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Analysis of The Level of Erosion Hazard in The Walanae Watershed and Land Conservation Directions to Reduce The Erosion Rate in The Walanae Watershed

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Erosion, Watershed, Walanae, Land Conservation, Reduce.

ABSTRACT
The Walanae Watershed (DAS) is one of the Walanae – Cenranae Sub Watersheds in several districts, including Wajo, Soppeng, Bone, and Maros regencies. The river flow in the Walanae watershed flows from south to north and empties into Lake Tempe, Wajo Regency. The condition of Lake Tempe, which continues to experience silting due to erosion and sedimentation, is still happening. This siltation resulted in sediment discharges reaching 519,000 m3/year. This siltation can cause a narrowing of the lake area and flooding around Lake Tempe. The purpose of this study is to model erosion control in the Walanae watershed to reduce the level of siltation that occurs in Lake Tempe. Analysis of the erosion rate of the Walanae watershed using the USLE method. The analysis results show that the erosion rate that occurred in 2000 was 187.52 Tons / Ha / Yr, while in 2022, it was 253.336 Tons / Ha / Yr. Scenarios based on land conservation actions can reduce the erosion rate by 149,034 tons/ha / Year. The scenario was carried out by considering slope classes and land cover in the Walanae watershed. In flat to gentle slope conditions, ground cover crops and livestock grazing are needed; in rice fields and dryland agriculture, rural and annuals and mulch reinforcement are needed. Conservation measures are needed in steep to very steep slope classes, such as bench terraces and plant cover crops for agricultural land cover. As for forest areas, permanent vegetation or agroforestry is needed.

INTRODUCTION

Natural resource management, especially land and water resources, has an increasingly important role in using them sustainably (Syarif et al., 2023). The form of water problems in Indonesia is characterized by environmental conditions that are not conducive to accelerating water scarcity (Atmojo, 2006). According to Mawardi (2008), environmental damage is, among others, caused by degradation of the carrying capacity of upstream watersheds (DAS) due to uncontrolled forest destruction so that the critical land area in Indonesia has reached 18.5 million hectares. This decreases the watershed's ability to store water in the dry season, increasing the frequency and magnitude of floods (An et al., 2022; Hasanuzzaman et al., 2023; Li et al., 2022; Lufira et al., 2022). High erosion rates also result in silting in reservoirs, lakes, and rivers, reducing their carrying and flowing capacity (Lin et al., 2023; Samekto & Winata, 2010; B. Zhu et al., 2022). One of the lakes that experienced considerable silting is Lake Tempe.

Lake Tempe has currently undergone intensive silting, and much of the effective area of the lake has been converted to permanent land (Nur, 2019). The results of multi-time mapping and interpretation of satellite imagery (1981, 1989, 2000, and 2015) show that the effective area of the lake continues to shrink over time, as shown in Figure 1. This effective widespread shrinkage is caused by high erosion in the upstream area, which causes massive sediment flow towards the lake in each rainy season (Soewaeli, 2014). High erosion in the upper

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reaches of this river is caused by the conversion of large land areas from protected forests and other protected areas to dryland plantation cultivation areas (Jayathilaka et al., 2023; Obiahu & Elias, 2020; Rakib et al., 2023; X. Zhu et al., 2023).

The catchment area of Lake Tempe is the Walanae – Cenranae watershed, which consists of five sub-watersheds, including the Bila, Wette'e, Batu Batu, Padangeng, and Walanae sub-watersheds. The largest sub-watershed is the Walanae watershed, with an area of 3170 km2, while the sub-watershed with the smallest area is the Batu Batu Sub watershed, with an area of 139 km^2.

The Walanae watershed is one of the watersheds that affects the condition of Lake Tempe and has been designated as a watershed included in the critical watershed in the super-priority category (Razak, 2020). The upstream Walanae watershed, with an area of 3170 km2, includes areas affecting the Lake Tempe system from the southern part. The results of a study conducted by Soewali (2014) stated that the rate of erosion that occurred in the Walanae watershed increased from 384,060 m 3 / year based on the results of studies in 1976-1995 to 1,186,142.9 m^3 / year.

