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Research Paper

Performance of Wanggu Watershed Management Based on Land Indicators

Kahirun[1]*, Nurnaningsih Hamzah[2], Arwan A. Rahman[3], Wa Ode Yusria[4], Nurhayati Hajar[1], Erich Nov Putra[5]

[1] *Department of Environmental Science, Faculty of Forestry and Environmental Science, Universitas Halu Oleo, Kendari, Sulawesi Tenggara, 93232, Indonesia*
[2] *Department of Forestry, Faculty of Forestry and Environmental Science, Universitas Halu Oleo, Kendari, Sulawesi Tenggara, 93232, Indonesia*
[3] *Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Universitas Halu Oleo, Kendari, Sulawesi Tenggara, 93232, Indonesia*
[4] *Department of Agribusiness, Faculty of Agriculture, Universitas Halu Oleo, Kendari, Sulawesi Tenggara, 93232, Indonesia*
[5] *Department of Civil Engineering, Faculty of Engineering, Universitas Halu Oleo, Kendari, Sulawesi Tenggara, 93232, Indonesia*
***Corresponding author e-mail**: irkahirun@gmail.com

Abstract
Based on the study, it was found that the land in the Wanggu Watershed is highly dynamic due to community activities such as agriculture, plantations, forestry, and settlement development. This can affect the performance and carrying capacity of the land in the watershed. The purpose of study was to evaluate the performance of watershed management and analyze the land-carrying capacity based on indicators of land. The parameters analyzed were the percentage of critical land area, the percentage of vegetation cover, and the erosion index. To obtain the data needed for the study, both primary and secondary data were used. Primary data was obtained through the overlay of the base map to obtain a map of critical land, making land cover maps, and calculating erosion prediction and carrying capacity analysis of the Wanggu Watershed. Secondary data was obtained from related agencies in the form of critical land data, land cover data, literature, policy documents, and study reports that are relevant to watershed management performance. The results of the study showed that the percentage of critical and somewhat critical land area in the Wanggu Watershed is 16.07 percent, which means that this value still qualifies as high-category critical land recovery. The percentage of vegetation cover, especially forest cover, is 27.10 percent, which is still in bad condition. The average erosion index value is 2.00, which is high. Based on these three parameters of land condition indicators in the Wanggu Watershed, the performance of watershed management has a poor land carrying capacity category with a value of 50. Overall, the study highlights the need for better management and conservation of the land in the Wanggu Watershed to improve its performance and carrying capacity.

Keywords
Critical Land, Erosion Index, Land Cover, Land Carrying Capacity, Wanggu Watershed

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1. INTRODUCTION

The management performance of a watershed is determined by several indicators and criteria as characteristics of a watershed. One that plays a very important role in determining watershed performance is the condition of the land (Sriyana, 2019; Sudia et al., 2023). Land conditions are a dynamic characteristic, always changing along with the influence of human activities within a watershed (Setyowati et al., 2021). Determination of watershed management performance by monitoring the carrying capacity of land in several watersheds in Indonesia has been widely carried out in order to determine the classification of watershed management performance carrying capacity with the status of each parameter varying from bad to good management status (Sriyana, 2019; Supangat and Wahyuningrum, 2021).

Dynamics of changes in land conditions such as increasing changes in land cover, critical land, erosion, and landslides as parameters that determine watershed damage (Nurhayati et al., 2021; Sugianto et al., 2022). Conversely, if these parameters are still below the damage threshold, the performance of a watershed is still said to be good, which means that the watershed's carrying capacity for environmental sustainability is still maintained (Noywuli et al., 2019). The carrying capacity of an environment including watersheds is a condition that is not static but is dynamic depending on changes in the biophysical conditions of the land and is also determined by changes in human activity (Hui, 2015).

Land use and expansion into cultivation areas without regard to soil and water conservation principles can cause unwanted impacts such as increased erosion and sedimentation, land degradation, and decreased land productivity (Wang et al., 2022). Subsequent impacts are not only on biophysical factors in the form of expanding critical land, decreasing the quantity, quality, and continuity of streams but also socio-economically causing people to increasingly lose their ability to do business on their land and decrease people's welfare (Abdul-Rahim et al., 2018; Kalfas et al., 2023).

Wanggu Watershed is one of the large watersheds in Southeast Sulawesi which is strategic and has been widely used by the community. The problem in the Wanggu Watershed is the dynamics of land use which has caused land degradation, disruption of hydrological functions, and sedimentation. The results of research by Marwah and Alwi (2014), it is known that the dynamics of land use in the Wanggu Watershed have caused a decrease in the area of forest and shrubs per year, followed by an increase in the area of mixed gardens, moor/rice fields, and settlements per year. As a result, it has a significant impact on decreasing land characteristics, namely soil porosity, soil organic matter, land cover, potential interception, increasing soil unit weight, and increasing hydrological indicators. Floods that occur almost every year, the largest of which occurred in July 2013, have resulted in damage to public facilities and infrastructure, gardens, rice fields, and residential areas, especially in areas around the channel and estuary of the Wanggu River (Deby et al., 2019). The cause of the flooding that occurred in the Wanggu Watershed was sedimentation that was so large that it reduced the capacity of the Wanggu River to accommodate floods (Alwi et al., 2021). The role of vegetation in land use in the Wanggu Watershed is very important in increasing land resilience to the hazards of floods and landslides (Restele et al., 2022).

