JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 10 No 1 2026

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Performance Assessment of the Semajid River Watershed and Improvement Strategy Through Land Cover Optimization

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Received: January, 20 2026
Accepted: May 29, 2026
Published: June 11, 2026

Abstract
The Semajid River Basin (DAS) faces complex environmental problems, including flooding during the rainy season, drought during the dry season, increased river sedimentation, and uncontrolled land use changes. This study aims to assess the performance of the Semajid Watershed in accordance with the Minister of Forestry Regulation Number 61 of 2014 on Monitoring and Evaluation of Watershed Performance, and to formulate strategies to improve watershed performance through land-cover optimization scenarios. The watershed performance assessment includes criteria for land, water management, socio-economics, building investment value, and space utilization. The evaluation results show that the Semajid Watershed performance value is 113.75, which indicates that the watershed is in the category of needing to be saved. The application of the additional land cover scenario has a significant impact on improving the criteria for vegetation cover and protected areas. The Percentage of Permanent Vegetation Cover (PPV) increased from 5.5% (very high recovery category) to 32.44% (low recovery category), while the value of the protected area criteria decreased from 68.64 to 9.37, indicating an improvement in the ecological condition of the watershed. Although the watershed's carrying capacity increased to 107.5, the Semajid watershed remains in need of restoration. Therefore, restoration of the Semajid watershed requires integrated management that sustainably integrates technical and non-technical efforts.

Keywords: Watershed Performance Evaluation, Land Cover Change, Watershed Carrying Capacity, Vegetation Cover, Watershed Rehabilitation

1. Introduction

Indonesian watersheds (DAS) are increasingly facing complex and interconnected environmental pressures resulting from rapid land-use change, deforestation, and population growth. Upstream degradation due to land conversion, illegal logging, and agricultural expansion without conservation principles has increased soil erosion, river sedimentation, and reduced water quality, ultimately disrupting the overall hydrological function of the watershed.(Narendra et al., 2021)In the middle and downstream areas, land use that exceeds environmental carrying capacity, such as the development of settlements and industrial areas, is further exacerbating the hydrological imbalance and environmental degradation of the watershed.(Sun et al., 2023)This condition emphasizes the importance of systematic monitoring and evaluation of watershed health as a basis for sustainable watershed management.

Watershed health reflects the integrated condition of land, water, ecological, and socioeconomic systems in maintaining hydrological stability and the sustainability of ecosystem services. One effective approach to capturing this complexity is through watershed performance assessment, which integrates various biophysical and socioeconomic indicators into a comprehensive evaluation framework.(Roestamy and Fulazzaky, 2022)In Indonesia, formal assessment of watershed performance refers to the Minister of Forestry Regulation Number 61 of 2014 concerning Monitoring and Evaluation of Watershed Management, which stipulates assessment criteria covering aspects of land, water management, socio-economics, investment value of water structures, and utilization of regional space.

The Semajid Watershed, located in Pamekasan Regency, East Java, is one of the watersheds currently facing quite serious environmental problems, particularly related to the imbalance in land use and degradation of the upstream area. Data from the East Java Provincial Public Works and Water Resources Agency shows that the Semajid Watershed experiences flooding almost every year due to decreased soil infiltration capacity, increased river sedimentation, and uncontrolled land use changes. Current Conditions of the Semajid Watershed in Pamekasan Regency(East Java Regional Center for Agricultural Research, 2024). On the other hand, during the dry season, several sub-districts in the Semajid watershed area, such as Pegantenan, Larangan, Palengaan, and Pademawu, experience drought conditions with levels of severity ranging from rare to severe dry.(Regent of Pamekasan, 2023). These extreme conditions of flooding and drought are further exacerbated by the increasing population which drives up the need for clean water, while the availability of water resources tends to remain the same or even decrease. (Amparo-Salcedo et al., 2025).

Various previous studies have assessed watershed performance in Indonesia, including in the Upper Brantas Watershed.(Riskihadi et al., nd), Unda River Basin in Bali(Wahyudi Toban et al., 2016), Bila Sub-DAS in Wajo, South Sulawesi(Fitrah et al., 2020), Bondoyudo Watershed in East Java(Budi et al., 2021), Bedadung Watershed in East Java(Wibisono, 2021)and the Asem Sub-DAS in East Java(Bana et al., 2022).). The results of this study consistently show that land criteria have the greatest assessment weight and play a dominant role in influencing water management criteria. Changes in land use have been shown to have a significant impact on the hydrological response of the watershed, including increased flood discharge and changes in river flow characteristics.(Kahirun et al., 2023;Basthoni, 2020;Andono et al., 2014).

However, most previous studies have focused on assessing the existing condition of watersheds and have not explored proactive scenarios for improving watershed performance, particularly through land cover optimization approaches. However, developing planned land cover scenarios has significant potential to increase watershed carrying capacity and support sustainable watershed rehabilitation efforts, particularly in small- to medium-scale watersheds like the Semajid watershed.

Based on this, this study aims to (1) assess the performance of the Semajid Watershed based on the Minister of Forestry Regulation Number 61 of 2014 concerning Monitoring and Evaluation of Watershed Performance, and (2) develop strategies for improving watershed performance through land cover optimization scenarios. The results of this study are expected to provide a scientific basis for the formulation of integrated watershed management strategies and become a consideration for stakeholders in planning and making decisions on future management of the Semajid Watershed.

2. Method

2.1. Research Location

The research location is in the Semajid River Basin (DAS), which is administratively located in Pamekasan Regency, between 6° 51' – 7° 31' South Latitude and 113° 19' – 113° 58' East Longitude.

The Semajid Watershed is one of the largest watersheds in the Madura-Bawean River Basin, experiencing flooding during the rainy season and drought during the dry season. The Semajid Watershed covers approximately 310.10 km2, with a main river length of 14.09 km. The technical rice paddy area covers 2,955 ha, with most of the area located in the densely populated Pamekasan City. The research location can be seen in Figure 1.