Given that Lake Tempe is one of the super-priority lakes, this study aims to analyze the magnitude of the erosion rate that occurs in the Walanae watershed and model erosion control to reduce the sedimentation rate in Lake Tempe.

METHODS

The research was conducted on the Walanae watershed located in several districts, namely Wajo, Soppeng, Bone, and Maros regencies. Geographically located at position 3º 59' 03" - 5º 8' 45" S and 119° 47' 09" –120° 47' 03" E. The Walanae watershed flows from south to north and empties into Lake Tempe. The Walanae sub-watershed is shown in Figure 2.

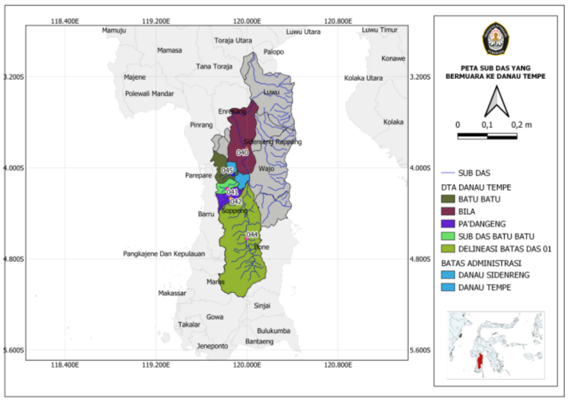

Figure 1. Sub watershed that empties into Lake Tempe

The data used in this study consisted of time series data and spatial data. Time span data consists of daily rainfall data. Spatial data consists of attribute data and object data. Attribute Walanae watershed. Rainfall data from 1995 – 2022, soil type, topographic, and land cover data in 2000 and 2022. Data types and sources are presented in Table 1.

Table 1. Required data

Data	Source	Picking Method
Walanae Watershed DEM Map	http://tides.big.go.id/DEMNAS/	Metadata
Rain and precipitation station data	BBWS Jeneberang	Document
Climate data	https://power.larc.nasa.gov/data access-viewer/	Metadata

Soil type map	https://sig.pertanian.go.id/	Metadata
Soil parameter data	BBWS Jeneberang	Document
Land use map	https://geoportal.menlhk.go.id/webgis/index.php/en/	Document
Regional Spatial Plan	Bappelitbangda South Sulawesi Province	Document

Analysis of erosion in the Walanae watershed was carried out using a GIS application to create an erosion hazard level map layout. Modeling by Prasetyo et al. (2021) revealed that scenarios in erosion control are based on land conservation directions or land cover simulations. Thus, erosion control efforts in the Walanae watershed use land conservation-based scenarios by considering the RTRW (Regional Spatial Plan).

Erosion prediction is done using the Universal Soil Loss (USLE) equation. The maximum soil loss (erosion) amount is determined using a formula developed by Smith and Wischmeier (1978) with Equation 1.

$$A = R \times K \times LS \times C \times P \qquad (1)$$

where

A = amount of eroded soil (ton/ha/year)

R = rain erosion (MJ/ha/year)

K = soil erodibility

LS = slope factor and slope length

C = plant factor

P = soil conservation

RESULTS

In the erosion rate analysis, several factor analyses are needed, including rain erosion, soil erodibility, slope and slope length factors, plant factors, and soil conservation.

Rain erosion factor (R).

The rain erosion index is calculated by the Bols method (1978). The determination of value is determined from the amount of monthly average rainfall, the number of monthly average rainy days, and the maximum rainfall in the month concerned (Alka, 2022). The data used are data from 1995 to 2020 at 5 stations. The R values of the rain data of the five stations can be seen in Table 2.

Table 2. Erosivity value

Rain station	Precipitation (mm)	Rain erosion (MJ.mm/ha.jm/th)
Waeputtange	168	1008
Bancee	177	1072
Pacciro	223	1444
Tapale	207	1363
Lapajuang	150	858

Based on Table 2, it is obtained that the largest value of the R factor (the ability of rain to cause erosion/erosion of rain) is found at Pacciro Station with a rain erosion value (R) of 1444 MJ.mm/ha.jm/th with rainfall of 223 mm. The smallest erosion value (R) is at Lalange Lajoa Station, with a value of 858 MJ.mm/ha.jm/th with rainfall of 150 mm.

