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SOIL EROSION ASSESSMENT AND CONSERVATION SCENARIOS IN THE WAY SEKAMPUNG DAM CATCHMENT AREA, INDONESIA

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ABSTRACT

Soil erosion in dam catchment areas poses a serious threat to watershed sustainability and reservoir performance. This study assessed erosion characteristics and conservation scenarios in the Way Sekampung Dam catchment area, Lampung Province. Soil erosion was estimated using the Universal Soil Loss Equation (USLE) by integrating rainfall erosivity, soil erodibility, slope, land cover, and conservation practices in a GIS environment. The results show that the existing average erosion rate reached 141.55 ton ha^{-1} yr^{-1}, far exceeding the tolerable soil loss (38.7 ton ha^{-1} yr^{-1}), with very high erosion risks dominating the watershed. Conservation-based development scenarios significantly reduced erosion, with the integrated conservation scenario achieving the lowest rate (19.9 ton ha^{-1} yr^{-1}). These findings highlight the importance of sustainable watershed management to reduce erosion, prolong reservoir service life, and support water availability and food security.

Keywords: Soil erosion, Watershed management, USLE, Dam catchment area, Food security

1. INTRODUCTION

A watershed is a single ecosystem that plays a vital role in regulating the hydrological cycle, water resource availability, and the environmental and socio-economic sustainability of surrounding communities. One of the main challenges in watershed management, particularly in dam catchment areas, is the high rate of erosion, which has the potential to reduce hydrological function

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and the service life of water resource infrastructure. Uncontrolled erosion can lead to land degradation, increased sedimentation, and decreased water quality and quantity entering reservoirs.

The Way Sekampung Dam is a strategic infrastructure facility in Lampung Province, serving for irrigation, flood control, raw water supply, and supporting regional food security. However, changes in land use and cover in the Way Sekampung Dam catchment area in recent years, such as the conversion of forest and conservative agricultural land to residential areas, intensive plantations, and open spaces, have increased the land's vulnerability to erosion. The undulating to steep topography, combined with relatively high rainfall, further increases the potential for soil erosion.

Erosion in the dam's catchment area not only impacts upstream land degradation but also directly impacts increased sedimentation in the reservoir. Sediment accumulation can reduce the reservoir's capacity, decrease its operational efficiency, and increase maintenance and dredging costs. In the long term, this condition could threaten the sustainability of the Way Sekampung Dam's function as a supporter of irrigation systems and food security in downstream areas.

While previous studies have assessed erosion risk in tropical watersheds, most focus on single land-use conditions or lack scenario-based conservation evaluation. This study contributes novel insights by integrating spatial erosion assessment with multi-level conservation scenarios directly linked to dam sustainability and food security outcomes. The analysis explicitly connects erosion reduction targets with erosion tolerance values to guide practical watershed management decisions in dam catchment areas.

Soil erosion in the catchment area contributes directly to sediment accumulation in the reservoir. Sedimentation reduces effective storage capacity, decreases operational efficiency, and increases dredging and maintenance costs. Over time, this condition threatens dam sustainability and downstream irrigation reliability.

This study employs the Universal Soil Loss Equation (USLE) due to its suitability for data-limited tropical regions, its transparency in parameter interpretation, and its widespread application in watershed-scale erosion assessment. Compared with more complex models such as RUSLE or SWAT, USLE requires fewer input variables and allows clearer linkage between land-use change and erosion response. However, USLE estimates potential soil loss rather than actual sediment yield delivered to the reservoir, which is addressed as a limitation of this study.

This study aims to assess erosion levels and identify dominant contributing factors in the Way Sekampung Dam catchment area. The results support the formulation of effective and sustainable soil and water conservation strategies to maintain watershed function and dam performance.

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2. RESEARCH METHODS

This research was conducted in the Way Sekampung Dam catchment area, which is part of the downstream area of the Sekampung Hulu watershed in Lampung Province. Administratively, the research area covers several regencies in Lampung Province, including Tanggamus Regency, Pringsewu Regency, and Pesawaran Regency. A map of the research location is presented in Figure 1.