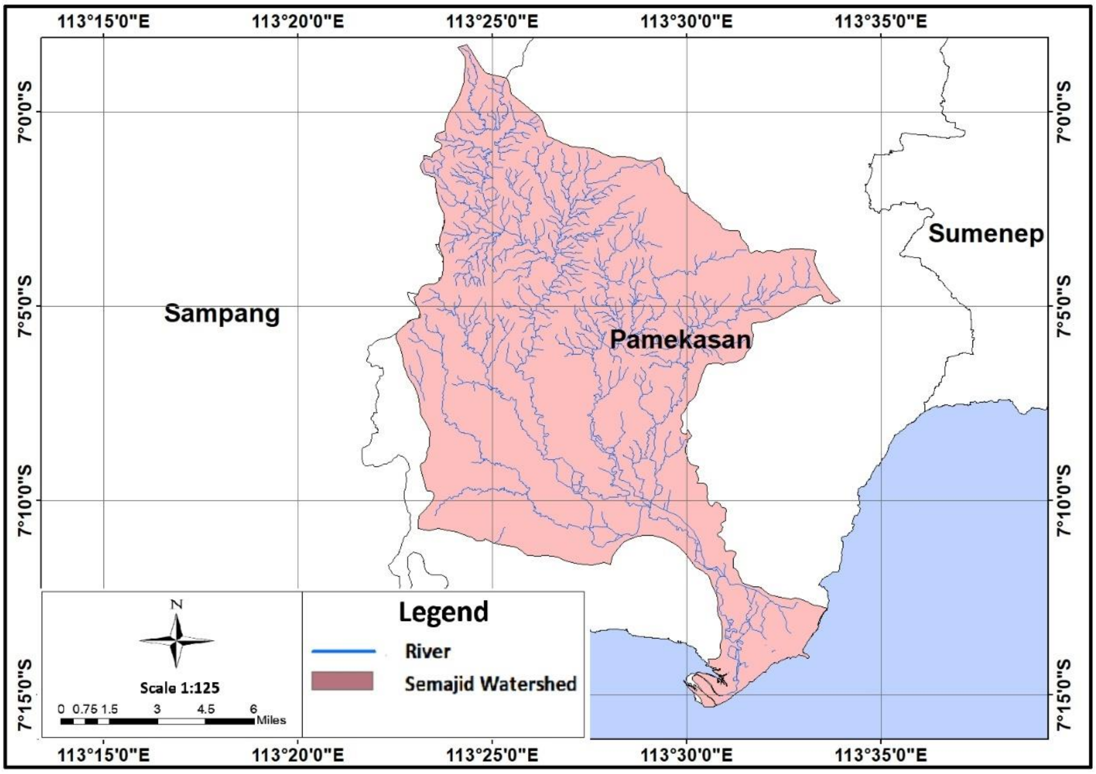


Figure 1. Study Location

2.2. Data Collection

This research uses secondary data obtained from related agencies, websites, and data processing.
Image data. The analysis of watershed carrying capacity uses rainfall data, discharge data, water balance data, dem data, and land cover data obtained from relevant agencies. The data used in this study can be seen in Table 1.

The rainfall and discharge data used in this study were obtained from the East Java Water Resources Agency (PUSDA). The hydrological dataset covers the period 2015–2024, representing the most complete available record for the Semajid Watershed. Discharge data were recorded at the Semajid River monitoring station, which represents the main outlet of the watershed. The discharge dataset was used to determine the maximum discharge (Qmax**)** and minimum discharge (Qmin**)** values for each year. Qmax refers to the highest recorded discharge within a given year, while Qmin represents the lowest recorded discharge during the same period. These values were used to calculate the Flow Regime Coefficient (KRA) and the Annual Flow Coefficient (KAT) as indicators of watershed hydrological variability

Table 1. Data Collection

No	Data	Source	Information
1	DEM Data	Geospatial Information Agency (https//tanahair.indonesia.go.id)	Size 8x8
2	Land Cover Data	Ministry of Environment and Forestry	2024 Data
3	Soil Type Data	Ministry of Environment and Forestry	2024 Data
4	Critical Land Data	Ministry of Environment and Forestry	2024 Data
5	Rain Data	Department of Public Works and Water Resources of East Java Province	Data for 2015-2024
6	Debit Data	Department of Public Works and Water Resources of East Java Province	Data for 2015-2024
7	Flood Incident Data	Department of Public Works and Water Resources of East Java Province	Data for 2020-2025
8	Water Balance Data	Department of Public Works and Water Resources of East Java Province	2025 Data
9	Socioeconomic Data	Central Bureau of Statistics	Population Data, Poor Family Data, and Farmer Family Data

Source: 2025 analysis results

2.3. Watershed Performance Assessment

Watershed performance assessment based on Government Regulation Number 37 of 2012 concerning Watershed Management(GOVERNMENT REGULATION OF THE REPUBLIC OF INDONESIA, 2012)and Regulation of the Minister of Forestry of the Republic of Indonesia Number: P. 61 /Menhut-II/2014(MINISTRY OF FORESTRY OF THE REPUBLIC OF INDONESIA, 2014).

Watershed performance monitoring is conducted periodically to obtain data and information related to watershed carrying capacity. Watershed performance monitoring includes land criteria, water management criteria, socioeconomic criteria, building investment value, and spatial utilization, as shown in Table 2 below.