Soil erodibility (K)

The distribution of soil erodibility in the Walanae watershed area based on the results of soil sample analysis is presented spatially. The value of the soil sensitivity index to erosion obtained ranged from 0.1 to 0.39.

The properties of soil that determine soil erodibility include properties that determine infiltration capacity, permeability, and water-holding power. The higher the K value, the higher the sensitivity of the soil to erosion (Hamida, 2023). The soil type and the value of the Erodibility of the Walanae watershed are described in Table 3.

Table 3. The value of soil erodibility

Soil Type	Koef K	Area (Ha)	Percentage
Alluvial	0,1	21249	7%
Latosol	0,38	90344	30%
Inceptisol	0,23	109892	37%
Molisol	0,27	2094	1%
Mediterranean	0,21	7782	3%
Ultisol	0,15	31644	11%
Entisol	0,39	19815	7%

The dominant soil type in the Walanae watershed is inceptisol with a percentage of 42% or 28323 ha. The largest soil erodibility value (K) is the latosol soil type with a K value of 34330.72. While the lowest soil erodibility value is the type of molisol soil.

Slope slope (LS)

Arsyad (2009) revealed that the length and slope of slopes are two topographic elements that most influence surface flow and erosion. Other elements that may have an effect are configuration, uniformity and slope direction. The steeper slope will further increase the amount and velocity of surface flow, thereby increasing kinetic energy and increasing the ability to transport soil grains.

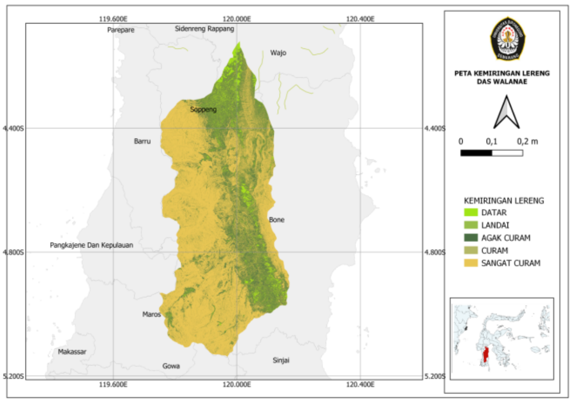

Figure 2. Topography of Walanae Watershed

The slopes in the Walanae watershed are dominated by very steep areas with an area of 87328 ha. The area in the smallest classification is a flat area with an area of 16932 ha (Figure 2). The analysis results found that the highest LS value was in the >45% category or a very steep area with an LS value of 829 616. The smallest LS value is in the classification of 0-8% or flat areas with an LS value of 16932 Ha with a percentage of 39%. Furthermore, in areas with a gentle slope of 19% with an area of 26,382 Ha. On a rather steep slope of 15% with an area of 20,567 Ha. While on steep and very steep slopes of 17% and 11%, respectively, with an area of 23,153 Ha and 15,822 Ha.

Land cover (C) and soil management (P)

Factor C is a factor that shows the overall influence of vegetation, litter, soil surface conditions, and land management on the amount of eroded soil. At the same time, the P factor is the ratio between the average eroded soil of land that receives certain conservation treatment and the average eroded soil of land cultivated without conservation action (Fahruddin et al., 2022). Land cover can be seen in Figures 3 and 4.

Land cover change is dominated by economic factors and population growth (Maghriza, 2022). These two things have a linear relationship where the increasing population will increase the need for food and shelter, impacting land cover change, including in the Walanae watershed. To see land use change in 2000 and 2022. It can be seen in Figure 3.