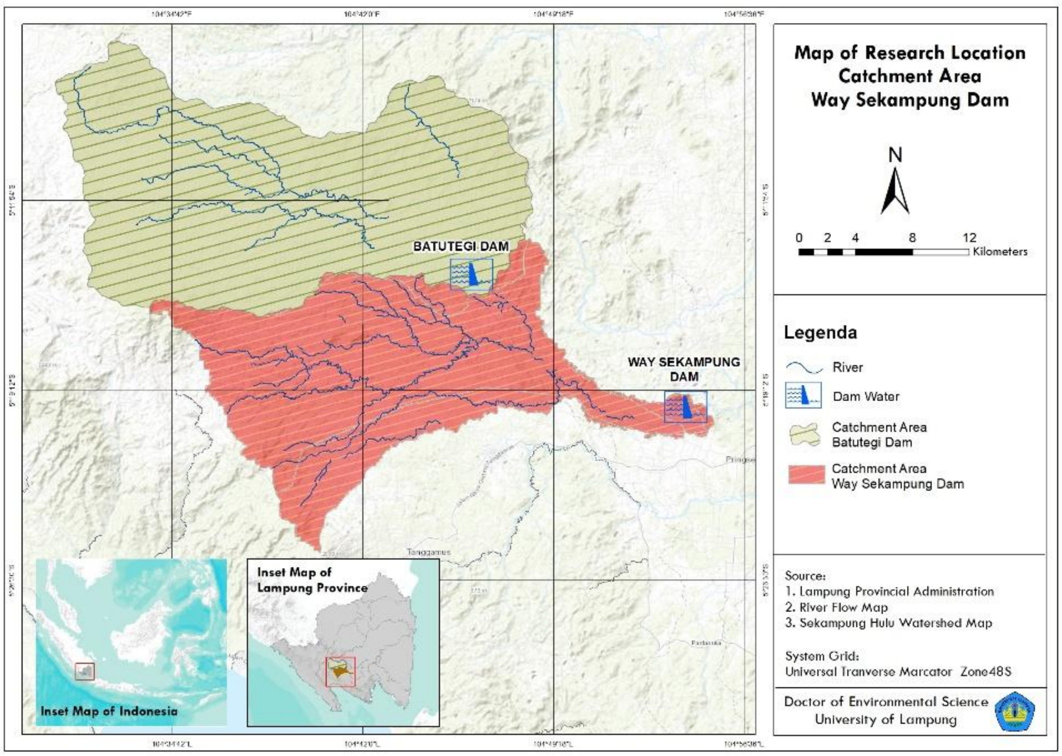

Fig. 1: Map of Research Location.

The materials used in this study include 1:150,000-scale land unit maps obtained by overlaying *topographic* maps, soil type maps, and land use/land cover maps. In addition, rainfall data from rain stations located around *the catchment area was also used.* Way Sekampung Dam. The tools used in this study consisted of a Global Positioning System (GPS) for field coordinate acquisition, a camera for field condition documentation, and supporting software in the form of ArcGIS 10.8 for spatial data processing, Google Forms for field data collection, and Microsoft Excel for tabular data processing.

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The research phase began with the determination of the research area boundaries in the Way Sekampung Dam *catchment area* . Next, rainfall data from each rainfall station was processed to obtain the average rainfall value for the area using the Thiessen polygon method, which was then used in calculating the rainfall erosivity factor (R). Spatial data in the form of soil erodibility maps (K), slope length and slope (LS), and land use and crop management factors (CP) were processed in *shapefile format* (SHP) using ArcGIS software.

The magnitude of soil erosion was estimated using the Universal Soil Loss Equation (USLE). The results of the erosion calculation were then compared with the Tolerable Soil Loss (TSL) value contained in the attribute table to determine the erosion hazard class. The classification of erosion hazard levels refers to the criteria stipulated in the Regulation of the Minister of Forestry of the Republic of Indonesia Number P.60/Menhut-II/2014. The final stage of the analysis was carried out by preparing a map layout of the results of the erosion estimation in the Way Sekampung Dam *catchment area* .

In addition to spatial analysis, ground checks were also conducted *at* locations with high erosion hazards. Based on the analysis and field survey results, recommendations for appropriate soil and water conservation measures to be implemented in the Way Sekampung Dam *catchment area were determined* .

The estimation of the magnitude of soil erosion is calculated using the USLE equation as follows:

$$A = R \times K \times L \times S \times C \times P$$

with the following information:

A	:	amount of eroded soil (tons/ha/year)
R	:	rainfall erosivity factor (MJ·cm/ha·hour/year)
K	:	soil erodibility factor (ton·ha·hour/ha·MJ·cm)
L	:	slope length factor (m)
S	:	slope steepness factor (%)
C	:	vegetation cover factors and plant management
P	:	soil conservation action factor

(Wischmeier and Smith, 1978 in Banuwa, 2013).

3. RESULTS AND DISCUSSION

3.1. Erosion Index (IE) of the Way Sekampung Dam Catchment Area

The erosion index (IE) is a parameter used to assess the level of erosion hazard by comparing the actual erosion rate to the tolerable soil loss (TSL). This index provides an overview of the risk of land degradation, which could potentially threaten the sustainability of land productivity and the hydrological function of a watershed (Naitkakin et al., 2021). An IE value >1 indicates that the erosion rate has exceeded the tolerance limit and has the potential to cause permanent land damage.

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Estimation of actual erosion in the Way Sekampung Dam catchment area was conducted using the Universal Soil Loss Equation (USLE) approach, taking into account rainfall erosivity (R), soil erodibility (K), slope length and gradient (LS), and land cover and conservation practices (CP). This analysis provides a spatial and quantitative overview of the land's vulnerability to erosion.