Table 2. Criteria for Watershed Performance Assessment

No	CRITERIA	Mark	Parameter	Mark	Class	Score
1	Land	Percentage of Critical Land (PLK)	$PLK = \frac{\text{Critical area}}{watershed\ area} X\ 100\%$	PLK ≤ 5	Very Low	0.5
				5 <PLK ≤ 10	Low	0.75
				10 <PLK ≤ 15	Currently	1
				15 <PLK ≤ 20	High	1.25
				PLK ≥ 20	Very high	1.5
		Percentage of Vegetation Cover (PPV)	$PPV = \frac{\text{vegetation cover area}}{watershed\ area} X\ 100\%$	PPV ≥ 80	Very Good	0.5
				60 <PPV ≤ 80	Good	0.75
				40 <PPV ≤ 60	Currently	1
				20 <PPV ≤ 40	Bad	1.25
				PPV ≤ 20	Very bad	1.5
		Erosion Index (IE)	$IE = \frac{\text{Erosi Aktual}}{Erosi\ yang\ ditoleransi}$	IE ≤ 0.5	Very Low	0.5
		Land management value (CP)		0.5 < IE ≤ 1.0	Low	0.75
				1.0 < IE ≤ 1.5	Currently	1
				1.5 < IE ≤ 2.0	High	1.25
				IE ≥ 2.0	Very high	1.5
2	Water management	Flow Regime Coefficient (KRA)	$KRA = \frac{\text{Qmax}}{Qmin}$	KRA ≤ 5	Very Low	0.5
				5 <KRA ≤ 10	Low	0.75
				10 <KRA ≤ 15	Currently	1
				15 <KRA ≤ 20	High	1.25
				KRA > 20	Very high	1.5
		Annual Flow Coefficient (KAT)	$KAT = \frac{\text{Q annual}}{P\ annual}$	KAT ≤ 0.2	Very Low	0.5
				0.2 < KAT ≤ 0.3	Low	0.75
				0.3 < KAT ≤ 0.4	Currently	1
				0.4 < KAT ≤ 0.5	High	1.25
				KAT > 0.5	Very high	1.5
		Sediment Load(MS)	$MS = A\ x\ SDR$	MS ≤ 5	Very Low	0.5
				5 <MS ≤ 10	Low	0.75
				10 <MS ≤ 15	Currently	1
				15 <MS ≤ 20	High	1.25
				MS > 20	Very high	1.5
		Flood	Frequency of Flood Events	Never	Very Low	0.5
				Once in 5 years	Low	0.75
				Once in 2 years	Currently	1
				Once a year	High	1.25
				More than 1 time in 1 year	Very high	1.5
		Water Use Index (WIP)	$IPA = \frac{water\ demand}{water\ suply}$	IPA ≤ 0.25	Very Low	0.5
				0.25 <IPA ≤ 0.50	Low	0.75
				0.50 <IPA ≤ 0.75	Currently	1
				0.75 <IPA ≤ 1.00	High	1.25
				IPA > 1.00	Very high	1.5
C	Socio-Economic	Population Pressure (TP)	Approached by Availability Index Land (IKL) $IKL = \frac{A}{P}$ A = Area of Agricultural Land B = Number of Farmer Households	TP > 4.00	Very low	0.5
				2.0 <TP ≤ 4.0	Low	0.75
				1.0 <TP ≤ 2.0	Currently	1
				0.5 <TP ≤ 1.0	High	1.25
				TP ≤ 0.5	Very high	1.5
		Population Welfare Level (TKP)	TKP is approached by comparing the number of poor families with the total number of families or with the average per capita income per year.	Crime Scene ≤ 5	Very good	0.5
				5 < TKP ≤ 10	Good	0.75
				10 < TKP ≤ 20	Currently	1
				20 < TKP ≤ 30	Bad	1.25
				Crime Scene > 30	Very bad	1.5
		Existence and Enforcement of Regulations	Whether or not there are community rules relating to conservation	Yes, it is widely practiced	Very good	0.5
				Yes, practiced on a limited basis	Good	0.75
				Yes, not practiced	Currently	1
				There are no rules	Bad	1.25
				There are rules but they are	Very bad	1.5

No	CRITERIA	Mark	Parameter	Mark	Class	Score
				counter-revolutionary		
D	Building Investment Value	City Classification	City Existence and Status	No City	Very Low	0.5
				Small town	Low	0.75
				Municipality	Currently	1
				Big city	High	1.25
				Metropolitan City	Very high	1.5
		Investment Value of Water Buildings	Value of water structures (reservoirs/dams / irrigation channels)	IBA ≤ 15 billion rupiah	Very Low	0.5
				15≤ IBA ≤ 30 billion rupiah	Low	0.75
				30 ≤ IBA ≤ 45 billion rupiah	Currently	1
				45 ≤ IBA ≤ 60 billion rupiah	High	1.25
				IBA > 60 billion rupiah	Very high	1.5
E	Utilization Regional Space	Protected Area (KL)	$KL = \frac{\text{L Vegetation Cover Area}}{L\ Protected\ Watershed\ Area}\ X\ 100\%$	KL ≤ 5	Very good	0.5
				5 < KL≤ 10	Good	0.75
				10 < KL ≤ 20	Currently	1
				20 < KL ≤ 30	Bad	1.25
				KL > 30	Very bad	1.5
		Cultivation Area (KB)	$KB = \frac{\text{L Area with } 0-25\% \text{ slope}}{L\ Cultivation\ Watershed\ Area}\ X\ 100\%$	KB ≤ 5	Very good	0.5
				5 < KB ≤ 10	Good	0.75
				10 < KB ≤ 20	Currently	1
				20 < KB ≤ 30	Bad	1.25
				KB > 30	Very bad	1.5

Source: Minister of Forestry Regulation No. P.61/Menhut-II/2014

2.4 Land Erosivity

The erosivity index analysis calculation is approached by comparing the actual erosion value with the allowable erosion value. The actual erosion value is obtained using the USLE formula. The USLE method allows predicting the average erosion rate of a particular land on a slope with a specific rainfall pattern for each type of soil and land management application. The formulation used is the formula from Wischmeier and Smith (1960) in (C Asdak, 2015) as follows.

$$A = R \cdot K \cdot LS \cdot C \cdot P. \quad (1)$$

The value of A is the rate of land erosivity, R the value of the rainfall erosivity factor, K the value of the soil erodibility factor, LS the value of the length and slope factor, C the value of land cover, and P the value of the land processing factor.

The permissible erosion value is calculated based on the standard criteria for soil damage on dry land from Government Regulation (PP) No. 150 of 2000 concerning Control of Soil Damage for Biomass Production (GOVERNMENT OF THE REPUBLIC OF INDONESIA, 2000), can be seen in Table 3 below.