Watershed management performance evaluation refers to the Minister of Forestry Regulation No. 61/MenhutII/2014 Concerning Monitoring and Evaluation of Watershed Management that monitoring and evaluation of watershed management can be carried out effectively and efficiently to obtain performance information and land carrying capacity of a watershed that can be used as a basis for watershed management planning (Sriyana, 2018). One of the efforts is to evaluate the classification of watershed management performance, with one of the indicators being studied in this study is the land indicator with several parameters in it that need to be assessed to determine the effect of the presence of land conditions on the management performance of the Wangu watershed. So this study aims to evaluate the performance of watershed management through analysis of land carrying capacity based on indicators of land conditions in the Wanggu Watershed.

2. EXPERIMENTAL SECTION

2.1 Research Area

The location of this research activity is the Wanggu Watershed, geographically located at 3° 56' 54" South Latitude - 4° 10' 24" South Latitude and 122° 22' 30" East Longitude – 122035'12" East Longitude. The geographical area of the Wanggu Watershed is 33,950.82 hectares or 339.51 km2 which is administratively divided into two regencies, namely Konawe Selatan Regency, and Kendari City. The administrative area of Konawe Selatan Regency which is included in the Wanggu Watershed includes six sub-districts, and Kendari City covers eight sub-districts. Overall the number of sub-districts in the Wanggu Watershed is fourteen sub-districts, where the activity locations are presented in Figure 1.

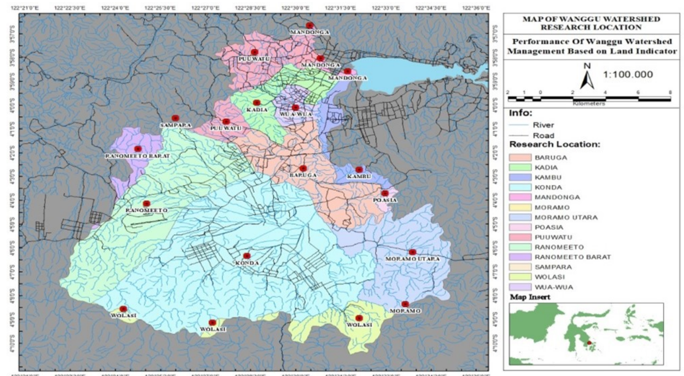

Figure 1. Wanggu Watershed Research Location

Data requirements in implementing activities are in the form of primary data and secondary data. Primary data was obtained from field observations. The primary data that will be collected includes land conditions, namely critical land, vegetation cover, and erosion index/land management. Critical land data in the Wanggu Watershed comes from a map of critical land overlaid with land use maps, slope maps, erosion hazard maps, land productivity, and land management. Land use data is generated from the latest imagery data on land use in Southeast Sulawesi. While the erosion index data is obtained from erosion calculation data and land use approaches and land management practices. Observations in the field to check the critical condition of the land, land use, and erosion events directly in the field (ground check). Secondary data collection is carried out by collecting relevant literature, report documents, maps, studies, or studies related to watershed management performance. Types of secondary data include thematic maps, topographical maps, satellite imagery maps, soil maps, slope maps, land cover maps, land use maps, and erosion hazard maps. Secondary data were obtained from related agencies, including maps of the Wanggu Watershed, erosion maps, and critical land maps obtained from the Sampara Watershed Management Center, thematic maps obtained from the Southeast Sulawesi Forest Area Consolidation Center (BPKH), data on the condition of conservation forest areas obtained from the Natural Resources Conservation Center, Southeast Sulawesi, and data on forest condition reports from the Forestry Service, Province of Southeast Sulawesi.

Data analysis in this study has been widely used in research to assess the carrying capacity in watershed management (Hikmat and Marselina, 2021), based on land indicators is based on Minister of Forestry Regulation No. 61/MenhutII/2014 Concerning Monitoring and Evaluation of Watershed Management. The parameters analyzed were Percentage of Critical Land Area (PCL), Percentage of Vegetation Cover (PVC), Erosion Index (EI), and Land Use and Soil Conservation (CP). Data processing is done using Microsoft Excel with existing formulas. Data analysis is done by giving a score to the parameters that have been processed so that they have a value. The scoring method used is by multiplying the weights and scores by the Equation (1).

$$\text{Score} = \text{Weight} \times \text{Score} \tag{1}$$

2.2 Analysis of the Percentage of Critical Land Area

Determination of critical land is carried out by identifying and analyzing the critical level of land in the Wanggu Watershed based on parameters or approaches from the Directorate General of Watershed Management Number: P.4/V-Set/2013 concerning Spatial Arrangement of Critical Land. Critical land analysis was carried out using an overlay technique to determine the criticality level of land in the Wanggu Watershed, including maps of land cover, slope, erosivity of rain, soil erodibility, permissible erosion, land productivity, and land management (Supangat and Wahyuningrum, 2021). Then do the weighting and score. These results are classified into five critical land classes, namely, not critical, moderately critical, moderate, critical, and very critical (Aktab et al., 2021; Riviana et al., 2020).

