between rainfall and soil conditions to plan effective water resources management. On the other hand, heavy rainfall can also affect water quality and ecosystem health in catchment areas. As rainfall increases, the risk of surface water pollution also increases, especially if there is poorly managed sewage. This can reduce the effectiveness of catchment areas in filtering and storing clean water. Therefore, good management of rainfall and protection of water catchment areas is essential to maintain ecosystem balance and ensure the availability of clean water in Ambon City.

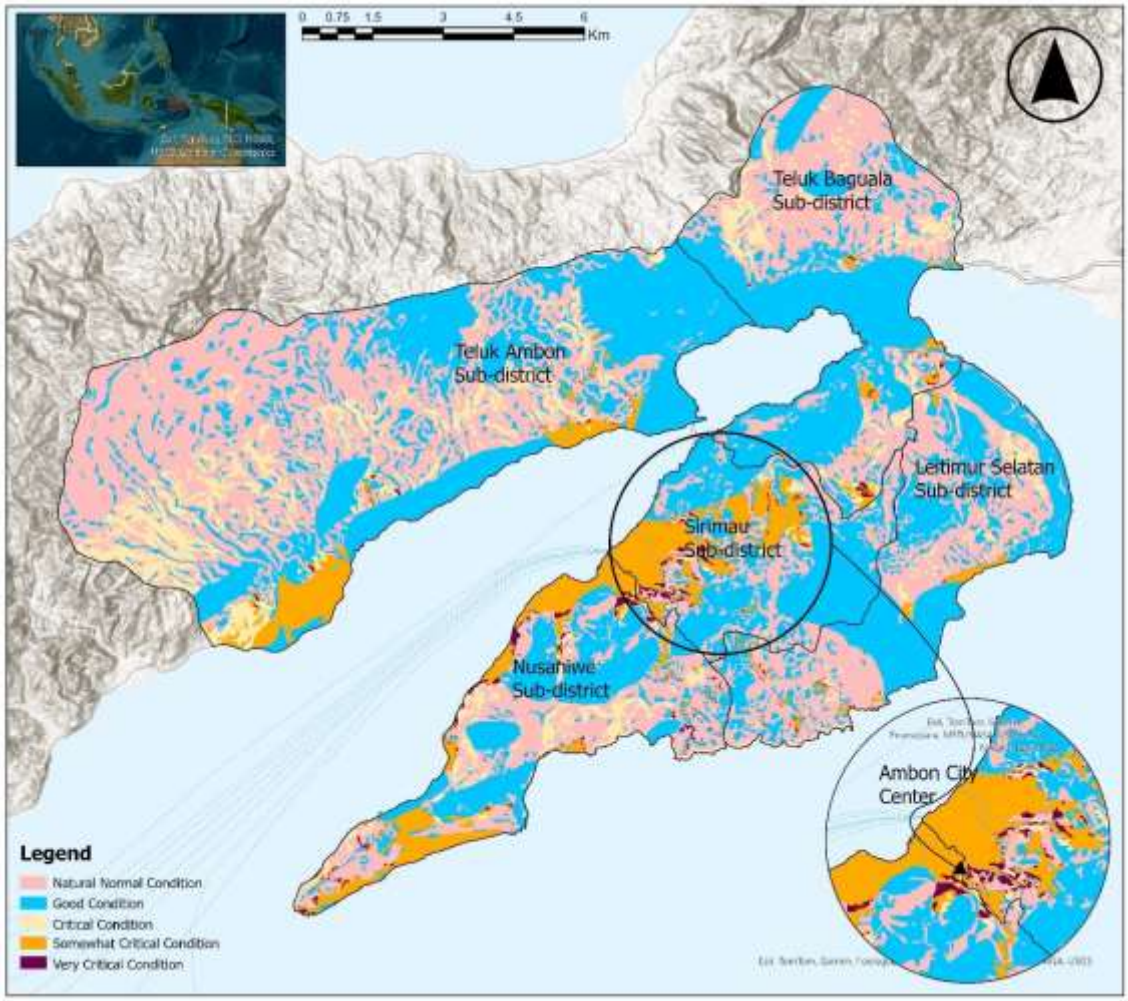
3.2 Ambon City Water Catchment Area

The results of the analysis of water catchment areas in Ambon City show that the total area of water catchment areas classified in various conditions covers 32,573.68 ha. Of this total, areas in good condition dominate with an area of 13,524.39 ha, followed by critical conditions covering 2,827.62 ha, and very critical conditions covering only 236.12 ha. This shows that although there are stressed areas, most of the water catchment areas in Ambon City are still in good condition and able to support optimal water infiltration. At the sub-district level, Teluk Ambon sub-district has the most extensive water catchment area in good condition, reaching 4,884.65 ha. This shows great potential for sustainable water resources management in the area.

In contrast, the sub-districts of Leitimur Selatan and Nusaniwe show smaller areas of highly critical condition, 12.75 ha and 110.16 ha respectively. Nonetheless, these two sub-districts also have sizable areas in the good category, namely 2,227.22 ha and 1,682.81 ha, indicating that there are opportunities to improve the management of water catchment areas in these areas. The varied condition of water catchment areas in Ambon City is also influenced by factors such as land use, slope, and rainfall. Unplanned land use can reduce the soil's ability to absorb water, increasing the risk of runoff and flooding (Rakuasa & Somae 2022). Therefore, it is important for the government and communities to work together to plan for sustainable land use and keep water catchment areas functioning properly.

Water catchment areas in Ambon City play an important role in maintaining ecosystem balance and groundwater availability. Based on the analysis, there are variations in the condition of water catchment areas in several sub-districts, with Sirimau and Nusaniwe sub-