Table 3 Standard Criteria for Land Damage Due to Erosion

TSoil thickness (cm)	Critical Threshold of Erosion tons/ha/year	mm/10th
< 20	0.1<T1≤	0.2 <T≤1.3
20 - <50	1 < T ≤3	1.3 <T≤4
50 - <100	3 < T ≤7	4.0 <T≤9.0
100 – 150	7< T≤ 9	9.0<T≤12
>150	T >9	T>12

Source: Minister of Forestry Regulation No. P.61/Menhut-II/2014

2.5 Assessment of Watershed Carrying Capacity

Watershed carrying capacity is assessed by adding up the weights of each assessment criterion. Watershed condition assessments are conducted under existing conditions and scenarios involving increased land cover. The watershed carrying capacity assessment categories are shown in Table 4 below.

Table 4. Weight, Score, and Parameters for Watershed Carrying Capacity Assessment

No	Mark	Category
1	DDD≤70	Very good
2	70<DDD≤90	Good
3	90<DDD≤110	Currently
4	110<DDD≤130	Bad
5	DDD>130	Very bad

Source: Minister of Forestry Regulation No. P.61/Menhut-II/2014

2.6 Land Criteria Optimization

In this study, land criteria analysis optimization uses a scenario of increasing vegetation cover in the Semajid Watershed. Referring to Forestry Law No. 19 of 2004 concerning forestry, this method maintains a minimum forest condition or vegetation cover of 30% of the watershed area. This threshold is widely recognized as the minimum ecological requirement for maintaining watershed stability, as adequate vegetation cover improves infiltration capacity, reduces surface runoff, and helps regulate streamflow variability within the watershed. It should be maintained as forest or permanent vegetation to support ecological stability and maintain watershed hydrological functions.

The optimization scenario was developed using GIS-based spatial analysis of land-cover data obtained from the Ministry of Environment and Forestry (2024). Existing land-cover classes were first analyzed to identify areas with low vegetation coverage. Based on this analysis, shrubland and unused land were identified as potential areas for vegetation restoration, while built-up areas (settlements), agricultural land, rivers, and water bodies were excluded from conversion to ensure realistic land-use conditions.

The spatial distribution of the optimized vegetation cover scenario is illustrated in Figure 4. The land-cover optimization process was conducted through the following steps:

1. Identification of existing land cover distribution using the latest land-cover dataset.
2. Selection of candidate restoration areas, primarily shrubland and open land with low ecological function.
3. Application of land-cover conversion scenarios, where selected areas were reclassified as permanent vegetation.
4. Recalculation of watershed performance indicators, particularly the Percentage of Permanent Vegetation Cover (PPV) and Protected Area (KL) criteria.
5. Comparison of watershed carrying capacity values before and after the implementation of the optimization scenario.

This scenario-based approach allows the evaluation of the potential impact of vegetation restoration on watershed performance indicators and provides a basis for identifying feasible strategies to improve the ecological condition of the Semajid Watershed.

2.7 Recommendations for Semajid Watershed Restoration

Based on the analysis of watershed carrying capacity assessments under various scenarios, a strategy for restoring watershed carrying capacity in the future was designed. The approach was both technical and non-technical.

3. Results and Discussion

3.1 Land Criteria Analysis

Land criteria analysis is approached using 3 sub-criteria, namely critical land analysis, land cover analysis, and erosivity index.

3.1.1 Critical Land Sub-Criteria Analysis

Critical land data was obtained from data from the Indonesian Ministry of Environment and Forestry in 2025. Critical land in the Semajid Watershed is divided into 5 criteria. The potential for critical land in the Semajid Watershed can be seen in the following table 5.

Table 5. Critical Land Potential of Semajid Watershed

No	Land Potential	Area (ha)	Percentage
1	Not Critical	9.07	2.93%
2	Critical Potential	218.51	70.46%
3	Somewhat Critical	56.19	18.12%
4	Critical	22.48	7.5%
5	Super Critical	3.58	1.24%

Source: 2025 analysis results

Critical land classification is determined by comparing the area of critical and super-critical land to the total area of the Semajid Watershed. Critical land is land that meets critical and super-critical criteria. Table 5 shows a critical land area of 26.33 ha. The critical land analysis value is approximated by comparing the critical land area to the watershed area. Based on table 5, the PLK value of 8.49% is included in the land criteria class with a very low recovery rate.

3.1.2 Analysis of Vegetation Cover Subcriteria

The Semajid Watershed is located in the urban area of Pamekasan Regency, with most of the land use being residential. The land use analysis for the Semajid Watershed includes residential areas, agricultural land, shrubs, vegetation, and water. The distribution of land use and extent is presented in Table 5 and Figure 2 below.

Table 6. Land Cover of Semajid Watershed

No	Allocation	Wide (Ha)	Percentage
1	Vegetation	1,711.03	5.52%
2	Settlement	13,617.57	43.91%
3	Agricultural land	6,916.25	22.30%
4	Shrubs	8,346.63	26.92%
5	Empty land	13.28	0.04%
6	Swamp	2.55	0.01%
7	Rivers and waters	402.58	1.30%

Source: 2025 analysis results

Based on the land cover data in Table 6, the vegetation cover area is 1,711.03 ha. The Percentage of Vegetation Cover (PPV) is calculated by comparing the vegetation cover value to the watershed area. The Percentage of Vegetation Cover (PPV) is 5.52%. This PPV value is included in the very high recovery level category.

3.1.2 Analysis of Erosivity Index Subcriteria

Land erosion calculation based on the USLE equation. Rainfall erosivity values were obtained from data from six rainfall stations in the Samiran watershed spanning 10 years. The calculated rainfall erosivity value for the Semajid watershed over a 10-return period was 99.725 cm/yr.

Based on the processing of DEM data of Semajid Watershed, 5 categories of slope values and area (LS) were obtained with a range of 0-8%, 8-15%, 15-25%, 25-45%, and >45%. More than 90% of the Semajid Watershed area is at a slope of 0-8%. The slope area and LS values of Semajid Watershed can be seen in Table 7.

The Soil Erodibility Factor (K) is the ability of the soil to erode easily or with difficulty. The value of K or the soil erodibility factor, is influenced by the type of soil in the location. The soil types in the Semajid watershed consist of alluvial soil in the downstream part of the watershed, grumosol soil in the middle part, and Mediterranean soil in the upstream part of the watershed.

The land cover factor (C) and land management value (P) are based on the land cover of the Semajid Watershed. Based on the results of the land cover analysis in Table 6, most of the Semajid Watershed area is built-up land with a fairly high land cover factor value.

