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Soil Erosion Control Practices and Their Effect on Watershed Degradation Reduction in the Upper Citarum Watershed, West Java, Indonesia

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ABSTRACT: The Cisangkuy Sub-Watershed in the Upper Citarum Basin, West Java, Indonesia, has experienced increasing environmental degradation due to intensive agricultural activities, deforestation, and unsustainable land management on sloping areas. These conditions have accelerated soil erosion, sedimentation, declining soil fertility, and hydrological imbalance, threatening watershed sustainability and increasing downstream flood risks. This study aims to analyze the effect of soil erosion control practices on watershed degradation reduction in the Cisangkuy Sub-Watershed. The research employed a quantitative explanatory approach using a cross-sectional survey combined with field observations. Data were collected from 135 respondents consisting of farmers, land managers, and environmental stakeholders through structured questionnaires, erosion assessments, and land condition observations. The study examined terracing, vegetative conservation, agroforestry systems, contour farming, and check dam implementation as soil conservation practices. Data were analyzed using multiple linear regression supported by descriptive environmental analysis. The findings indicate that all conservation practices significantly contribute to watershed degradation reduction. Vegetative conservation and agroforestry systems showed the strongest influence on reducing surface runoff, improving soil stability, and increasing water infiltration capacity. Furthermore, community participation and environmental awareness strengthened conservation effectiveness. The study concludes that integrated soil conservation strategies are essential to support sustainable watershed management in the Cisangkuy Sub-Watershed.

Keywords: Watershed Degradation, Soil Erosion, Conservation Practices, Agroforestry, Sustainable Watershed Management

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INTRODUCTION

Watersheds have an important role in maintaining environmental balance, regulating water systems, preserving soil fertility, and supporting community livelihoods (Zerga, 2025). A well-managed watershed can reduce flood risk, maintain water availability, and support sustainable agricultural activities. Increasing land conversion, deforestation, and intensive agricultural expansion have caused serious environmental pressure in many watershed areas, especially in developing tropical countries (Wiwoho et al., 2023). These conditions have accelerated watershed degradation, which is characterized by increased surface runoff, erosion, sedimentation, declining water quality, and reduced ecological carrying capacity.

One of the most serious environmental problems associated with watershed degradation is soil erosion. Soil erosion occurs when soil particles are detached and transported by rainfall and runoff due to inadequate vegetation cover and inappropriate land management practices (Sumaryanto et al., 2022). In tropical regions with high rainfall intensity and steep slopes, erosion processes generally occur more rapidly and are often difficult to control. Excessive soil erosion not only decreases soil fertility and agricultural productivity but also increases sediment accumulation in rivers, causing river shallowing and higher flood potential in downstream areas (Kardhana et al., 2024; Nahib et al., 2024; Perkasa et al., 2021). Therefore, soil conservation has become an essential component in sustainable watershed management.

In Indonesia, watershed degradation remains a major environmental issue, particularly in the Upper Citarum Basin. The upstream region of the Citarum watershed has experienced significant environmental changes due to forest conversion, settlement expansion, and intensive cultivation activities on sloping land. One of the areas facing serious degradation problems is the Cisangkuy Sub-Watershed. Agricultural activities that are not accompanied by proper conservation measures have increased erosion rates and sediment transport in this area (Rashmi et al., 2022). In addition, declining vegetation cover and weak land management practices have contributed to reduced infiltration capacity and increased runoff during the rainy season. These conditions have affected the hydrological function of the watershed and increased environmental vulnerability in surrounding areas.

Various soil conservation practices have been implemented to reduce erosion and restore watershed conditions. These include terracing, contour farming, vegetative conservation, agroforestry systems, and the construction of check dams. Vegetative conservation is considered effective in reducing runoff velocity and improving soil stability because plant roots can strengthen soil structure and increase water infiltration (Hao et al., 2020). Agroforestry systems also provide environmental benefits by integrating trees with agricultural crops, which helps reduce erosion while maintaining land productivity. Meanwhile, terracing and contour farming are commonly applied in sloping agricultural areas to reduce soil loss and surface runoff.