3.1.1. Rain Erosivity (R)

Rain erosivity reflects the ability of rain to release and transport soil particles through the kinetic energy of raindrops and rainfall intensity. The R value in the Way Sekampung Dam catchment area was calculated based on rainfall data from three rain stations: PH 018 (Panotan), PH 015 (Way Kunyir), and PH 067 (Air Naningan).

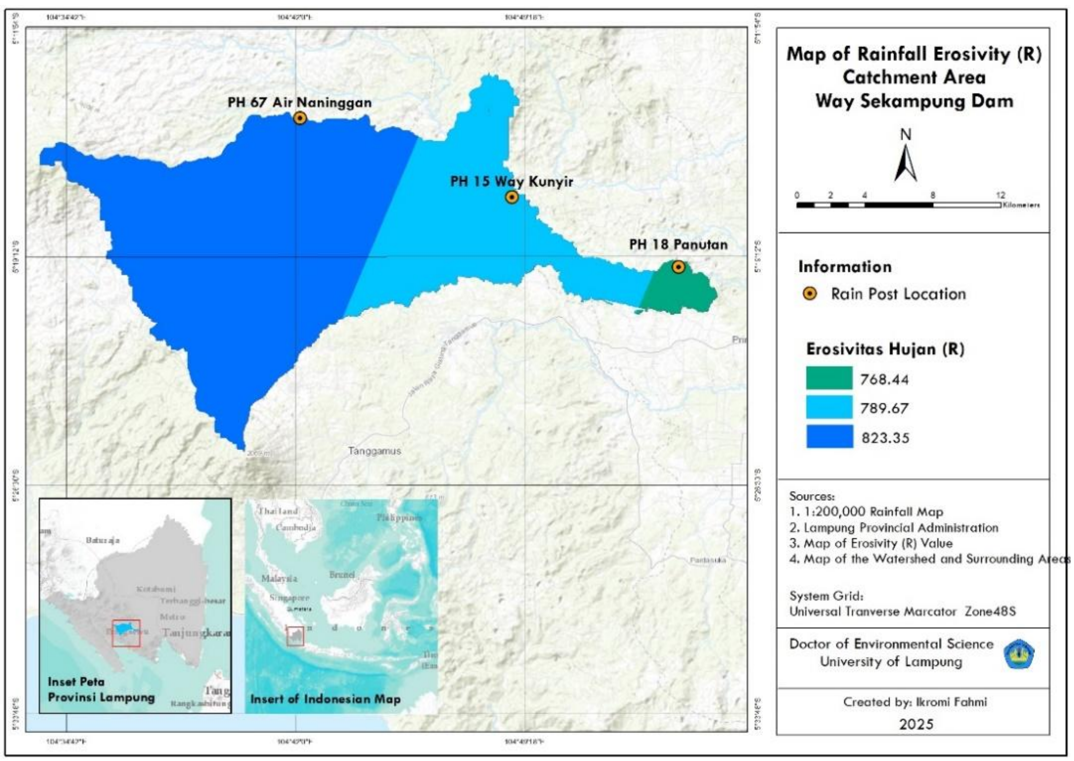

Fig. 2: Erosivity map rain catchment area of Way Sekampung Dam.

The analysis results show that rainfall distribution is seasonal, with peak rainfall occurring in January–March. The highest rainfall values were recorded in March across all rain stations, at 319 mm (PH 018), 337 mm (PH 015), and 263.4 mm (PH 067). Conversely, the dry period occurs in August–September, with minimum rainfall ranging from 10–13 mm.

Rain erosivity (R) values show spatial variations influenced by topographic and microclimate conditions. The Air Naningan rainfall post (PH 067) has the highest total annual rainfall of 823.35

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mm, followed by PH 015 at 789.67 mm and PH 018 at 768.44 mm. This pattern indicates that the Way Sekampung Dam catchment area has a relatively high potential for rain erosivity, especially at the beginning of the rainy season, thus contributing significantly to increasing soil erosion rates if not balanced with adequate land cover.

3.1.2. Soil Erodibility (K)

Soil erodibility (K) indicates the level of sensitivity of the soil to the destructive forces of erosion which are influenced by the physical and chemical properties of the soil, such as texture, structure, organic matter content, and permeability (Utomo, 1999 in Taslim, 2019).

Based on the USDA Soil Taxonomy classification, the Way Sekampung Dam catchment area is dominated by three main soil types: Inceptisols (63.66%), Andisols (23.27%), and Ultisols (13.07%). Inceptisols and Andisols have relatively high erodibility values (K = 0.29), while Ultisols have a lower value (K = 0.19).