The value of the land erosion rate of the Semajid watershed (A), the value of the slope gradient factor (LS), the value of the soil erodibility factor (K), the value of the land cover factor (C), and the value of land processing (P) can be seen in Table 7.

Table 7. Erosivity of Semajid Watershed Land

No	Slope	Wide (Ha)	Percentage	R cm/yr	CP	LS	K	A mm/ton/ha/yr
1	0 – 8%	28,296.49	93.25%	99,725	0.253	0.4	0.40	3,762
2	8 – 15%	1,519.7	4.90%	99,725	0.253	1.4	0.41	0.710
3	15 – 25%	434.75	1.40%	99,725	0.239	3.1	0.42	0.437
4	25 – 45%	129.54	0.42%	99,725	0.227	6.8	0.43	0.276
5	> 45%	9.52	0.03%	99,725	0.224	9.5	0.43	0.028
Total Land Erosivity								5.21

Source: 2025 analysis results

The results of the land erosion analysis using the USLE method for the Semajid Watershed in Table 7 are 5.21 mm/ton/ha/year. The land erosion subcriteria are the comparison of the erosion index (A) with the tolerable erosion index in Table 3. According to the Madura Bawean Watershed water resource pattern report, the average soil thickness of the Semajid Watershed is 100-150 cm, and the land erosion threshold is (T) 8 tons/ha/year. The land erosivity index (IE) value is 0.652 tons/ha/year. This value is included in the very low recovery rate category. The erosion rate map for the Semajid Watershed can be seen in Figure 3.

3.2 Analysis of Water Management Criteria

Water management analysis is approached using five sub-criteria, namely flow regime coefficient (KRA), annual flow coefficient (KAT), sediment load (MS), number of flood events, and water use index (IPA).

3.2.1 Sub-criteria analysis of flow regime coefficients

The Semajid River Basin is located in the Madura Island region with a dry climate. Analysis of the flow regime coefficient (KRA) in the dry region by comparing the maximum and minimum discharge in the watershed. The calculation of KRA was based on the ratio between the annual maximum discharge (Qmax) and the annual minimum discharge (Qmin). The discharge data used are the results of recording the Semajid River water estimation post with a data span of 10 years.

The highest average annual discharge during the observation period of 2015 to 2024 was 417 m^3/s, and the lowest average annual discharge was 0.185 m3. The KRA sub-criteria value was approximated by comparing the maximum discharge with the minimum discharge.

The results of the KRA analysis of Semajid Watershed were 2,247; the KRA value is included in the very high recovery level category.

3.2.2 Analysis of Annual Flow Coefficient Subcriteria

The annual runoff coefficient (AR) is the percentage of rainfall that flows as runoff. The annual runoff coefficient (AR) is the ratio of the annual flow thickness (Q, mm) to the annual rainfall thickness (P, mm) in the watershed, or the percentage of rainfall that becomes runoff in the watershed. This study used data from six rainfall stations in the Semajid watershed over a 10-return period. The results of the Semajid watershed KRA calculation can be seen in Table 8 below.

Table 8. Annual Flow Coefficient Values of Semajid Watershed

No	Year	R cm/yr	Watershed area m2	Runoff Q (m3/sec)	P (m3) (R/1000)*A	KAT
1	2015	1439.44	310,100,000.00	69,317,856	447,377,175	0.154
2	2016	2416.00	310,100,000.00	271,405,728	750,892,800	0.361
3	2017	1744.14	310,100,000.00	249,944,832	54,2077,935	0.461
4	2018	1441.50	310,100,000.00	29,756,160	44,8018,200	0.066
5	2019	1356.25	310,100,000.00	226,189,152	421,522,500	0.536
6	2020	2043.41	310,100,000.00	367,040,160	635,092,605	0.577
7	2021	1834.79	310,100,000.00	392,643,936	570,251,955	0.688
8	2022	2439.53	310,100,000.00	790,958,392	758,204,370	1,043
9	2023	1152.20	310,100,000.00	718,038,310	358,103,760	2,005
10	2024	1568.55	310,100,000.00	540,015,552	487,505,340	1,107
			Average	365,531,007	541,904,664	0.670

Source: Results of analysis for 2025

The annual runoff coefficient analysis measures the percentage of rainfall that flows as runoff. The annual runoff coefficient (KAT) value in the Semajid watershed is 0.67, which is considered a high recovery rate. This indicates that the absorption rate in the Semajid watershed is less than optimal because most of the watershed area is residential or built-up.

3.2.3 Analysis of Annual Flow Coefficient Subcriteria

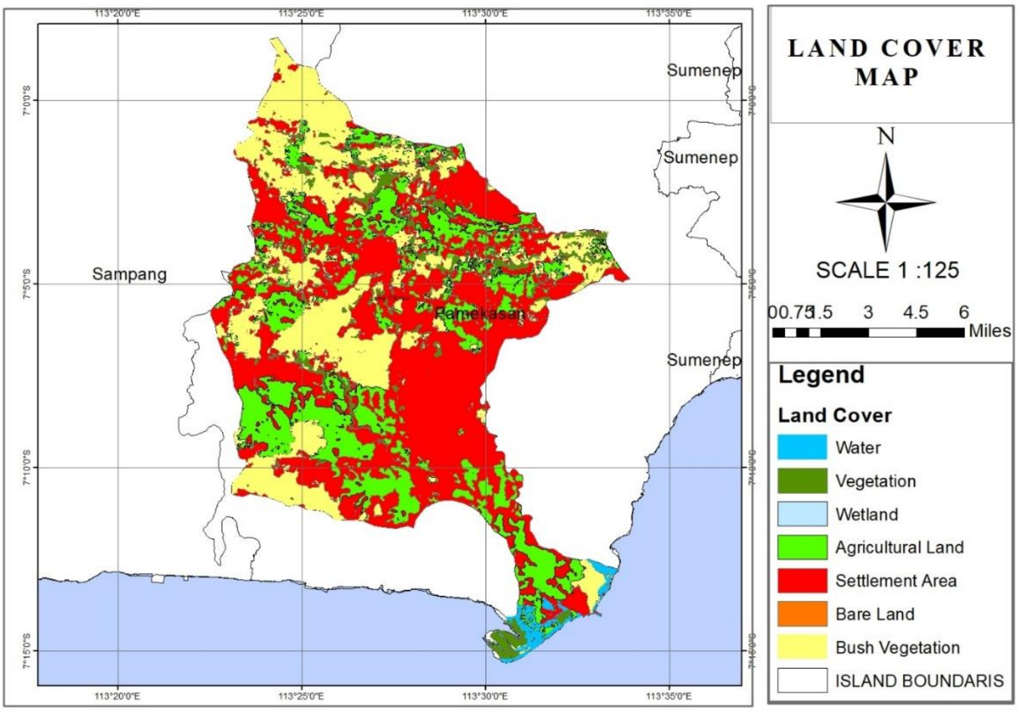
Sediment load analysis (MS) is a comparison of the erosivity rate of the Semajid watershed with the sediment delivery ratio. The erosivity rate of the Semajid watershed is 5.22 mm/ton/ha/year. The Semajid watershed area is 310.10 km2, resulting in a sediment delivery ratio of 31.2%.(MINISTRY OF FORESTRY OF THE REPUBLIC OF INDONESIA, 2014). The sediment load value of the Semajid watershed is 4.34 tons/ha/year included in the low recovery rate category.