Several previous studies have discussed soil erosion and watershed conservation in the Upper Citarum area. However, many of these studies mainly focused on technical aspects such as sediment estimation, hydrological modeling, or erosion prediction. Research examining the combined effect of various soil conservation practices together with community participation in reducing watershed degradation is still limited, particularly in the Cisangkuy Sub-Watershed area. In fact, community involvement and environmental awareness are important factors that influence the long-term success of conservation programs.

Based on these conditions, this study aims to analyze the effect of soil erosion control practices on watershed degradation reduction in the Cisangkuy Sub-Watershed, Upper Citarum Basin, West Java, Indonesia. This study focuses on several conservation practices, including terracing, vegetative conservation, agroforestry systems, contour farming, and check dam implementation. The findings are expected to provide useful information for policymakers, environmental managers, and local communities in developing more sustainable watershed conservation strategies.

THEORETICAL REVIEW

Watershed Degradation

Watershed degradation refers to the decline of ecological and hydrological functions within a watershed caused by unsustainable land use, deforestation, agricultural expansion, and environmental exploitation (Hassan et al., 2025). Degraded watersheds are commonly characterized by increasing runoff, declining vegetation cover, sedimentation, soil fertility loss, and reduced water infiltration capacity. According to Asdak (2023), watershed degradation in tropical regions is strongly associated with inappropriate land management practices occurring in upstream areas. Rapid land conversion without proper conservation measures often accelerates erosion and destabilizes watershed ecosystems.

In Indonesia, watershed degradation has become an important environmental issue due to increasing population pressure and intensive agricultural activities in upland areas. The Upper Citarum Basin is one of the watershed regions experiencing severe environmental pressure caused by settlement expansion, land conversion, and cultivation activities on sloping terrain. Environmental degradation in upstream areas contributes significantly to flooding, sediment accumulation, and declining water quality in downstream regions.

Soil Erosion and Environmental Impact

Soil erosion is the process of soil particle detachment and transportation caused primarily by rainfall and surface runoff. Zhao et al. (2021) explained that erosion intensity is influenced by rainfall erosivity, slope steepness, soil characteristics, vegetation cover, and conservation practices. In tropical environments with high rainfall intensity, erosion generally occurs more rapidly, especially in areas lacking adequate vegetation cover.

Excessive soil erosion creates serious environmental consequences. The removal of topsoil reduces soil fertility and agricultural productivity, while sediment transported into rivers contributes to river shallowing and hydrological disturbance. Farooqi et al. (2024) emphasized that long-term soil erosion can threaten food security and ecological sustainability because degraded soils become less productive and more vulnerable to environmental stress.

The Cisangkuy Sub-Watershed has experienced increasing erosion problems due to agricultural cultivation on steep slopes and weak implementation of conservation measures. As a result, sedimentation and runoff intensity have increased in several areas within the watershed system.

Soil Erosion Control Practices

Soil erosion control practices are conservation measures aimed at reducing soil loss, improving infiltration capacity, and maintaining land productivity. These conservation methods generally include vegetative, agronomic, and mechanical approaches.

Vegetative conservation practices such as reforestation, grass barriers, and cover crops are widely recognized as effective methods for reducing runoff velocity and strengthening soil structure. Vegetation cover protects soil surfaces from direct rainfall impact while root systems improve soil aggregation and infiltration. According to Jessica et al. (2026), vegetation-based conservation is one of the most sustainable approaches for controlling erosion in tropical watersheds.

Agroforestry systems integrate trees with agricultural crops to improve ecological stability and land productivity. Jafari et al. (2022) explained that agroforestry contributes to erosion reduction through canopy protection, root reinforcement, and increased soil organic matter. Agroforestry systems also provide economic benefits for local communities because they support diversified agricultural production.