Determination of the percentage of critical land in the Wanggu Watershed is calculated based on Minister of Forestry No. 61 of 2014 as shown in Table 1. The percentage of critical land area in question is the percentage of the total area of very critical land and critical land in the Wanggu Watershed. Analysis of the weight and score of the assessment of the percentage of critical land area is presented in Table 1.

2.3 Percentage of Vegetation Cover (PVC) Analysis

Monitoring and evaluation of the percentage of vegetated land cover is the ratio between the area of land covered with permanent vegetation (LCV) compared to the area of the watershed. Permanent vegetation in the form of forest land, shrubs, annual crops, and gardens. The weight analysis and score of the percentage of vegetation cover are presented in Table 2.

2.4 Erosion Index Analysis (IE)

Erosion analysis was carried out using the prediction of the erosion rate on land units using the Revised Universal Soil Loss Equation (RUSLE) formula proposed by (Wischmeier and Smith, 1978), as follows (Equation (2)):

$$A = RKLSCP \tag{2}$$

where A: is the amount of erosion (tons/ha/year), R: is the erodibility of rain, L: is the length of the slope, S: is the slope factor, C: is the crop factor (land use), P: is the factor of soil conservation measures. Next, determine the value of erosion that can be tolerated by the Equation (3).

$$E_{\text{Tol}} = \frac{De - FD}{MPT} + LPT + BD \times 10 \tag{3}$$

where De: is the equivalent depth of soil, FD: is the depth factor based on soil type, MPT: is the lifetime of soil (400 years), LPT is: the rate of soil formation, and BD: bulk density. Then the index of erosion (IE) is calculated by comparing the amount of actual erosion (A) with tolerable erosion (E_{Tol}) with the Equation (4).

$$IE = (A/E_{\text{Tol}}) \tag{4}$$

The index of erosion is included in the weight and score calculation in Table 3 using the weighted index of erosion with the Equation (5).

$$IE_{\text{WatershedS}} = \sum (Wi/W_{\text{Watershed}}) \times IEi) \tag{5}$$

where Wi is the land use area, WWatershed is the watershed area and IEi is the index of erosion for each land use.

Land monitoring related to the index of erosion used is a weighted index of erosion based on the area of land use units in the Wanggu Watershed. Calculation of the index of erosion value using weight values and scores is presented in Table 3.

2.5 Performance Analysis of Wanggu Watershed Land Indicators

The final results of the Wanggu Watershed management performance evaluation based on land indicators are carried out by adding up the results of the weights and scores for all parameters. The results of multiplying the values and weights of the land indicators are presented in Table 4.

Calculation of land carrying capacity of the watershed (LCC) based on land conditions can be calculated by the following Equation (6).

$$\begin{aligned} LCC = \sum &(\text{Score} \times \text{Weight } PCL) + (\text{Score} \times \\ &\text{Weight } PVC) + (\text{Score} \times \text{Weight } IE) \end{aligned} \tag{6}$$

Table 1. Weight Analysis and Assessment Scores of Percentage of Critical Land Area (PCL)

Sub Criteria	Weight	Parameter	Value	Class	Score
Percentage of Critical Land	20	PCL = Critical Land Area /Watershed Area × 100%	PCL ≤ 5	Very Low	0.50
			5 ≤PCL≤10	Low	0.75
			10 ≤PCL≤15	Moderate	1.00
			15 ≤PCL≤20	High	1.25
			PCL≥ 20	Very High	1.50

Table 2. Weight Analysis and Score According to Percentage of Vegetation Cover (PVC)

Sub Criteria	Weight	Parameter	Value	Class	Score
Percentage of Vegetation Cover	10	PVC = LCP /Watershed Area × 100%	PCL PVC>80	Very Good	0.50
			60 <PVC≤80	Good	0.75
			40 <PVC≤60	Moderate	1.00
			20 <PVC≤40	Bad	1.25
			PVC≤20	Very Bad	1.50

The classification of the carrying capacity of the Wanggu Watershed based on water management criteria is determined based on Permenhut No. 61 of 2014, presented in Table 5.