3.2.4 Analysis of Annual Flow Coefficient Subcriteria

According to flood disaster data from the East Java Regional Water Resources Development Agency (PUSDA) from 2020 to 2025, flooding is expected to occur more than once per year. Flooding in the Semajid Watershed is caused by overflowing rivers, the Semajid River, the Jombang River, the Sumberpayung River, and the Kloang River. In 2025, there were nine flood disasters in the Semajid Watershed. On average, there were five floods in a six-year period. According to Table 2, flooding occurring more than once per year is categorized as having a very high recovery rate.

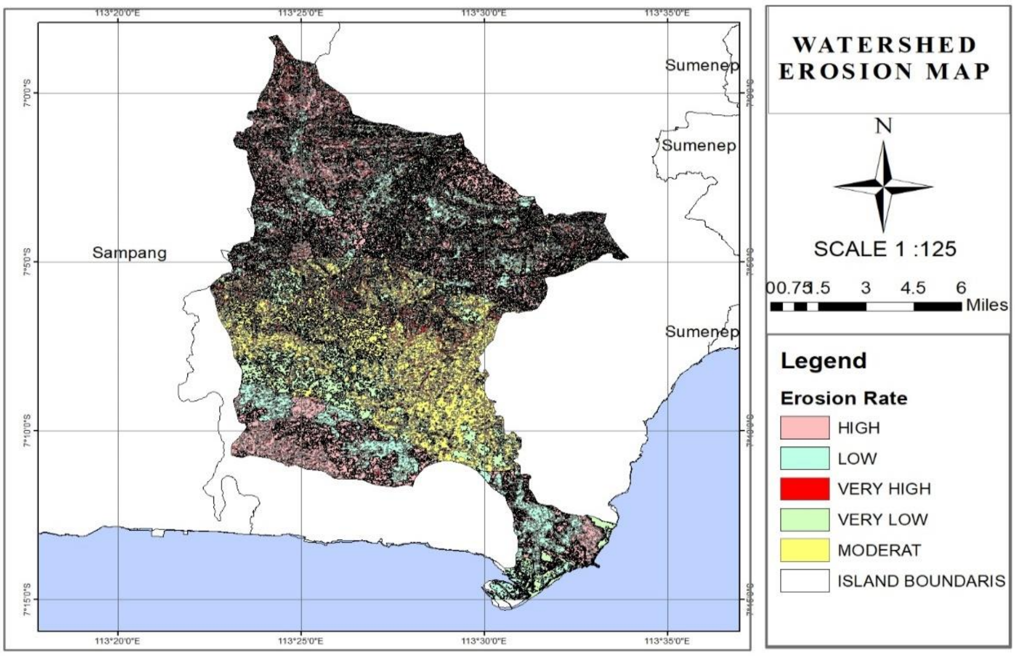
3.2.5 Analysis of Water Use Index Subcriteria

In this study, the water use index (IPA) sub-criteria uses a comparison of water demand and water availability in the Semajid watershed. The data used in the IPA calculation are based on the published results of the Semajid watershed water balance in 2025, which amounted to 72.85 million m3/year, and the Semajid watershed water supply value of 151.54 million m3/year. (East Java Department of Water Resources, 2025). From the results of the analysis of the Semajid Watershed IPA value, the IPA value was obtained at 0.48, which is included in the very low recovery level category.



Source: 2025 Analysis

Figure 2 Land Cover Map of Semajid Watershed



Source: 2025 Analysis

Figure 3. Map of Erosivity Rate of Semajid Watershed Land

3.3 Analysis of Socio-Economic Criteria

The analysis of socio-economic criteria is approached using three sub-criteria: population pressure (TP), population welfare level (TKP), and availability of regulations and enforcement of regulations.

3.3.1 Population Pressure Sub-Criteria Analysis

Population pressure (TP) sub-criteria analysis is approached by comparing the number of farming families in a watershed compared to the area of agricultural land in the watershed. Based on data from the Pamekasan Regency Statistics Agency (BPS) from the 2023 agricultural census, the number of farming families is 60% of the total number of families in Pamekasan Regency.(BPS, 2025). The number of farming families in the Semajd watershed is 71,309 families, with a total area of technical agricultural land of 2,955 ha and rain-fed rice fields of 4,011 ha. From the analysis of population pressure criteria, the TP value of 0.098 is included in the very high recovery level category.

3.3.2 Analysis of Sub-Criteria for Population Welfare Level

The sub-criteria for the level of population welfare are the ratio of the number of poor people to the number of people in the watershed. The Semajid watershed area is in Pamekasan Regency. According to BPS data in 2025, the number of poor people in Pamekasan Regency is 123,460 and the population of Pamekasan Regency is 893,300. The TKP criteria value in the Semajid watershed is 13.82%, which is included in the moderate recovery level category.