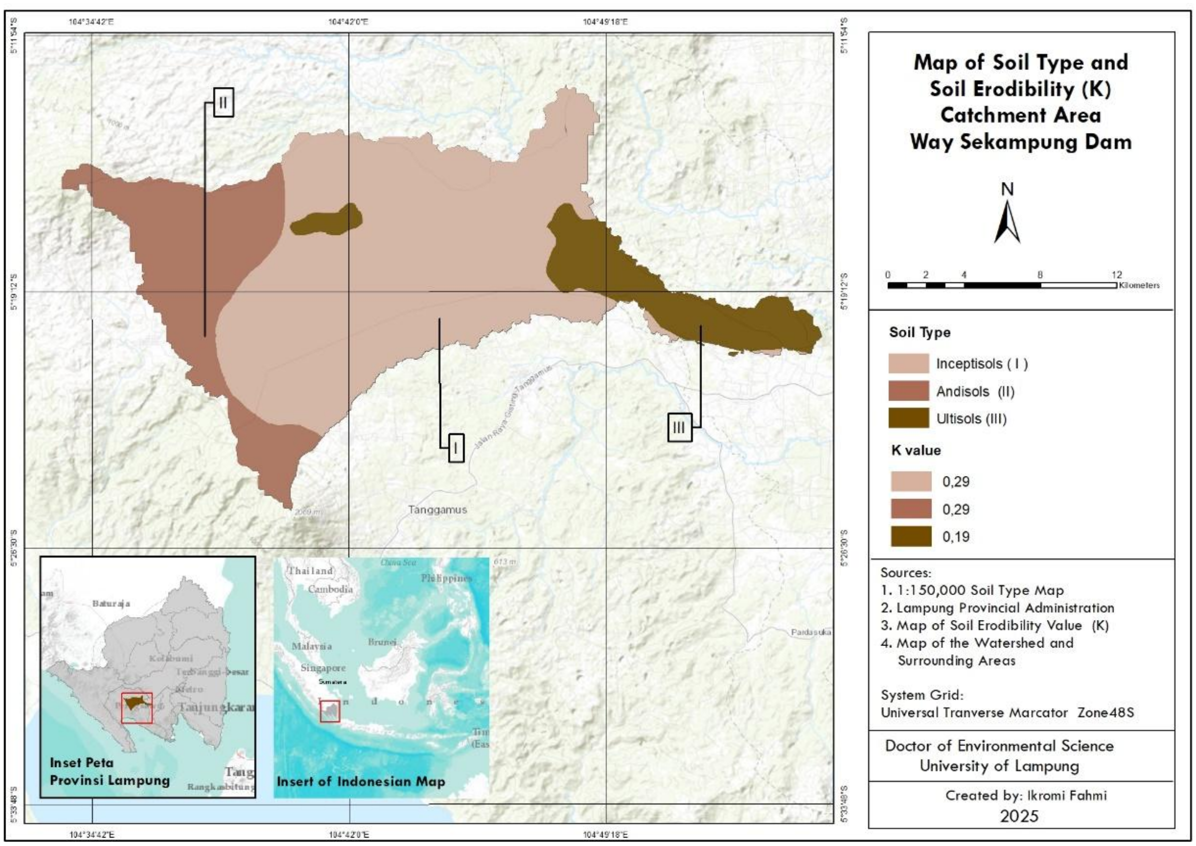

Fig. 3: Soil erodibility map of The Way Sekampung Dam catchment area.

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Table 1: Types of Soil *in Catchment Area* Way Sekampung Dam

Soil Type	**Surface area**	
	Ha	**%**
Inceptisols	20,583.60	63.66
Andisols	7,524.22	23.27
Ultisols	4,226.03	13.07
Total	**32,333.85**	**100.00**

The dominance of Inceptisols and Andisols indicates that most areas are highly susceptible to erosion. These soils generally have a relatively loose structure and low to moderate organic matter content, making them easily dispersed by surface runoff. This condition directly impacts increased sedimentation at the Way Sekampung Dam if not accompanied by sustainable land management

3.1.3. Length and Gradient of Slope (LS)

The LS factor describes the influence of topography on the potential for soil erosion.