districts showing a good proportion of areas, while Teluk Ambon and South Leitimur sub-districts have more critical areas. This suggests that despite good potential, challenges in managing water catchment areas remain, particularly in relation to land use change and rapid urbanization. One factor that affects the condition of water catchment areas is unplanned land use. Changes in land use, such as conversion of agricultural land to residential or commercial areas, can reduce the soil's ability to absorb water. Therefore, it is important to implement policies that support the protection of water catchment areas, including the establishment of protection zones and regulation of sustainable land use (Liu et al. 2022). Research shows that good management can increase water infiltration capacity and reduce flood risk.



(Figure 2. Water catchment area of Ambon City)

Mitigation efforts that can be taken to improve the condition of water catchment areas in Ambon City include land rehabilitation, tree planting, and infiltration ponds. Land rehabilitation aims to restore ecosystem functions that have been disturbed, while tree planting can increase water infiltration and reduce soil erosion. The construction of infiltration ponds is also an effective measure to increase water infiltration capacity, especially in densely populated areas. By involving the community in these programs, awareness of the importance of water catchment areas can be raised. In addition, education and socialization to the community on the importance of water catchment areas and the negative impacts of deforestation and unplanned development are needed. Local governments can work with non-governmental organizations to organize campaigns and trainings on sustainable water resources management. With a comprehensive and

participatory approach, it is hoped that the condition of water catchment areas in Ambon City can be improved, so that they can function optimally in supporting water availability and reducing the risk of natural disasters such as floods.

4. Conclusion

This research shows that soil characteristics, land use, slope, and rainfall in Ambon City have a significant influence on the capacity of water catchment areas. By using spatial analysis method through ArcGIS Pro Software, this research successfully identified and classified water catchment areas based on these variables. The results of the analysis show that alluvial soils have better infiltration capacity compared to a other the soil types, while conversion of agricultural land into settlements can reduce water infiltration capacity and increase flood risk. Therefore, a deep understanding of the environmental characteristics and sustainable management is essential for disaster mitigation and local economic development in Ambon City.

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The author declare no conflict of interest.

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