3. RESULTS AND DISCUSSION

3.1 Critical Land

The definition of critical land varies between one scientific discipline and another due to differences in the interests and purposes of land use (Candra, 2011; Aktab et al., 2021). According to the agricultural discipline, critical land is land that has been damaged so that it loses its function related to land productivity or the production capacity of land is decreasing (Mey et al., 2020; Budiastuti et al., 2020), while forestry and environmental disciplines see critical land related to the function of the land as a medium for regulating water management, production of forest products and as flood protection and/or downstream sedimentation (Irwansah, 2021; Ginting et al., 2022). According to Government Regulation Number 26 of 2020 on Forest Rehabilitation and Reclamation, critical land is land that is inside and outside the forest area which, according to its function, is an element of production and a media for controlling watersheds.

Factors that affect the criticality of land in protected areas and buffer areas are land cover (canopy density percentage) (da Silva et al., 2021), slope, erosion hazard level, land productivity and management (Nuralamsyah and Marselina, 2023). As for cultivation areas, five factors influence watershed physical parameters, namely slope class, level of erosion hazard, management, productivity, and rock outcrops (Mey et al., 2020). These factors are further divided into several classes and given weight, magnitude, and score by the guidelines in Permenhut No. P32/Menhut-II/2009. Meanwhile, based on the Regulation of the Director General of Watershed Management and Protection Forest No.3/PDASHL/SET/KUM.1/7/2018, the variables that determine critical land include land cover, slope, erosion hazard level, and area/area.

The assessment of the percentage of critical land in the Wanggu Watershed is based on the results of compiling critical land spatial data, so the critical land area is then a percentage between the critical land level and the Wanggu Watershed area, as shown in Table 6 and Figure 2.

Based on Table 6, the area of critical land in the Wanggu Watershed is dominated by land with a potential critical area of 21,482.03 hectares (63.27% of the area of the Wanggu Watershed), followed by non-critical land area of 7,013.58 hectares (20.66% of the area of the Wanggu Watershed. The condition of the land is affected by the use of forest land and shrubs which still function as land cover as forest areas to reduce land degradation (Kouassi et al., 2021). While critical land has an area of 3,725.41 hectares (10.97% of the Wanggu Watershed area) and a slightly critical area of 1,729.80 hectares (5.10% of the Wanggu Watershed area). This results from changes in land use to use of dry land agriculture by not applying soil and water conservation principles (Barchia et al., 2018). Thus the Wanggu Watershed, which qualifies as critical land recovery in the high category with a percentage distribution of critical land, has a percentage of critical land area with an area of 16.07% of the total area of the Wanggu Watershed. Critical and moderately critical land conditions are land that has been damaged due to the absence of soil and water conservation measures so these conditions require special attention and handling to create a sustainable Wanggu Watershed ecosystem (Mey et al., 2020).

Figure 2 shows that the condition of the distribution of potentially critical land is spread throughout the Wanggu Watershed, especially in the ridge and mountain areas with a high chance of turning into critical land (Erwanto et al., 2021; Riviana et al., 2020). Critical land in the Wanggu

Table 3. Weight Analysis and Index of Erosion (IE) Assessment Score

Sub Criteria	Weight	Parameter	Value	Class	Score
Index of Erosion (IE)	10	IE = A/E_{Tol}	IE> 0.50	Very Low	0.50
			0.5 <IE≤1.0	Low	0.75
			1.0 <IE≤1.5	Moderate	1.00
			1.5 <IE≤2.0	High	1.25
			IE≤2.0	Very High	1.50

Table 4. Weights and Values on Land Criteria

Parameter	Weights	Weight Total (%)	Value	
			Lowest	Highest
Percentage of Critical Land (PCL)	20		10	30
Percentage of Vegetation Cover (PVC)	10	40	5	15
Index of Erosion (IE)	10		5	15

Table 5. Classification of Land Carrying Capacity of the Wanggu Watershed (LCC)

Value	Category
LCC ≤ 34	Very Good
34 < LCC ≤ 40	Good
40 < LCC ≤ 46	Moderate
46 < LCC ≤ 52	Bad
LCC > 52	Very Bad

Source: Modification of watershed carrying capacity according to land conditions based on Minister of Forestry Regulation No.P.61 of 2014.

Table 6. Percentage Critical Land (PCL) at Wanggu Watershed

Critical Land	Area (ha)	Percent (%)	∑PCL
Critical	3,725.41	10.97	10.97
Slightly Critical	1,729.80	5.10	5.10
Critical Potential	21,482.03	63.27	
Not Critical	7,013.58	20.66	
Total	33,950. 82	100	16.07

Watershed is spread in general in the upstream watershed areas. In contrast, land conditions that are not critical and rather critical are generally scattered in the middle and downstream areas of the Wanggu Watershed (Kusratmoko and Dayanti, 2017; Eraku et al., 2019).