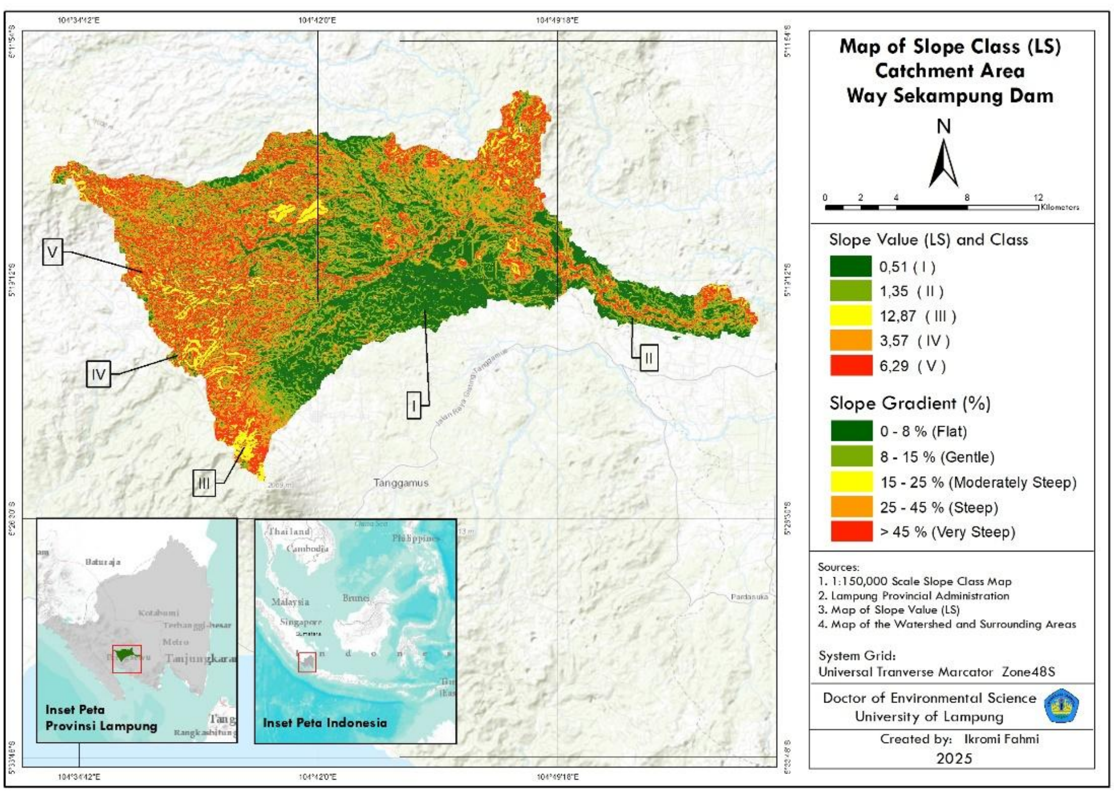

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Fig. 4: Class map slope of The Way Sekampung Dam catchment area.

Table 2: Classification class slope *catchment area* of Way Sekampung Dam

No	Slope	Surface area	
		Ha	Percentage (%)
1	0 - 8% (Flat)	8,530.95	26.38
2	8 - 15% (Slope)	7,889.59	24.40
3	15 - 25% (Somewhat Steep)	7,560.63	23.38
4	25 -45% (Steep)	6,610.33	20.44
5	> 45% (Very Steep)	1,742.36	5.39
Total number		**32,333.85**	**100**

Source: Processed Data (2024).

The analysis results show that the Way Sekampung Dam catchment area has quite complex slope variations. Flat to gently sloping land (0–15%) covers approximately 50.78% of the area, while moderately steep to very steep land (>15%) accounts for 49.22%. The presence of land with slopes of 15–45%, which covers more than 43% of the area, significantly increases the potential for erosion, especially when used for dryland agriculture without conservation measures. On steep slopes, the kinetic energy of surface runoff increases, accelerating the release and transport of soil particles. Therefore, topography is a major determinant of the high erosion rate in this region.

3.1.4. Land Cover and Conservation Practices (CP)

The CP factor represents the influence of human activities on the level of erosion.

Table 3: Land cover and cp value of The Way Sekampung Dam catchment area

No	Land Closure	Area (Ha)	CP Value
1	Thicket	28.61	0.05
2	Secondary Dryland Forest	569.14	0.005
3	Settlement	1,526.34	0.95
4	Dryland Farming	88.31	0.4
5	Mixed Dryland Farming	28,972.86	0.2
6	Ricefield	1,122.28	0.1
7	Open Land	26.32	1
	Amount	**32,333.85**	

Source: Processed Data (2024); Satellite Imagery 2023.

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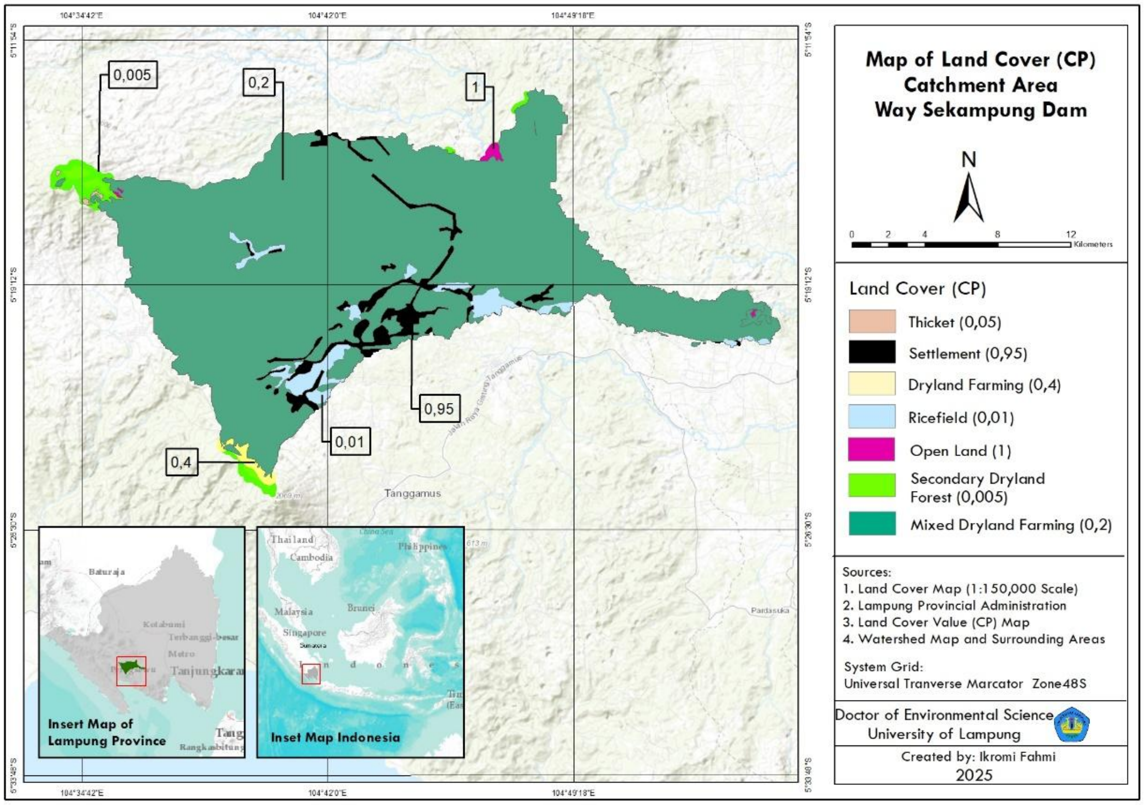