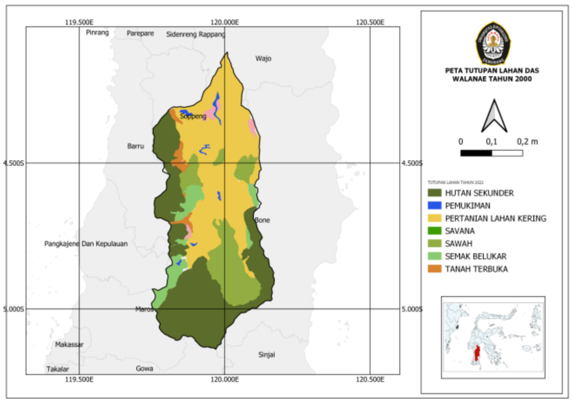

Figure 3. Land cover in 2000

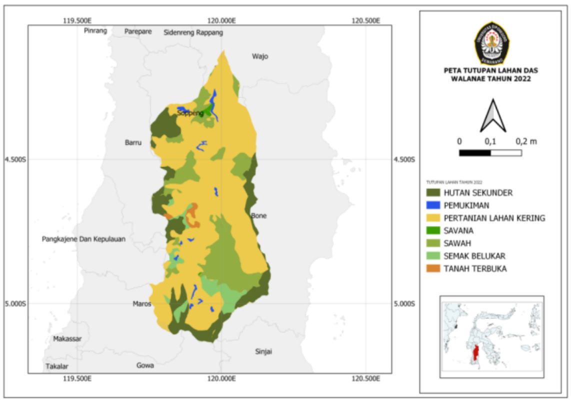

Figure 4. Land cover in 2022

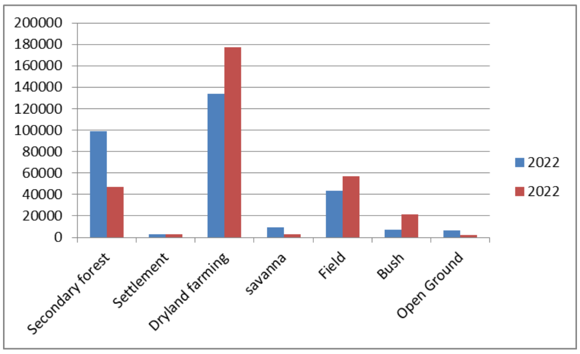

Figure 5. Addition and Subtraction of Land Cover Types

Erosion rate (A)

Erosion rate analysis is intended to predict the rate of erosion that occurs on soils with specific land use and management (Tuhepaly et al., 2022). Estimation of soil erosion in the Walanae watershed was analyzed in each land unit using parameter values of soil erosion factors from the USLE equation. Erosion estimation in the Walanae watershed in 2000 and 2022. The results of erosion rate analysis based on land cover are then classified to obtain erosion hazard class. The results of erosion rate analysis in 2000 and 2022 are presented in Figures 6 and 7. The classification into erosion hazard classes can also be seen in Table 4.