3.2 Vegetation Cover

Land cover in the watershed is the main element that determines land criticality, especially in relation to rapid and dynamic changes in land use (Hou et al., 2023). Land cover conditions are needed as a basis for managing a watershed which must be carried out periodically through monitoring and evaluation activities to determine appropriate conservation efforts (Cheng et al., 2022). The biophysical conditions

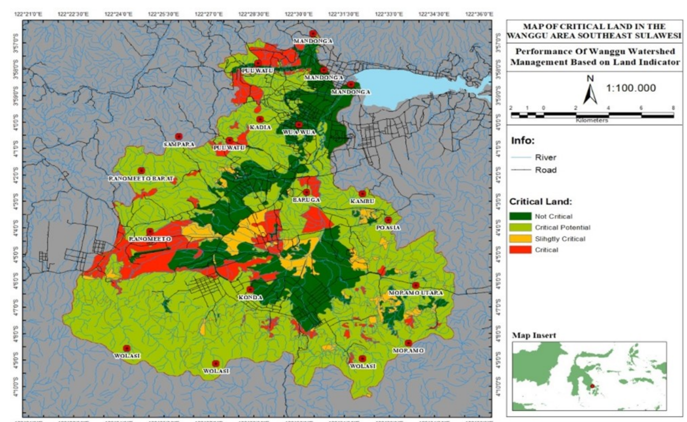

Figure 2. Map of Critical Land in the Wanggu Watershed

of the land strongly influence the land cover characteristics of an area as a driving factor and socio-economic conditions such as population growth and agricultural activity (Shumba et al., 2021). There is a strong relationship between population and the occurrence of land use change with different closing patterns (Setiawan and Yoshino, 2020; Dang and Kawasaki, 2017). In areas with high rainfall with a sparse population, the land cover pattern is more dominant on perennial crops. In contrast, in areas with high rainfall with a dense population, the land cover pattern is more dominant on annual crops. In contrast, in dry regions (low rain) with sparse populations, the land cover pattern is dominated by grasslands and drought-resistant plants (Chen et al., 2016; Tuladhar et al., 2019).

Based on spatial data analysis between the 2021 land cover map and field survey data in the Wanggu Watershed area in 2022, data on the percentage of vegetation cover in the Wanggu Watershed were obtained as shown in Table 7 and Figure 3.

Based on Table 7, the area of land covered with veg-

Table 7. Percentage of Vegetation Cover Area in the Wanggu Watershed

Land Cover	Area (ha)	Percent (%)	Land Cover Vegetation (LCV)	∑LCV (%)
Airport	59.42	0.18		
Secondary Dryland Forest	9,194.14	27.08	Secondary Dryland Forest	27.08
Secondary Mangrove Forest	6.75	0.02	Secondary Mangrove Forest	0.02
Settlement	3,430.49	10.10		
Mining	19.62	0.06		
Dryland farming	6,516.43	19.19	Dryland farming	
Mixed Dryland Agriculture	3,772.02	11.11	Mixed Dryland Agriculture	
Ricefield	3,148.46	9.27		
Shrubs	7,428.28	21.88	Shrubs	
Pond	158.07	0.47		
Open Land	119	0.35		
Water Body	98.15	0.29		
Total	33,950.83	100		27.10

etation in the Wanggu Watershed is dominated by land with secondary dryland forest covering an area of 9,194.14 hectares (27.08% of the area of the Wanggu Watershed), followed by land covered with shrubs covering an area of 7,428.28 hectares (21.88% of the area of the Wanggu Watershed), dryland agriculture covering an area of 6,516.43 hectares (19.19% of the area of the Wanggu Watershed), mixed dryland farming covering an area of 3,772.02 hectares (11.11% of the area of the Wanggu Watershed). Meanwhile, secondary mangrove forest cover has an area of 6.75 hectares (0.02% of the area of the Wanggu Watershed). Thus the Wanggu Watershed which qualifies for land restoration with poor level of vegetation cover has a percentage of land area covered with vegetation with an area of 9,194.14 hectares (27.10% of the total area of the Wanggu Watershed).

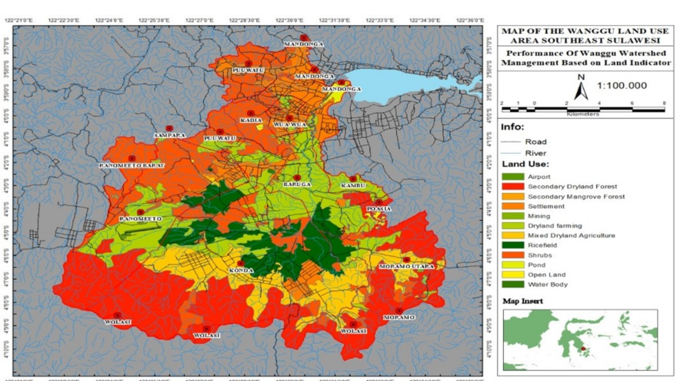

Figure 3. Land Use Map of the Wanggu Watershed

Figure 3 shows that the distribution of secondary forest land use is found in the ridges or mountains in the upper reaches of the southern part of the Wanggu Watershed. Likewise, the land use of shrubs is found in the upper western part of the Wanggu Watershed. Meanwhile, the use of mixed dryland farming and dryland farming dominates the central part of the Wanggu Watershed.