Fig. 5: Map of land cover The Way Sekampung Dam catchment area.

The analysis results show that mixed dryland agriculture dominates the study area (89.6%), with a CP value of 0.2. Although this value is considered moderate, the very large area makes the contribution to erosion significant.

In contrast, secondary dryland forests have the lowest CP value (0.005) and are very effective in suppressing erosion. Rice fields also exhibit low CP values (0.1) due to their controlled water management systems. Bare lands and settlements have very high CP values (0.95–1), making them major contributors to erosion.

This condition confirms that land cover degradation and minimal soil conservation practices are the dominant factors in the increasing rate of erosion in the Way Sekampung Dam catchment area.

3.1.5. Actual Erosion and Erosion Hazard Level

Erosion calculations show the actual erosion that occurred in the Way Sekampung Dam catchment area, which can be seen in the table and image.

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Table 4: Actual erosion of The Way Sekampung Dam catchment area (existing condition)

No	Land Use	Area (Ha)	Average Erosion (ton/ha/ yr)	TSL	Erosion Index	Erosion Danger Level
1	Thicket	28.61	55.42	38.7	1.43	Currently
2	Secondary Dryland Forest	569.14	4.75	38.7	0.12	Very Low
3	Settlement	1526.34	397.47	38.7	10.27	Very high
4	Dryland Farming	88.31	461.69	38.7	11.93	Very high
5	Mixed Dryland Farming	28972.86	129.65	38.7	3.35	Very high
6	Ricefield	1122.28	5.73	38.7	0.15	Very Low
7	Open Land	26.32	689.8	38.7	17.82	Very high
Amount /average		333.85	177.39			
Average Erosion Scenario-1 (Condition Existing) = 141.55 (ton/ha/ year)						

The erosion analysis indicates that land use and management practices are the dominant controls of erosion intensity. Of the total catchment area of 32,333.85 ha, most land falls within the very high erosion risk category, indicating severe vulnerability to degradation and sedimentation.

Bare land exhibits the highest erosion rate at 689.80 tons/ha/year, despite its limited spatial extent. The absence of vegetation allows direct rainfall impact and maximizes surface runoff, accelerating soil detachment and transport. This result is consistent with findings from tropical watershed studies that identify bare land as a critical erosion source (Gusma et al., 2023; Salma et al., 2024).

Dryland agriculture and residential areas also show very high erosion rates, reaching 461.69 tons/ha/year and 397.47 tons/ha/year. Intensive tillage without conservation practices and increased impervious surfaces reduce infiltration and amplify runoff generation (Chen et al., 2017; Rhofita, 2022). Mixed dryland farming dominates the catchment area and produces an average erosion rate of 129.65 tons/ha/year with an erosion index of 3.35. Although vegetation diversity is higher than in monoculture systems, weak conservation implementation maintains high erosion risk. This finding reinforces evidence that vegetation diversity alone is insufficient without proper land management (Octavia et al., 2023).

Secondary dryland forests and rice paddies show very low erosion rates of 4.75 tons/ha/year and 5.73 tons/ha/year. Forest canopy structure improves soil stability and infiltration, while flooded rice fields suppress runoff and sediment transport (Darwati et al., 2022; Basuki et al., 2025). The existing condition under scenario 1 records an average erosion rate of 141.55 tons/ha/year. This value far exceeds the erosion tolerance limit of 38.7 tons/ha/year (Banuwa, 2008), indicating a critical watershed condition.