Mechanical conservation methods such as terracing and check dam construction are commonly implemented in sloping watershed areas. Terracing functions to reduce slope length and runoff speed, thereby minimizing soil displacement during rainfall events. Meanwhile, check dams are constructed to trap sediment and control water flow within river channels. Contour farming is another important conservation practice in which cultivation follows contour lines to reduce runoff and increase infiltration capacity (Fahad et al., 2022).

Several studies have shown that soil conservation practices can significantly reduce erosion rates and improve watershed conditions. However, the effectiveness of these practices depends on environmental characteristics, land-use intensity, and consistency in conservation implementation.

Community Participation in Watershed Management

Community participation is an important component of sustainable watershed conservation. Local communities directly interact with land resources through agricultural and environmental activities, making their involvement essential in conservation programs. Pretty (2003) stated that environmental management programs tend to be more successful when communities actively participate in planning, implementation, and monitoring activities (Brotosusilo et al., 2020).

In many watershed areas, conservation programs often face challenges due to weak environmental awareness and inconsistent land management practices. Therefore, participatory approaches are necessary to strengthen conservation sustainability and improve environmental stewardship among local communities.

In the context of the Cisangkuy Sub-Watershed, community involvement is particularly important because local agricultural practices strongly influence erosion and watershed degradation processes. Integrating technical conservation measures with participatory environmental management is therefore necessary to support long-term watershed sustainability.

Conceptual Framework

This study examines the influence of soil erosion control practices on watershed degradation reduction in the Cisangkuy Sub-Watershed, Upper Citarum Basin, West Java, Indonesia. Soil conservation practices consisting of terracing, vegetative conservation, agroforestry systems, contour farming, and check dam implementation are considered independent variables affecting watershed degradation reduction as the dependent variable. The framework assumes that effective conservation practices can reduce runoff intensity, minimize sedimentation, improve soil stability, and restore watershed ecological functions.