The change in land use in the Wanggu Watershed is caused by various social and economic factors, including population growth, increased demand for arable land, and changes in livelihoods (Putri et al., 2019). Land cover in the form of the forest is usually an object to be converted by the community into other types of use that are felt to bring more economic value in a short time, for example, gardens or rice fields and the growth of residential land (Latue and Rakuasa, 2023), especially in the central area of the Wanggu Watershed (District Baruga, West Ranomeeto, Wua-Wua, and Kadia). The trend of changes in land cover in the Wanggu Watershed area is thought to have affected the quality of the watershed.

Overall the Wanggu Watershed has land covered with forest vegetation of 27.10% of the watershed area. The area of forest cover in the Wanggu Watershed does not meet the requirements as a function of protection and flow control. The quality and sustainability of a watershed is highly dependent on sufficient forest area (Shah et al., 2022). Lack of forest area can reduce the ability of watersheds to maintain water quality, reduce soil erosion, and regulate runoff. The minimum requirement for forest as a watershed protection function is 30% of the watershed area and the requirement as a flow control function is above 50% of the watershed area (Tarigan et al., 2018; Narendra et al., 2021). The reduction in forest land area to use built-up land and agriculture can affect the hydrological conditions, especially water quality in the Wanggu Watershed (Cheng et al., 2022; Caldwell et al., 2023). If the forest-vegetated land cover changes to uses other than forests, it can increase fluctuations in river discharge, run-off coefficient and peak discharge and reduce baseflow values (Ding et al., 2022). The role of vegetation cover is very important, especially as a regulator of the water system, especially in a watershed which affects runoff and soil erosion (Qazi et al., 2017; Ophiyandri et al., 2021; Sugianto et al., 2022). The effect of changing vegetation cover to become non-vegetated can reduce the function of

Table 8. Results of Erosion Prediction Calculations in the Wanggu Watershed

Land Unit	Land Use	R	K	LS	CP	Erosion (ton $ha^{-1}year^{-1}$)
1	Airport	2,044.82	0.27	0.9	1	496.89
2	Secondary Dryland Forest	2,044.82	0.07	13.6	0.05	97.33
3	Secondary Mangrove Forest	2,044.82	0.17	0.9	0.01	3.13
4	Settlement	2,044.82	0.18	4.1	1	1,509.08
5	Mining	2,044.82	0.21	4.1	1	1,760.59
6	Dryland farming	2,044.82	0.29	13.6	0.1	806.48
7	Mixed Dryland Agriculture	2,044.82	0.33	13.6	0.1	917.72
8	Ricefield	2,044.82	0.17	0.9	0.01	3.13
9	Shrubs	2,044.82	0.22	10.5	0.05	236.18
10	Pond	2,044.82	0.09	0.9	0.01	1.66
11	Open Land	2,044.82	0.37	0.9	1	680.93

Table 9. Results of Calculations of Tolerable Erosion in the Wanggu Watershed

Land Unit	Land Use	D (mm)	FD	DE (mm)	LPT	E_{Tol} (mm $year^{-1}$)	Bulk Density	E_{Tol} (ton ha^{-1} $year^{-1}$)
1	Airport	980	0.8	784	1.2	1.14	1.37	32.22
2	Secondary Dryland Forest	1,200	0.8	960	1.2	1.84	1.38	39.74
3	Secondary Mangrove Forest	1,250	0.8	1,000	1.2	0.8	1.42	42.6
4	Settlement	1,200	0.8	960	1.2	1.84	1.16	33.41
5	Mining	1,350	0.8	1,080	1.2	3.52	1.18	38.23
6	Dryland farming	1,030	0.8	824	1.2	1.3	1.42	35.1
7	Mixed Dryland Agriculture	1,200	0.8	960	1.2	1.84	1.27	36.58
8	Ricefield	980	1	980	1.2	0.72	1.22	35.87
9	Shrubs	1,350	1	1,350	1.2	2.84	1.46	59.13
10	Pond	400	0.8	320	1.2	0.48	1.39	13.34
11	Open Land	1,350	0.8	1,080	1.2	3.52	1.18	38.23

Description: D: soil solum depth; FD: depth factor; DE: effective depth land; ETol: tolerable erosion

the watershed to increase water infiltration (Nugroho and Hadi, 2021; Muñoz et al., 2017).

Increased use of dry land agricultural land has a high risk of soil erosion and if optimal management is not carried out in accordance with soil and water conservation principles it can result in land degradation (Prashanth et al., 2023). Soil erosion can reduce soil fertility, damage river ecosystems and increase sedimentation in the lower reaches of the river so that it can threaten the sustainability of the Wanggu Watershed (Novara et al., 2018; Koralay and Kara, 2018; Wynants et al., 2021). This can disrupt the function of the watershed as a regulator of water management and protect downstream areas from flooding and sedimentation (Sugianto et al., 2022). Inadequate vegetation cover can reduce the ecosystem functions of the Wanggu Watershed, such as increasing water infiltration, water regulation, and carbon sequestration (Nugroho and Hadi, 2021). Reduced ecosystem function can have a negative impact on water quality, biodiversity, and environmental sustainability.