3.3.2 Analysis of Sub-Criteria for the Existence of Rule Enforcement

The sub-criteria for the existence and enforcement of regulations in the Semajid Watershed were obtained from information from community leaders and reports from relevant agencies authorized to manage the Semajid watershed. Regulations related to watershed management and water resource conservation, including statutory regulations, ministerial regulations (Permen), regional regulations (Perda), and prevailing community norms, already exist. Based on these conditions, community regulations exist in the Semajid Watershed and their implementation is limited, with this value being included in the moderate recovery level category.

3.4 Water Building Investment Analysis

Water building investment analysis is approached with two sub-criteria of city classification and water building investment.

3.4.1 Analysis of City Classification Subcriteria

The Semajid watershed is mostly located in Pamekasan Regency, with the urban area in Pamekasan District. Pamekasan District has a population of 92,623.(BPS, 2025), with this number falls into the category of Small Urban Areas with a very low level of watershed carrying capacity recovery.

3.4.2 Analysis of Water Building Investment Subcriteria

The Semajid Watershed boasts a fairly comprehensive water infrastructure. These include the Samiran Dam, Klampar Dam, Blumbungan Dam, Toronan Dam, their irrigation networks, and one Samiran reservoir for raw water. The estimated investment value of the Semajid Watershed's water infrastructure is over 60 billion rupiah, categorized as having a very high recovery rate.

3.5 Analysis of Regional Space Utilization

Analysis of regional space utilization is approached using two sub-criteria: Protected Areas (KL) and Cultivation Areas (KB).

3.5.1 Analysis of Protected Area (KL) Subcriteria

The analysis of protected area criteria is obtained by comparing the area of vegetation cover with the area of the protected area. Based on Table 6, the area of vegetation cover in the Semajid Watershed is 1,711.03 ha. The protected area in the Semajid watershed consists of 1,174.53 hectares of mangrove forest downstream. The KL value obtained was 68.64, categorized as a very high level of recovery.

3.5.2 Analysis of Cultivation Area (KB) Sub-Criteria

Cultivation Area Analysis is a comparison of the area with a slope of 0-25% with the watershed area. Based on Table 7, the area with a slope of 0-25% is 30,870 ha. The KB value in the Semajid watershed is 99.5516, which is included in the very poor category.

3.6 Land Criteria Optimization

The land-cover optimization scenario was implemented based on the criteria described in Section 2.5, where shrubland and open land were converted into permanent vegetation to increase the vegetation cover within the watershed.

Scenarios for improving watershed performance include increasing vegetation cover in the Semajid watershed. This includes reforestation of open or scrubland areas with perennial plants. This increase in vegetation cover directly impacts the Percentage of Vegetation Cover (PPV) and Protected Area (KL) sub-criteria.

The results of the land cover area of the Semajid Watershed after optimization can be seen in Table 9 below.

Table 9. Land Cover Optimization of Semajid Watershed

No	Allocation	Wide	
		(Ha)	Percentage
1	Vegetation	10,060.31	32.44%
2	Settlement	13,617.57	43.91%
3	Agricultural land	6,916.25	22.30%
4	Empty land	13.28	0.04%
5	Rivers and waters	402.58	1.30%

Source: 2025 analysis results

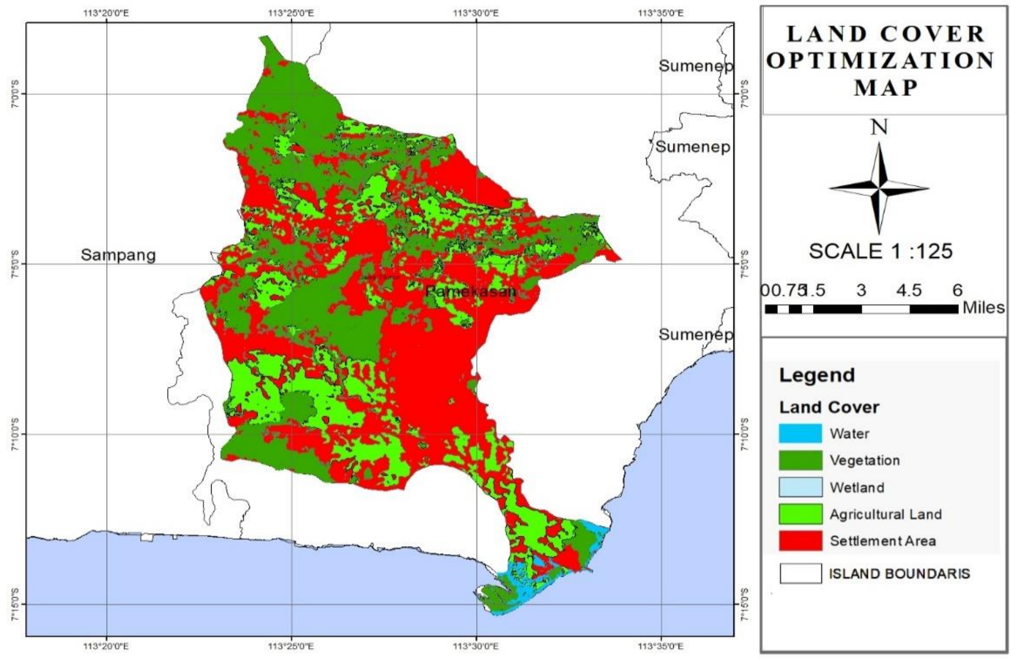
Based on the land cover data in Table 6, the vegetation cover area increased to 10,060.31 ha, corresponding to a PPV value of 32.44%. This PPV value falls within the high recovery level category. A land cover map with the scenario of increasing vegetation coverage can be seen in Figure 4.

With a scenario of increasing vegetation coverage to 10,060.31 ha, the KL value was 9.37, which falls into the low recovery level category. A summary of the Semajid Watershed performance improvement scenarios can be seen in Table 9.

3.7 Assessment of Watershed Carrying Capacity

Determination of the Semajid Watershed assessment classification by weighting each land criterion, water management criteria, socio-economic criteria, water building investment criteria, and regional space utilization criteria. Based on Table 2, the weighted value of 113.75 is included in the Poor category.