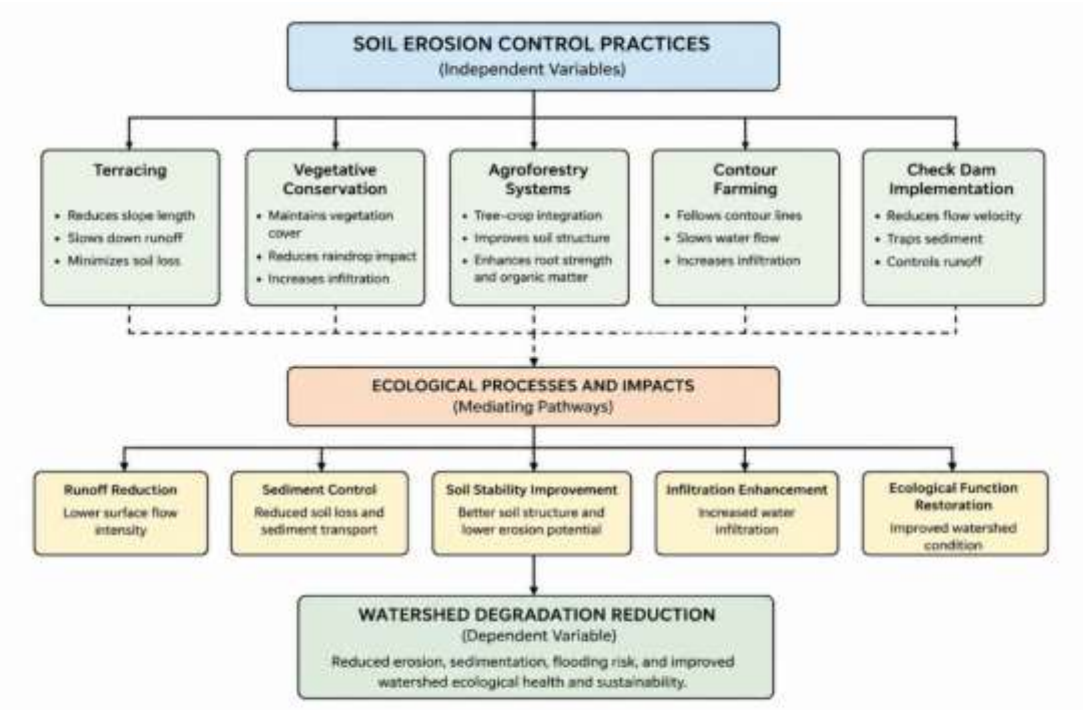

Figure 1. Conceptual Framework of Soil Erosion Control Practices and Watershed Degradation Reduction

METHODOLOGY

Research Design and Approach

This study employed a quantitative explanatory approach using a cross-sectional survey design. The study aimed to analyze the effect of soil erosion control practices on watershed degradation reduction in the Cisangkuy Sub-

Watershed. A quantitative approach was selected because the study focused on examining the relationship between several soil conservation variables and watershed degradation reduction using statistical analysis. The cross-sectional design was applied to obtain data from respondents at a specific period of time through field surveys and direct observations (Skinner & Dancis, 2026).

Research Location

The research was conducted in several erosion-prone agricultural areas within the Cisangkuy Sub-Watershed, which forms part of the Upper Citarum Basin. The study area was selected because it has experienced increasing environmental degradation characterized by soil erosion, sedimentation, declining vegetation cover, and land-use conversion in sloping areas. In addition, the watershed plays an important role in supporting hydrological functions in the upstream Citarum region.

Population and Sample

The population of this study consisted of farmers, land managers, and environmental stakeholders involved in land-use and conservation activities within the Cisangkuy Sub-Watershed area. The sample was determined using purposive sampling techniques based on several criteria, including respondents' involvement in agricultural activities, land management practices, and environmental conservation programs.

A total of 135 respondents participated in this study. The respondents consisted of local farmers cultivating sloping agricultural land, community members involved in conservation activities, and local environmental stakeholders. The sample size was considered adequate for multiple linear regression analysis because it met the minimum sample requirement for explanatory quantitative research.

Data Collection Techniques

Data were collected using several techniques to obtain both quantitative and environmental field information. The primary data collection methods included:

1) *Structured Questionnaires*

Questionnaires were distributed to respondents using a five-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire measured respondents' perceptions and implementation of soil erosion control practices, including terracing, vegetative conservation, agroforestry systems, contour farming, and check dam implementation (Armstrong, 1987).

2) *Field Observation*

Direct observations were conducted to assess land conditions, slope characteristics, vegetation cover, and visible erosion indicators within agricultural areas of the watershed.

3) *Documentation Study*

Supporting data were obtained from government reports, watershed management documents, environmental publications, and related scientific literature concerning watershed degradation and soil conservation practices in the Upper Citarum region.

Research Variables

This study consisted of independent and dependent variables.

1) Independent Variables
2) Terracing (X1)
3) Vegetative Conservation (X2)
4) Agroforestry Systems (X3)
5) Contour Farming (X4)
6) Check Dam Implementation (X5)
7) Dependent Variable
8) Watershed Degradation Reduction (Y)
9) Operational Definition of Variables

Terracing refers to land management practices using terrace structures to reduce runoff velocity and soil loss on sloping land. Vegetative conservation refers to the use of vegetation cover, grass barriers, and reforestation to improve soil stability and infiltration. Agroforestry systems refer to integrated land-use systems combining trees and agricultural crops for ecological and economic benefits. Contour farming refers to cultivation practices following land contour patterns to reduce runoff and erosion. Check dam implementation refers to the construction of small barriers within waterways to control sediment and water flow. Watershed degradation reduction refers to improvements in watershed conditions characterized by reduced erosion, lower sedimentation, improved infiltration, and enhanced environmental stability.