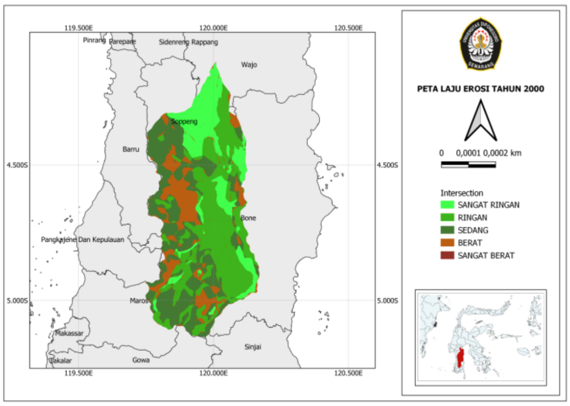

Figure 6. Erosion hazard class of 2000

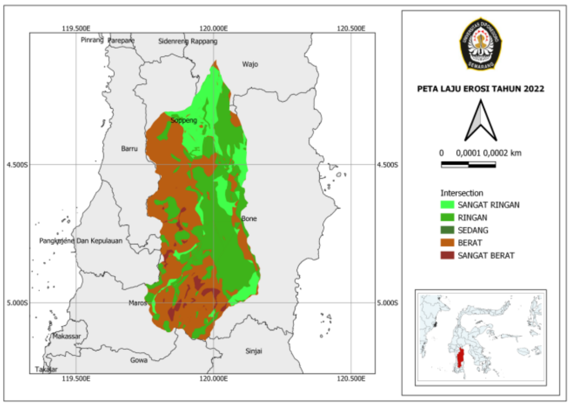

Figure 7. Erosion hazard class of 2000

Table 4 Erosion hazard classes of the Walanae watershed

Class	Area (Ha)	
	2000	2022
Very Light	34253	39507,49
Light	125422	59011,57
Keep	51418	78246,78
Heavy	93763	120564,22
Very Heavy	11265	9996,21

Based on the results of the analysis, it was found that the erosion class that dominates in the Walanae watershed is in the Heavy class with an area in 2022 reaching 120564.22 Ha. Thus, there is a need for land conservation efforts to reduce the rate of erosion in the Walanae watershed.

Land conservation directives

Law Number 32 of 2009 and Government Regulation Number 25 of 2000 give authority to manage natural resources (including natural resources in watershed areas) to regions, both at the provincial and district / city levels. Conservation actions with soil conservation application scenarios by making terraces in certain existing conditions refer to Table 5 related to slope conservation actions. Spatial analysis showing land conservation use areas can be seen in Figure 8.

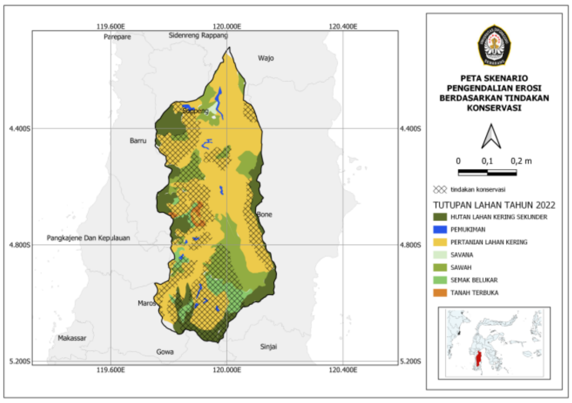

Figure 8. Land Conservation Directive

Dryland agricultural areas with rather steep slope conditions applied good bench terrace conservation measures. Cultivation areas are carried out the application of annuals with rotational or intercropping equipped with bench terraces, while in slope conditions and forest areas with permanent ground cover crops (agroforestry). Firman (2022) states that land management with slope limiting factors against erosion can be overcome by applying mechanical soil conservation. Land use that has steep slopes is recommended to be used as a permanent vegetation area and forest, so that the destructive power of rain on the soil is reduced.

Table 5. Land Conservation based on LS values

LS	Types of Land Cover	Conservation Measures	A	B
<15	Settlement	Grass planting, *cover cropping* and cattle grazing	0,6	0,05
	Dryland farming	Ground cover varies with Medium density	0,1	0,05
	Rice fields	Rorak and *strip cropping*	0,15	0,05
15 - 30	Settlement	Grass planting, *cover cropping* and cattle grazing	0,6	0,05
	Rice fields	Rorak and *strip cropping*	0,15	0,05
	Settlement	Grass planting, *cover cropping* and cattle grazing	0,6	0,05
	Dryland farming	Annuals, mulch and livestock boosters	0,1	0,05
31 - 45	Rice fields	Rorak, vertical mulch and Guludan terrace including *graded contour bund*	0,15	0,04
	Open Ground	Ground cover planting or grass planting	0,35	0,04
	Dryland farming	Perennial plants, gulud terraces, rorak and mulch as well as the application of bench terraces	0,1	0,04
>45	Secondary Forest Area	Agroforestry (permanent vegetation)	0,003	0,04
	Dryland farming	Perennial plants, gulud terraces, rorak and mulch as well as the application of bench terraces	0,1	0,04

Land conservation measures can reduce the area of each erosion rate class. The erosion class that is classified as heavy has reduced in area from 120564 Ha to 68553 Ha. Reductions in each erosion hazard class can be seen in Table 6 and Figure 9.