3.3 Erosion Index

The erosion index is a ratio value between the amount of actual erosion that occurs that can affect the sustainability of soil productivity in the long term with tolerated erosion which is directly proportional to the time of soil formation (McConkey et al., 2010). In order for soil productivity to be sustainable in the long term, land management is required in accordance with soil conservation principles on agricultural land, plantations, and forests (López-Vicente and Wu, 2019).

Erosion is a problem that causes land degradation (Rudiarto et al., 2020). This occurs due to the transportation of a number of soil due to rainwater and surface runoff from one place to another. Soil material transported due to erosion can be in the form of minerals and organic matter which can reduce the ability and fertility of the soil for agricultural or plantation activities (Novara et al., 2018). Erosion prediction results based on a land use approach supported by data on erosivity of rain, soil erodibility, slope and plant factors, and soil and water conservation, are presented in Table 8.

Based on Table 8, shows that the greatest erosion occurs in mining land use, settlements, dry land agriculture,

Table 10. Results of the Calculation of the Erosion Index in the Wanggu Watershed

Land Unit	Land Use	Area (ha)	Erosion (ton ha^{-1} $year^{-1}$)	E_{Tol} (ton ha^{-1} $year^{-1}$)	IE	Quality	IE Weighted
1	Airport	59.42	496.89	26.852	25.36	Very High	0.04
2	Secondary Dryland Forest	9,194.14	97.33	49.95	1.95	Moderate	0.53
3	Secondary Mangrove Forest	6.75	3.13	35.5	0.09	Low	0.00
4	Settlement	3,430.49	1,509.08	27.84	54.21	Very Hight	5.50
5	Mining	19.62	1,760.59	31.86	55.26	Very Hight	0.03
6	Dryland farming	3,772.02	806.48	29.252	27.57	Very Hight	3.08
7	Mixed Dryland Agriculture	6,516.43	917.72	30.48	30.11	Very Hight	5.81
8	Ricefield	3148.46	3.13	29.89	0.10	Low	0.01
9	Shrubs	7,428.28	236.18	49.275	4.79	High	1.05
10	Pond	158.07	1.66	11.12	0.15	Low	0.00
11	Open Land	119.00	680.93	31.86	21.37	Very Hight	0.06
Total	33,793.26						

Table 11. Classification of the Land Carrying Capacity of the Wanggu Watershed

Criteria	Class	Weight	Score	Weight × Score	LCC
Critical Land	High	20	1.25	25.00	
Vegetation Cover	Poor	10	1.25	12.50	50
Erosion Index	High	10	1.25	12.50	

and open land. While minor erosion occurs in rice fields, ponds, and mangrove forests. To assess the tolerable of erosion, which is calculated based on soil depth, effective soil depth, soil formation rate, and soil density (bulk density), a comparison can be seen in Table 9.

Tolerable erosion is the value of erosion that is naturally acceptable in land management so that it serves as a comparison of the actual erosion that occurs. The results of the comparison of actual erosion with tolerated erosion are expressed as erosion hazard index values. The erosion hazard index classification is based on (Hammer, 1981; Arsyad, 2010), namely; a. erosion hazard index value <1.0 is low; b. the erosion hazard index value of 1.01–4.0 is moderate; c. an erosion hazard index value of 4.01–10.0 is considered high; and c. an erosion index value of >10.01 is stated to be very high (Arsyad, 2010). The results of the erosion hazard index and the weighted erosion hazard index in the Wanggu Watershed are presented in Table 10.

Based on Table 10, a low to moderate erosion hazard index is found in secondary dryland forest land use, mangrove forests, shrubs, ponds, and paddy fields. The index of erosion hazard which is high to very high and very high is found in the use of bushland, airports, settlements, open land, mining, dryland farming, and mixed dryland farming. Overall the Wanggu Watershed has an average erosion index value of 2.00. This value is based on Permenhut No. 61 of 2014, included in the high category. This condition indicates that the condition of the land in the Wanggu Watershed is critical, so it is necessary to manage land wisely by taking into account the principles of soil conservation and the suitability of the carrying capacity of the land in land management in the Wanggu Watershed, especially the management of agricultural land and settlements by applying vegetative and mechanical conservation measures (Prashanth et al., 2023; Nasir Ahmad et al., 2023). The distribution value of the erosion index in the Wanggu Watershed area is shown in Figure 4.