Instrument Validity and Reliability

Instrument validity was tested using Pearson Product Moment correlation analysis. Questionnaire items were considered valid when the correlation coefficient exceeded the critical value at the 0.05 significance level. Reliability testing was conducted using Cronbach’s Alpha coefficient, with a minimum acceptable value of 0.70 indicating reliable measurement consistency.

Data Analysis Techniques

The collected data were analyzed using descriptive statistics and multiple linear regression analysis with IBM SPSS Statistics. Descriptive statistics were used to describe respondent characteristics and the implementation level of soil conservation practices. Multiple linear regression analysis was applied to examine the effect of soil erosion control practices on watershed degradation reduction.

The regression model used in this study is formulated as:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \varepsilon$$

Where:

- Y= Watershed degradation reduction
- X_1= Terracing
- X_2= Vegetative conservation
- X_3= Agroforestry systems
- X_4= Contour farming
- X_5= Check dam implementation
- β_0= Constant
- $\beta_1 - \beta_5$= Regression coefficients
- ε= Error term

Hypothesis testing was conducted using the t-test to examine the partial effect of each independent variable and the F-test to analyze the simultaneous effect of all independent variables on watershed degradation reduction. The coefficient of determination (R^2) was used to measure the explanatory power of the regression model

RESULTS

Respondent Characteristics

This study involved 135 respondents from several agricultural and conservation areas in the Cisangkuy Sub-Watershed. The respondents consisted of local farmers, land managers, and community members who were directly involved in land-use activities within the watershed area. Most respondents had relatively long experience in agricultural activities on sloping land, which made them familiar with erosion and runoff problems occurring during the rainy season.

Table 1. Respondent Characteristics.

Characteristics	Category	Frequency	Percentage (%)
Gender	Male	82	60.7
	Female	53	39.3
Age	20-35 years	34	25.2
	36-50 years	57	42.2
	>50 years	44	32.6
Education Level	Elementary School	43	31.9
	Secondary School	61	45.2
	Higher Education	31	22.9
Farming Experience	<10 years	35	25.9
	10-20 years	56	41.5
	>20 years	44	32.6

The data show that most respondents were within the productive age category and had experience managing agricultural land for more than ten years. This condition indicates that respondents had adequate understanding regarding land management practices and environmental conditions within the watershed area.

Descriptive Statistics

Descriptive analysis was conducted to identify the implementation level of soil conservation practices and respondents' perceptions regarding watershed degradation reduction.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Standard Deviation	Category
Terracing	3.81	0.71	High
Vegetative Conservation	4.08	0.65	High
Agroforestry Systems	3.96	0.69	High
Contour Farming	3.68	0.73	Moderate
Check Dam Implementation	3.42	0.81	Moderate
Watershed Degradation Reduction	3.94	0.64	High

Vegetative conservation showed the highest mean value among the conservation variables. Respondents generally stated that maintaining vegetation cover and planting perennial crops helped reduce surface runoff and improve soil conditions. Meanwhile, check dam implementation received the lowest average score because several areas within the watershed still had limited conservation infrastructure and maintenance problems.

Validity and Reliability Test

Validity testing indicated that all questionnaire items had correlation coefficients above the minimum requirement of 0.30, suggesting that all items were valid for measuring the research variables. Reliability testing using Cronbach's Alpha also showed acceptable consistency.

Table 3. Reliability Test Results

Variable	Cronbach's Alpha	Criteria
Terracing	0.736	Reliable
Vegetative Conservation	0.798	Reliable
Agroforestry Systems	0.781	Reliable
Contour Farming	0.714	Reliable
Check Dam Implementation	0.701	Reliable
Watershed Degradation Reduction	0.817	Reliable

All variables had Cronbach's Alpha values above 0.70, indicating that the research instrument was sufficiently reliable for statistical analysis.

Multiple Linear Regression Analysis

Multiple linear regression analysis was conducted to examine the effect of soil erosion control practices on watershed degradation reduction in the study area.