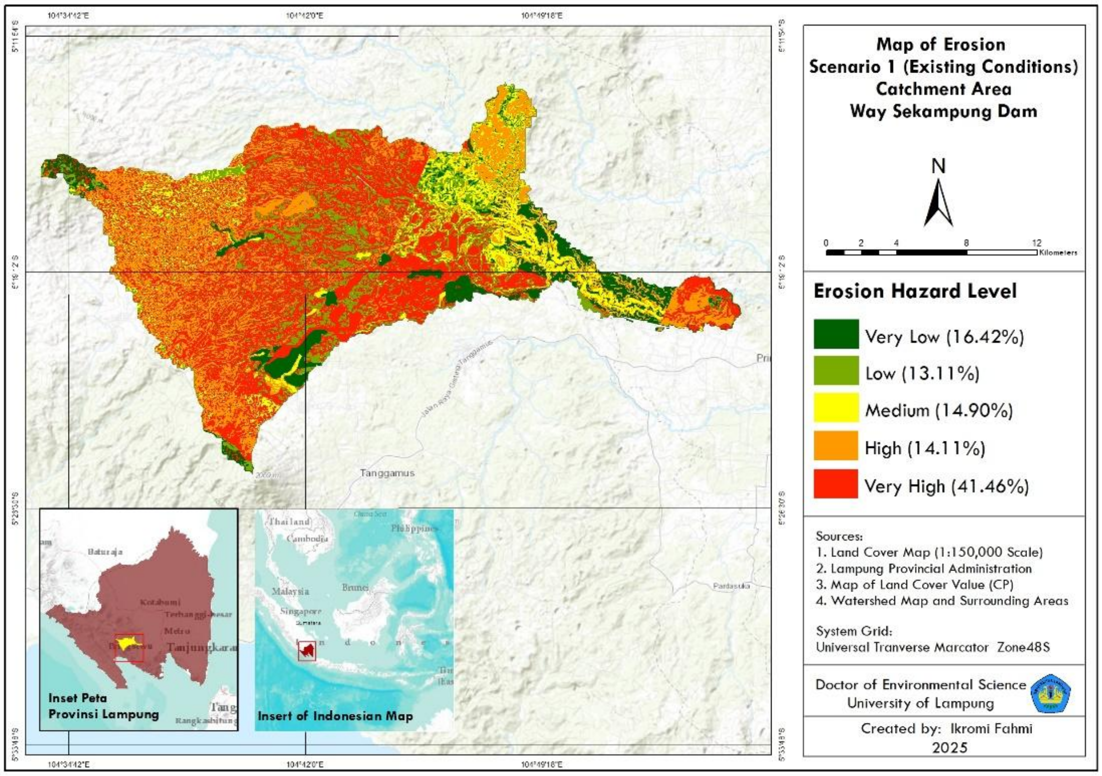

Fig. 6: erosion condition map existing catchment area of Way Sekampung Dam.

Table 6. Erosion danger level of the Way Sekampung Dam catchment area

Erosion Danger Level	Surface area	
	Ha	%
Very Low	5,310.66	16.42
Low	4,239.77	13.11
Currently	1,582.84	14.90
Tall	4,563.08	14.11
Very high	16,637.50	41.46
Total	**32,333.85**	**100.00**

Source: Processed Data (2024).

3.1.6. Erosion Estimation Based on Development Scenarios

Erosion estimation under different development scenarios illustrates how changes in land cover and the application of soil and water conservation (SWC) measures affect the average erosion rate in the Way Sekampung Dam catchment area. Four scenarios were developed to represent progressive management interventions, ranging from existing conditions to integrated conservation approaches, as summarized in Table 7.

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Scenario 1 represents existing conditions without additional conservation measures and serves as the baseline for erosion comparison. Scenario 2 simulates forest rehabilitation covering 30 percent of the catchment area, focusing on restoring permanent vegetation to improve infiltration, soil stability, and runoff control. Scenario 3 combines Scenario 2 with mechanical soil and water conservation through bench terracing on agricultural land to control erosion on steep slopes. Scenario 4 integrates Scenario 2 with vegetative conservation practices, specifically alley cropping on agricultural land, to enhance land cover while maintaining agricultural productivity.

Table 7: Erosion estimation based on development scenarios

No	Land Use	Scenario-1		Scenario-2	
		Average Erosion (ton/ha/ year)	Area (Ha)	Average Erosion (ton/ha/ year)	Area (Ha)
1	Thicket	55.42	28.61	-	-
2	Secondary Dryland Forest	4.75	569.14	5.16	9,717.35
3	Settlement	397.47	1,526.34	397.47	1,526.34
4	Dryland Farming	461.69	88.31	-	-
5	Mixed Dryland Farming	129.65	28,972.86	76.04	19,962.34
6	Ricefield	5.73	1,122.28	4.37	1,112.14
7	Open Land	689.80	26.32	345.06	15.69
Amount			32,333.85		32,333.85
Average Erosion / Scenario (ton/ha/ year)		141.55		69.73	