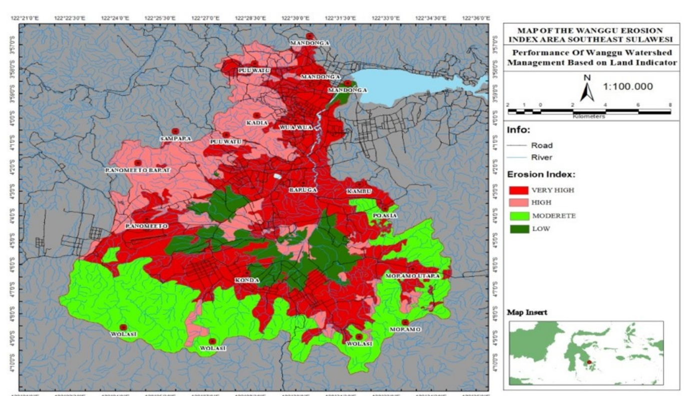

Figure 4. Erosion Index Map of the Wanggu Watershed

Based on the distribution of the Wanggu Watershed erosion index, the very high category is in the use of agricultural land, both dryland farming and mixed dryland farming. This occurs as a result of human intervention as farmers who do not understand crop management practices and soil and water conservation techniques (Mwanake et al., 2023; Adusumilli and Wang, 2018). In addition, a large amount of land conversion as a form of residential housing development has resulted in an increase in surface runoff as well as increased rates of soil and sediment erosion in the Wanggu Watershed (Wynants et al., 2021).

The upstream part of the Wanggu Watershed is still dominated by forest land use and shrubs. This condition is very useful in maintaining environmental sustainability, especially in reducing runoff and erosion rates (MacDonald and Coe, 2007; Kahirun et al., 2020). Naturally, forest land use is the most effective form of land cover in reducing the rate of erosion. This is because the forest ecosystem with a wide canopy can intercept rain so that the kinetic energy of rain is reduced to get to the ground. Besides that, forests can increase infiltration into the soil thereby reducing runoff as a driver of erosion (Paudel and Yadav, 2021). Changes in forest land cover can result in increased potential for surface runoff and erosion (Guo et al., 2008; López-Vicente and Wu, 2019). A class with a low erosion index due to obstacles from vegetation on each land cover, because vegetation has a large influence on erosion due to the presence of vegetation that has a canopy and plant stems that can block rainwater from falling directly on the ground, so that the energy of water strength is reduced (Bhan and Behera, 2014; Ma et al., 2014; Li et al., 2019).

3.4 The Carrying Capacity of the Wanggu Watershed

The dynamics that occur in the Wanggu Watershed, whether due to human intervention or natural processes, result in pressure on the carrying capacity of the watershed (Sriyana, 2018). If this pressure exceeds the carrying capacity of the watershed, it can result in environmental problems such as flooding, drought, erosion, sedimentation, landslides, and other environmental problems (Hikmat and Marselina, 2021). Watershed problems generally occur due to the use of land resources that exceed their carrying capacity. The carrying capacity of watershed land is an important aspect to be studied in watershed management. The carrying capacity of watershed land can be used to analyze the ability of watersheds to support the fulfillment of human and resource needs. Unlimited population growth in a watershed is impossible to achieve due to limited land resources, so the carrying capacity of a watershed is a measure of these limitations (Hui, 2015).

Table 11 shows that the Wanggu Watershed Land Carrying Capacity has a weight value of 50. Based on the classification of watershed land carrying capacity, the Wanggu Watershed is included in the category of poor Watershed Land Carrying Capacity with a scale of $46 < \text{LCC} \leq 52$. Poor land carrying capacity The Wanggu Watershed is caused by the high area of critical land, the percentage of poor vegetation cover, and a high erosion index (Sudia et al., 2023). An increase in land use means a reduction in the percentage of vegetated land cover it can reduce the capacity of water resources, soil degradation, decreased productivity, and an increase in degraded land increases sharply every year (Rudiarto et al., 2020). This occurs due to a lack of water absorption which can increase the runoff rate as a cause of soil erosion (Nugroho and Hadi, 2021).

4. CONCLUSIONS

The results of the analysis of the carrying capacity of watershed land indicators show that the Wanggu Watershed is classified as a watershed with poor performance in land management. The parameters of land indicators that cause poor management are the high area of critical land, the lack of vegetated land cover, especially forest cover, and the high erosion index value. The expansion of critical land is due to land clearing for dry land farming and an increase in residential development areas converted from agricultural land or shrubs. Reduced vegetation cover due to reduced diversity of forest vegetation and crops, increases soil erosion as a cause of land degradation into critical land. Therefore, the Wanggu Watershed, especially in terms of land management, needs to be improved with soil and water conservation efforts that can prevent or reduce high erosion rates, and rehabilitate critical land. Good soil and water conservation methods are methods that suit land conditions and are acceptable based on community social and economic considerations. An inexpensive and acceptable method for the use of dryland agriculture is by diversifying plants with a model of combining forestry plants with crops (Agroforestry). Forest land which still has rather high erosion needs to be done with efforts to rehabilitate the forest through reforestation with a plantation forest pattern. The use of shrubs is carried out by developing community forest plants with an agroforestry pattern.

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