Table 4. Multiple Linear Regression Results

Variable	B	Std. Error	t-value	Sig.
Constant	1.492	0.521	2.864	0.005
Terracing	0.173	0.081	2.131	0.035
Vegetative Conservation	0.284	0.074	3.847	0.000
Agroforestry Systems	0.248	0.078	3.194	0.002
Contour Farming	0.142	0.070	2.014	0.046
Check Dam Implementation	0.097	0.069	1.406	0.162

The regression results indicate that terracing, vegetative conservation, agroforestry systems, and contour farming significantly affected watershed degradation reduction because their significance values were below 0.05. Vegetative conservation showed the strongest influence among all variables, indicating that vegetation-based conservation practices played an important role in controlling erosion and maintaining soil stability.

Agroforestry systems also showed a positive contribution to watershed improvement because tree-based land management helped reduce runoff and improve infiltration capacity. Terracing and contour farming were found to contribute moderately to erosion reduction, especially in agricultural areas with sloping terrain.

Meanwhile, check dam implementation showed a positive but statistically insignificant effect on watershed degradation reduction. Field observations revealed that several check dams within the study area were partially damaged or not regularly maintained, reducing their effectiveness in controlling sediment and runoff flow.

Simultaneous Test (F-Test)

Table 5. ANOVA Test Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	36.514	5	7.303	27.862	0.000
Residual	33.811	129	0.262		
Total	70.325	134			

The F-test results indicate that all independent variables simultaneously had a significant effect on watershed degradation reduction ($p < 0.001$). This finding suggests that soil conservation practices collectively contributed to improving environmental conditions within the Cisangkuy Sub-Watershed.

Coefficient of Determination

Table 6. Coefficient of Determination (R^2)

Model	R	R Square	Adjusted R Square
Regression Model	0.721	0.520	0.501

The coefficient of determination indicates that the independent variables explained 52.0% of the variation in watershed degradation reduction, while the remaining 48.0% was influenced by other factors outside the research model, such as rainfall intensity, land ownership patterns, slope characteristics, and local environmental policies.

$$R^2 = 0.549$$

Overall, the results indicate that soil conservation practices contributed positively to reducing watershed degradation in the Cisangkuy Sub-Watershed, although the effectiveness of each conservation method varied depending on field conditions and implementation consistency.

DISCUSSION

The results of this study indicate that soil erosion control practices generally contributed to watershed degradation reduction in the Cisangkuy Sub-Watershed. Vegetative conservation showed the strongest influence among all independent variables. This finding suggests that maintaining vegetation cover remains one of the most effective approaches for reducing erosion and improving watershed conditions in sloping agricultural areas. Field observations revealed that agricultural land with better vegetation cover tended to experience lower surface runoff and better soil moisture conditions compared to more open land areas. Vegetation helps reduce the direct impact of rainfall on soil surfaces while improving infiltration through root systems and organic matter accumulation. This finding is consistent with Tang et al. (2021), who explained that vegetation plays an important role in controlling erosion because plant cover can reduce runoff velocity and improve soil stability.

Agroforestry systems also showed a significant positive effect on watershed degradation reduction. Respondents who implemented agroforestry practices generally stated that integrating trees with agricultural crops helped maintain soil moisture and reduce erosion during heavy rainfall periods. In several areas of the watershed, agroforestry systems were commonly applied through mixed planting patterns involving perennial trees and seasonal crops. These practices contributed not only to environmental improvement but also to economic sustainability because farmers could diversify agricultural production. This finding supports the study by Lorenz & Lal (2014), which stated that agroforestry systems improve ecological stability through canopy protection, increased soil organic matter, and root reinforcement. Compared to monoculture cultivation systems, agroforestry practices were observed to provide better environmental protection in erosion-prone upland areas.