After land cover optimization, the PPV sub-criteria value increased to 32.44%, and the land cover sub-criteria value increased to 9.37. The Semajid watershed's carrying capacity weighting value was 107.5, falling into the moderate category. A summary of the Semajid watershed performance monitoring can be seen in Table 10.



Source: 2025 analysis results

Figure 4. Semajid Watershed Vegetation Cover Optimization Map

Table 10. Results of Semajid Watershed Performance Assessment

No	CRITERIA	Weight (%)	Calculation		Score		Results	
			At the moment	Optimization	At the moment	Optimization	At the moment	Optimization
A	Land Conditions							
1	Critical percentage	20	8.49%	8.49%	1	1	20	20
2	Percentage of vegetation cover	10	6%	32%	1.5	1	15	12.5
3	Erosion index	10	0.65%	0.65%	0.75	0.75	7.5	7.5
B	Water System Condition							
1	Flow regime coefficient	5	2.247	2.247	1.5	1.5	7.5	7.5
2	Annual flow coefficient	5	0.67	0.67	1.5	1.5	7.5	7.5
3	Sediment Load	4	4.34	4.34	0.5	0.5	2	2
4	Flood	2	5	5	1.5	1.5	3	3
5	Water Use Index	4	0.48	0.48	1.5	1.5	2	2
C	Socio-Economic Conditions							
1	TPopulation pressure	10	0.1	0.1	1.5	1.5	15	15
2	Tlevel of population welfare	7	0.14	0.14	1	1	7	7
3	Existence and enforcement of regulations	3	There is limited practice	There is limited practice	0.75	0.75	2.25	2.25
D	Building investment							
1	City classification	5	Small town	Small town	0.5	0.5	2.5	2.5
2	Classification of water building values	5	More than 60 M	More than 60 M	1.5	1.5	7.5	7.5
E	Utilization of Regional Space							
1	Protected Area	5	68.64	10.68	1.5	0.5	7.5	3.75
2	Cultivation Area	5	99.55	99.55	1.5	1.5	7.5	7.5
	Amount	100					113.75	107.5

Source: 2025 analysis results

3.8 Discussion

The research results show that the watershed carrying capacity value of 113.75 is classified as poor. This condition reflects an imbalance between biophysical and socioeconomic aspects due to significant land use changes. This condition has resulted in an increase in built-up area (43.9%) and very low vegetation cover (5.5%).

Land criteria are the dominant component determining the carrying capacity of the Semajid watershed. The critical land percentage (PLK) of 8.49% places Semajid in the very low recovery category, while vegetation cover only reaches 5.5%. A study on the performance of the Unda Watershed (Bali) found that a PLK value above 7% indicates an increased risk of erosion and a decrease in riverbed discharge. (Wahyudi Toban et al., 2016).In the Bondoyudo watershed performance research, it was confirmed that a 10% reduction in vegetation cover can increase the runoff coefficient by up to 25%. (Budi et al., 2021).

The water management criteria assessment shows an increase in surface runoff, indicated by a KAT value of 0.67, which is categorized as a high recovery rate. This value indicates low infiltration capacity in the Semajid watershed. The difference between high and low discharge is quite large, with a KRA value of 2.247, and flooding has recurred an average of five times in the last six years. This indicates that the absorption rate in the Semajid watershed is less than optimal because most of the watershed area is residential or built-up land.

The socioeconomic assessment of the Semajid watershed showed very high population pressure (TP) with a value of 0.098, indicating limited productive agricultural land for farming families in the watershed. The population welfare level (TKP) was in the moderate category with a value of 13.82%. Conservation law enforcement was limited, despite the existence of formal and customary regulations. This condition mirrors Wibisono's findings. (Wibisono, 2021)In the Bedadung Watershed, conservation success depends not only on land rehabilitation techniques but also on the social role of the community and the effectiveness of local law enforcement. A local community-based approach to vegetation rehabilitation has proven more effective in small-scale watersheds, as exemplified by the Asem Sub-Watershed. (Bana et al., 2022).

The vegetation cover optimization scenario with reforestation on open land and shrubs increases the vegetation cover area to 32.44%. This scenario affects the improvement of the PPV subcriteria value from 5.5% to 32.44%, a decrease in the KL value from 68.64 to 9.37 (a better conservation category), and an increase in the watershed carrying capacity category from a poor condition of 113.75 to a moderate condition of 107.5. This scenario model has been carried out in the Brantas watershed, stating that an increase in vegetation cover of at least 30% is the optimal ecological limit for maintaining hydrological balance and reducing the risk of watershed damage in tropical areas. (Roestamy and Fulazzaky, 2022).

3.9 Recommendations for Semajid Watershed Performance Recovery

As an effort to restore the Semajid Watershed, every activity must be integrated from upstream to downstream and involve interested parties or stakeholders. The stakeholders are grouped into 4 (four), namely the owner/regulator (Government), operator (technical service, BUMN, or BUMD), developer, and user (community).

Referring to the East Java Provincial Spatial Planning Plan, the restoration of the carrying capacity of the Semajid Watershed is carried out with several activity plans, namely water resource conservation, water resource utilization and control of the destructive power of water.

4. Conclusions

The Semajid watershed's carrying capacity index of 113.75% is categorized as requiring protection. The scenario of increasing land cover improves several watershed indicators, particularly the Percentage of Permanent Vegetation Cover (PPV), which increased from 5.5% (very high recovery category) to 32.44% (low recovery category). At the same time, the protected area criteria value decreased from 68.64 to 9.37, indicating an improvement in the ecological condition of the watershed.

Following the land cover improvement scenario, the watershed carrying capacity index increased to 107.5. Despite this improvement, the Semajid watershed is still classified as requiring restoration. Therefore, watershed restoration should not rely solely on land cover improvement but must involve integrated management strategies, including urban runoff control, enhancement of river channel capacity, stricter enforcement of land-use regulations, and community-based watershed management programs.

This study is subject to several limitations, including the feasibility of land cover change scenarios, the spatial resolution of the available data, and the sensitivity of the scoring thresholds used in the watershed carrying capacity assessment, which may influence the resulting classification.

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