Table 6. Reduced erosion rate based on land conservation measures

Class	Year 2022		Conservation Measures	
	Erosion Rate (Ton/Ha/yr)	Area (Ha)	Erosion Rate (Ton/Ha/yr)	Area (Ha)
Very Light	10,259	39507,49	4,83	38362
Light	33,635	59011,57	27,89	101450
Keep	97,165	78246,78	68,90	96070
Heavy	234,893	120564	163,55	68553
Very Heavy	561,678	9996,21	480,00	2890,96
Average	253,336	307326	149,034	307326

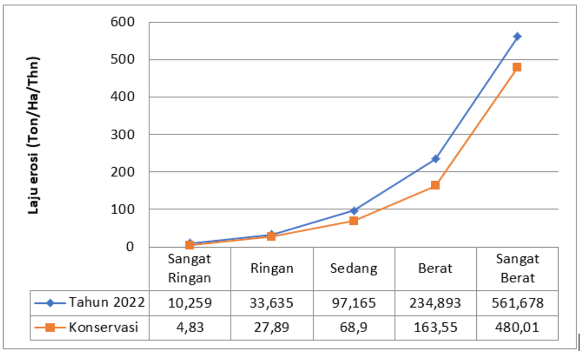

Figure 9. Erosion rate decline graph

Discussion

Conservation actions with soil conservation application scenarios by making terraces in certain existing conditions which refer to slope conservation actions. Dryland agricultural areas with rather steep slope conditions applied good bench terrace conservation measures. Cultivation areas are carried out the application of annuals with rotation or intercropping equipped with good bench terraces Agroforestry cultivation areas are applied with medium bench terraces on slope conditions and forest areas with permanent ground cover plants. Harjianto (2018) stated that land management with slope limiting factors against erosion can be overcome by applying mechanical soil conservation. Land use that has steep slopes is recommended to be used as a permanent vegetation area and forest, so that the destructive power of rain on the soil is reduced.

Scenarios with the concept of land cover conservation actions against erosion estimation in the Walanae watershed can be a reference used in watershed management planning that considers erosion rates. Land cover as a vegetation factor can reduce the kinetic energy of rain through stratified headers, rainwater interception, stem flows, header droplets, and canopy escapes to reduce surface flow speed and water-destroying power by roots and plant litter remnants (Nurazzi et al., 2021).

There is a significant decrease in erosion rates from land with very high and high erosion hazard levels with efforts to determine alternative land cover and soil conservation actions based on existing conditions in the Walanae watershed area. Land cover has decreased the estimation of erosion rates with the application of mixed garden crop management of medium density and good quality bench terrace conservation measures on steep slope conditions. Agricultural areas with the application of annuals in the pattern of intercropping / intercropping are equipped with good bench terraces.

Mahendro (2015) stated that land management with slope-limiting factors against erosion could be overcome by applying technical soil conservation with plant reinforcement. Land that has steep slopes, the use of land is recommended to be used as a permanent vegetation area and forest.

Erosion control scenarios with land conservation measures can reduce the rate of erosion classes in various erosion hazard classes, including the Heavy class, from an area of 120564, 22 Ha to 68553 Ha. Thus, Land Cover using conservation measures becomes the best scenario for erosion control in the Walanae watershed.

CONCLUSION

Analysis of the erosion rate obtained from the Walanae watershed in 2000 was 187.52 Tons / Ha / Yr, while in 2022, it was 253.336 Tons / Ha / Yr. Based on the scenario, it was found that land cover using land conservation measures can reduce the erosion rate in various erosion classes. In flat to gentle slope conditions, ground cover crops and livestock grazing are needed; in rice fields and dryland agriculture, rural and annuals and mulch reinforcement are needed. In steep to very steep slope classes, conservation measures are needed, bench terraces and plant cover crops for agricultural land cover. As for forest areas, permanent vegetation or agroforestry is needed. With the implementation of conservation measures in the Walanae watershed, it reduced the erosion rate by 149,034 tons/ha/year.

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