Terracing was also found to significantly influence watershed degradation reduction, although its effect was lower compared to vegetative conservation and agroforestry systems (Rachman et al., 2020). Several respondents explained that terracing helped slow down water flow and reduce soil loss on steep agricultural land. However, field observations indicated that not all terrace structures were properly maintained, particularly in areas with limited economic resources and irregular conservation assistance programs. In some locations, damaged terraces reduced the effectiveness of runoff control during periods of high rainfall intensity. This condition may explain why the influence of terracing was moderate rather than dominant in the regression analysis. Nevertheless, the findings remain consistent with previous studies showing that terracing is an important mechanical conservation practice for minimizing erosion in sloping agricultural landscapes (Sauer et al., 2021).

Contour farming also demonstrated a positive and statistically significant effect on watershed degradation reduction. Farmers who practiced contour farming generally experienced lower runoff intensity compared to those using conventional cultivation patterns following slope direction (Kumar & Pandey, 2024). Contour-based cultivation helps reduce water flow velocity and increases water infiltration into the soil. However, the implementation of contour farming in the study area was still relatively inconsistent because some farmers preferred cultivation methods considered simpler and faster during planting periods. As a result, the effectiveness of contour farming varied across locations depending on farmer awareness and land management consistency (Telles et al., 2022). This finding indicates that conservation effectiveness is influenced not only by technical approaches but also by farmer behavior and environmental understanding.

Unlike the other conservation variables, check dam implementation showed a positive but statistically insignificant effect on watershed degradation reduction. Although several check dams functioned effectively in controlling sediment flow, field observations revealed that many structures were not optimally maintained and some had experienced sediment accumulation or partial damage (Adamo et al., 2021). In addition, the distribution of check dams within the watershed was still limited, meaning that their impact was not evenly felt across all study areas. This condition likely contributed to the weaker statistical influence of check dam implementation compared to vegetation-based conservation practices. The finding suggests that mechanical conservation structures alone may not be sufficient to reduce watershed degradation if they are not supported by proper maintenance and integrated land management strategies.

The findings of this study indicate that vegetation-based conservation approaches were more effective than purely mechanical conservation methods in reducing watershed degradation within the Cisangkuy Sub-Watershed. The results also demonstrate that conservation effectiveness is strongly influenced by implementation consistency, local environmental conditions, and community participation. Respondents who actively participated in conservation activities generally showed greater awareness regarding sustainable land management practices. This finding supports participatory environmental management theory, which emphasizes that successful watershed conservation requires collaboration between technical conservation measures and community involvement. Therefore, integrated conservation strategies combining vegetative approaches, sustainable agricultural systems, and community-based environmental management are necessary to support long-term watershed sustainability in the Upper Citarum region.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that soil erosion control practices generally contributed to watershed degradation reduction in the Cisangkuy Sub-Watershed. Vegetative conservation and agroforestry systems showed the strongest influence in reducing runoff, improving soil stability, and supporting watershed sustainability. Terracing and contour farming also demonstrated significant positive effects, although their effectiveness varied depending on land conditions and implementation consistency. Meanwhile, check dam implementation showed a positive but statistically insignificant effect due to maintenance limitations and uneven infrastructure distribution in several areas of the watershed.

Based on these findings, this study recommends strengthening vegetation-based conservation practices and expanding agroforestry implementation in erosion-prone areas. Greater community participation and environmental awareness are also needed to improve the sustainability of watershed conservation programs. In addition, local governments and environmental institutions should improve monitoring and maintenance of conservation infrastructure, particularly check dams and terracing systems, to support long-term watershed management in the Upper Citarum region.

FURTHER STUDY

This study has several limitations, particularly regarding the cross-sectional research design and the limited coverage of observation areas within the Cisangkuy Sub-Watershed. Future studies are recommended to use longitudinal approaches and broader spatial analysis to better understand long-term watershed dynamics and erosion patterns. Further research may also incorporate remote sensing, Geographic Information Systems (GIS), and hydrological modeling to obtain more comprehensive environmental data. In addition, future studies should examine the influence of climate variability, land ownership patterns, and local environmental policies on watershed conservation effectiveness.

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