No	Land Use	Scenario-3		Scenario-4	
		Average Erosion (ton/ha/ year)	Area (Ha)	Average Erosion (ton/ha/ year)	Area (Ha)
1	Thicket	-	-	-	-
2	Secondary Dryland Forest	5.16	9,717.35	5.16	9,717.35
3	Settlement	397.47	1,526.34	397.47	1,526.34
4	Dryland Farming	-	-	-	-
5	Mixed Dryland Farming	21.73	19,962.34	11.41	19,962.34
6	Ricefield	4.37	1,112.14	4.37	1,112.14
7	Open Land	345.06	15.69	345.06	15.69
Amount			32,333.85		32,333.85
Average Erosion / Scenario (ton/ha/ year)		141.55	26.79	19.9	

Erosion estimation results based on four development scenarios indicate that the implementation of soil and water conservation measures significantly reduced erosion rates in the Way Sekampung Dam catchment area. Under scenario 1, which represents existing conditions, the average erosion rate reached 141.55 tons/ha/year. This value far exceeds the erosion tolerance threshold and reflects the critical condition of the watershed under current land use and management practices.

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The implementation of scenario 2, through forest rehabilitation covering 30 percent of the catchment area and the reduction of mixed dryland agriculture, reduced the average erosion rate by nearly 50 percent to 69.73 tons/ha/year. This result highlights the important role of permanent vegetation in enhancing infiltration and suppressing surface runoff. From a practical perspective, this scenario requires moderate financial investment and strong institutional support, particularly related to land tenure arrangements, reforestation programs, and long-term management commitments. Although effective, erosion levels under this scenario remain above the tolerance limit.

Scenario 3 applies more intensive soil and water conservation measures on agricultural land, specifically bench terracing combined with forest rehabilitation. This approach further reduced erosion to 26.79 tons/ha/year, which is below the erosion tolerance value. The result confirms that mechanical and vegetative conservation practices are highly effective in controlling land degradation on sloping terrain. However, the relatively high construction and maintenance costs of bench terraces may limit adoption by smallholder farmers unless supported by financial incentives, technical assistance, and strong institutional facilitation.

Scenario 4 produced the most optimal outcome, with the lowest average erosion rate of 19.9 tons/ha/year. This scenario integrates forest rehabilitation with vegetative conservation practices in the form of alley cropping on agricultural land. In addition to its strong erosion control performance, this approach offers higher practical feasibility due to lower implementation costs and greater social acceptance. Alley cropping can be incorporated into existing farming systems and provides direct economic benefits through crop diversification. Overall, the results demonstrate that an integrated conservation strategy supported by institutional coordination, extension services, and active community participation is the most effective and sustainable option for maintaining watershed functions and ensuring the long-term sustainability of the Way Sekampung Dam.

3.1.7. Implications of Watershed Management for Welfare and Food Security

The results show that high erosion rates in the Way Sekampung Dam catchment area directly degrade watershed hydrological functions, increase reservoir sedimentation, and reduce irrigation system reliability. These impacts lead to declining agricultural productivity and heightened socio-economic vulnerability among communities that depend on watershed-based water resources. Similar findings have been reported in tropical dam catchments, where erosion-driven sedimentation reduces water availability and irrigation performance (Keesstra et al., 2021; Pandey et al., 2023).

Unsustainable watershed management exacerbates disparities between upstream land use benefits and downstream environmental costs. In contrast, integrated soil and water conservation practices

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reduce erosion to tolerable levels, extend reservoir service life, and stabilize year-round water supply. Stable hydrological conditions support soil fertility, improve crop yields, and enhance regional food security, particularly in irrigation-dependent agricultural systems (FAO, 2021; Mekonnen et al., 2022).

Beyond biophysical improvements, effective watershed management generates economic benefits by lowering flood and drought risks, reducing water infrastructure maintenance costs, and increasing household income through conservation-based farming systems such as agroforestry and alley cropping. These practices strengthen livelihood resilience while maintaining ecosystem services, making sustainable watershed management a key foundation for long-term community welfare and food security (Reed et al., 2020; Dagar et al., 2024).

4. CONCLUSION

This study shows that the Way Sekampung Dam catchment area has a relatively high erosion rate and has exceeded the tolerance value, especially in dryland agricultural land and open land. The main factors causing erosion include high rainfall erosivity, erosion-sensitive soil characteristics, steep sloping topography, and suboptimal land cover. The implementation of integrated soil and water conservation has proven effective in reducing erosion rates and maintaining the sustainability of watershed functions. Sustainable watershed management not only plays a role in controlling erosion and sedimentation, but also supports improving community welfare and strengthening food security.

SUGGESTION

Prioritizing soil and water conservation in areas with high erosion risk by increasing permanent vegetation cover and implementing conservation techniques appropriate to slope conditions is essential. The development of sustainable agricultural systems, such as agroforestry, should be encouraged to reduce erosion while increasing farmer incomes. Furthermore, integrated and cross-sectoral management of the Way Sekampung Dam watershed is essential to ensure the sustainability of the watershed's ecological and socio-economic functions.

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